

DESIGN AND IMPLEMENTATION OF INCENTIVE BASED SMART PLASTIC BOTTLE DISPOSAL SYSTEM

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A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering (BSEEE)

Electrical and Electronic Engineering

Brac University

September 2023

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Electrical and Electronic Engineering
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Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is our own original work while completing degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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Ethics Statement

This research has been carried out with honesty and transparency, accurately reporting methods, results, and any limitations or biases. Proper citations and references from the referred research papers, journals, and articles have been included to acknowledge the intellectual contributions of the respective authors. Furthermore, a plagiarism check on the complete project report confirmed that we have successfully maintained the similarity index within the accepted range.

Abstract/ Executive Summary

This project presents a comprehensive solution to address the growing environmental concerns associated with plastic waste. Through image processing and machine learning algorithms, the system accurately identifies plastic bottles, facilitating their proper disposal. By integrating microcontrollers and motors, this system encourages responsible disposal practices among users by automating the detection and categorization of plastic bottles into respective trash compartments. IoT technology records the weight of the plastic bottle, associating it with the user as virtual currency in the cloud. Users are incentivized through this rewards system which they can conveniently track via a mobile application. The reward points can be redeemed for various benefits, promoting sustainability. Real-time data tracking and IoT integration further enhance efficiency of the system. At its core, this innovative system seeks to revolutionize the way we interact with plastic waste, fostering a cleaner, greener, and more conscientious society.

Keywords: Plastic waste; image processing; categorization; IoT technology; virtual currency; real-time data tracking

Dedication

This work is dedicated to our parents and family members for their unwavering support and encouragement throughout the completion of our project. We would also like to express appreciation for our friends who helped us by sharing their experiences in project work. Finally, we would like to extend our heartfelt gratitude to the faculty members who inspire us to seek knowledge and make a difference in the world.

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1 Introduction [CO1, CO2, CO10, PO-L, PO-C, PO-F]

1.1 Introduction

In the past decades, our world has experienced mind-blowing population growth and massive transformations due to the industrial revolution. Just imagine, in 2019 alone, we had around 7.7 billion people sharing our planet [5], and brace yourself, because this number is predicted to skyrocket even more in the coming years. This surge in population means that we'll be producing a whole lot more industrial and human waste, which isn't exactly friendly to our environment or the economies of nations [6]. Environmental scientists and researchers have dedicated their efforts studying waste disposal management and developing new business models focused on transforming, reusing, and recycling materials throughout their lifecycle [4], as illustrated in Figure 1.

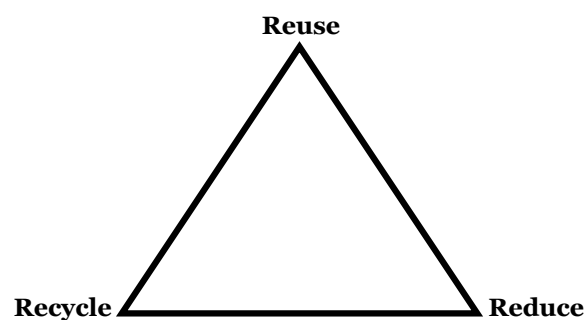


Figure 1: Conceptual frame definition for circular economy [4].

1.1.1 Problem Statement

Plastic has become an essential constituent in everyday products due to advantageous features such as low density, light weight, durability, low cost, and versatile applications. However, with the widespread consumption of plastic goods arises a growing concern about managing the consequent plastic waste produced, as plastic waste poses severe environmental risks. Due to the non-biodegradable nature of plastic, plastic remains in soil and water bodies for extended periods, turning into leachate, which pollutes the soil and water, causing harm to entire ecosystems and food chains [7]. Plastic also emits harmful greenhouse gases upon exposure to heat which further contributes to global warming.

One of the leading causes of plastic mismanagement is the significant amount of plastic littering on land and in water, usually done out of carelessness or laziness or due to a lack of access to trash receptacles [8], [9]. Plastic littering results in water logging, a grave issue for a country like Bangladesh which has a tropical monsoon climate [10]. Additionally, plastic in water bodies is a major threat to marine life. To illustrate, the large volumes of plastic waste in Cox's Bazar caused the death of many turtles due to getting entangled within the plastic.

1.1.2 Background Study

Considering these severe environmental impacts, it is urgent to find a solution to manage the increasing amounts of plastic waste. Sohail, Ullah, Khan, *et al.* [11] proposed an *Intelligent Trash Bin* that monitors trash levels and notifies the bin location once it is full through an Android application. However, this system lacks a waste identification system as well as the motivation to dispose of waste. Balamurugan, Ajithx, Ratnakaran, *et al.* [12] proposed a similar Smart Trash Bin but with a rewards exchange system based on the weight of the disposed trash. The bin is designed to open and close automatically, which may lead users to misuse the rewards feature. A user authentication system is required here. Pelonero, Fornai, and Tramontana [13] have stated that typically, individuals are only involved in incentive systems via a dedicated smartphone app when they engage with smart bins. So, it might be a good choice to motivate users by giving some incentives.

Also, to analyze the current market, we have talked to the stakeholders of various levels. We surveyed 90 anonymous users to get an idea about their opinion on the plastic disposal system, how frequently they drink and how they process those empty bottles. The survey result has been attached at the end of this report.

1.1.3 Literature Gap

In the conventional system of managing municipal waste, it is the responsibility of citizens to separate the waste generated in their homes. However, relying solely on public awareness and advertising to ensure proper waste separation is difficult. When citizens fail to sort waste according to the separation scheme, it can undermine the entire municipal waste management system. Additionally, traditional waste processing methods like landfill and incineration are becoming more expensive and inefficient in terms of energy usage [14], [15]. Research [16] has demonstrated that incorrect waste sorting can impose significant costs on society. Moreover, a malfunctioning waste management system can lead to environmental pollution and negative consequences for future generations. Furthermore, due to the large population size and complexity of individual behavior, traditional research methods such as surveys and simulations have limitations in analyzing waste disposal behavior. This poses a significant challenge for decision-makers to allocate resources for waste collection operations and improve regulations [17].

1.1.4 Relevance to Current and Future Industry

Relevance to Current and Future Industry of Incentive-Based Smart Plastic Bottle Disposal System:

1. **Environmental Sustainability:** With increasing concerns about plastic pollution and its detrimental impact on the environment, incentive-based smart plastic bottle disposal systems offer a practical solution. These systems encourage individuals to dispose of their plastic bottles responsibly, leading to reduced litter, cleaner surroundings, and the conservation of natural resources. Industries can play a significant role by implementing and supporting these systems, showcasing their commitment to sustainability and environmental stewardship.

2. **Consumer Engagement and Brand Reputation:** Incentive-based systems provide an opportunity for industries to engage with environmentally conscious consumers. By promoting recycling practices and offering rewards or incentives for proper disposal, companies can build a positive brand image and enhance their reputation as socially responsible entities. This can lead to increased customer loyalty, a competitive advantage, and positive word-of-mouth promotion.
3. **Waste Management Efficiency:** The implementation of smart plastic bottle disposal systems can contribute to the development of more efficient waste management processes. By incorporating technology like sensors, data analysis, and automation, industries can streamline collection, sorting, and recycling operations. This can lead to cost savings, improved resource allocation, and reduced environmental impact associated with waste disposal.
4. **Collaborative Partnerships:** Developing and operating incentive-based smart plastic bottle disposal systems require collaboration between various industry players, including manufacturers, retailers, waste management companies, and technology providers. Such partnerships promote cross-sector collaboration, innovation, and knowledge sharing. Industries that actively participate in these collaborations can establish themselves as leaders in sustainable practices, fostering a positive industry image and demonstrating their commitment to collective environmental goals.
5. **Market Opportunities:** Incentive-based smart plastic bottle disposal systems open up new market opportunities for industries involved in waste management, recycling, technology development, and sustainable product packaging. The increased consumer demand for eco-friendly activities gives options for the creation and marketing of creative solutions, providing a niche market for enterprises to thrive on. By investing in research, development, and deployment of these systems, industries may position themselves for long-term growth and profitability.

The relevance of incentive-based smart plastic bottle disposal systems to the current and future industry lies in their potential to foster environmental sustainability, promote consumer engagement, optimize waste management processes

1.2 Objectives, Requirements, Specifications and Constraints

1.2.1 Objectives

Our objectives for this project are as follows:

- Sorting out plastic from the environment
- Motivating users to dispose plastic appropriately

The main objective of our project is to make the environment clean and hygienic by encouraging people to dispose of plastic bottles in the respective bins. The system aims to prevent overflow of the bin by automatically detecting the trash level and then sending a message to respective municipal authorities notifying the status of the bin once it is full. Based on the disposed bottle weight, users can earn reward points which can be redeemed later on. This can keep the surrounding area neat and pollution-free while eliminating the overflow of waste outside the bin as a result of regular cleaning.

1.2.2 Functional and Non-functional Requirements

Functional Requirements

Table 1: Functional requirements.

Title	Description
User Authentication	The user has to be authenticated before he can put waste into the bin so that data can be saved against the user
Plastic Bottle Identification	The bin must be able to identify plastic bottles from other types of waste
Weight Measurement	The user will be rewarded based on bottle weight
Trash Level Measurement	The bin must be able to detect the amount of waste to prevent overflow
Rewards System	The user must be rewarded in exchange for putting bottles into the bin
Android Application	An Android application will display all the relevant statistics both to the user and to the respective authorities

Non-functional Requirements

Table 2: Non-Functional Requirements.

Title	Description
Backup Power Source	An additional power source will ensure uninterrupted service
Internet Connection	An active internet connection will display different statistics instantly, such as trash level, user reward points and redeem history
Trash Level Status Indicator	LEDs will be used to indicate current bin's different waste levels
Anti-theft Technology	It is common to get the bin or any of its components lost. To track the bin's current location, a GPS module will be utilized, which will prevent theft

1.2.3 Specifications

Table 3: Specifications in Brief.

Parameter		Value
Trash Bin	Dimension	845 mm × 569 mm
	Waste Capacity	100 L
	Threshold	80%
Plastic Bottle	Weight	Multiples of 250 mg

Trash bin size The bin should be 845 mm in height and 569 mm in width.

Bin capacity The bin should be capable of storing 100 L of waste in total.

Trash level threshold To avoid waste overload, the bin will stop consuming waste after a certain level of waste consumption. By default, the bin will close after its capacity has been filled up to 80%. The bin will remain closed until the contents have been emptied. This threshold can be modified as per necessity.

Bottle weight Considering typical bottle weights, the bottles which users are going to throw must be of multiples of 250 mg in weight. For example, the bottle might weigh 250 mg, 500 mg, 1000 mg and so on. This will help the bin to process a wide range of bottles from different companies.

1.2.4 Technical and Non-technical Consideration and Constraints in Design Process

The following technical considerations and constraints have been identified from the design process:

Arbitrary bottle weight The disposed bottle weight may not be an exact multiple of 250 mg at all times. Values like 350 mg, 420 mg are just as valid. To reward users fairly, such values in between must be considered and accounted for accordingly.

Partially filled plastic bottle Based on the weight of the bottle, users will receive reward points. So, if the bottle is not empty, then the weight of the waste will increase needlessly and the user will be rewarded without valid effort. To avoid this problem, the system must empty the bottle before measuring it.

Crumpled up bottle The disposed bottles need to be vertically positioned in order to be identified properly. So, if any bottle is in crumpled up condition, it may end up being positioned horizontally or haphazardly in the scanning area, thus impeding the scanning and identification process.

It is also important to note the non-technical considerations of our project. We have outlined some of them below:

Environmental considerations Eco-friendly and recyclable materials have been chosen to minimize the project's environmental impact. The system has been designed to be energy-efficient to reduce energy consumption and carbon emissions. Strategies have been implemented to minimize resource usage and waste generation during manufacturing and operation.

Societal considerations The local community has been involved in project planning and decision-making so as to gain their input and support. Safeguards and warnings have been implemented to prioritize the safety of users and the community. Transparency has been maintained in project implementation along with proper communication with stakeholders. The project promotes fairness and equity, avoiding any discriminatory practices.

Cultural considerations The project has been designed in a way that respects and aligns with the cultural values and norms of the community it serves. We have also considered cultural diversity and inclusivity in project design and outreach efforts.

Health and safety considerations We have conducted thorough risk assessments to identify and mitigate potential health and safety hazards. In order to prioritize the safety of end-users and the broader community, we have implemented robust safety protocols. The project complies with all relevant local, national, and international regulations and standards.

1.2.5 Applicable Compliance, Standards and Codes

There are many applicable standards and codes for many of the components of our project. However, we have included few standards and codes including:

- Bangladesh Data Protection Act, 2022
- National Environment Policy, 2018
- IEEE 610.4-1990
- IEEE 1221-1993
- ISO 15270:2008

Bangladesh data protection act, 2022 The Bangladesh Data Protection Act, 2022 is a significant legislative framework that defines essential standards for the collecting, use, and protection of personal data in Bangladesh. This legislation is expected to take effect in 2022. This Act is especially pertinent in the context of Internet of Things and microcontroller-based smart garbage bin initiatives, where there may be issues over the ethical collection and use of personal data. This Act will help address those concerns.

When it comes to the collection of personal data through Internet of Things devices like smart garbage cans, privacy is one of the most important ethical factors that must be taken into account. The Act places a strong emphasis on the significance of protecting the personal information of persons by offering recommendations on how to guarantee that their data is secure and cannot be accessed or disclosed by unauthorised third parties. The implementation of effective security mechanisms by businesses is required to

safeguard the personal data of consumers from being accessed by hackers and other criminals. In addition to this, they are obligated to take measures to protect the availability, integrity, and confidentiality of the data that they have gathered.

Before collecting people's personal information, the Act also places a significant emphasis on obtaining the appropriate consent from individuals first. Before a company may collect its users' data, it is required to first gain the users' explicit and informed consent. Users must be notified of the specific data that will be collected, how it will be used, and who will have access to it. In addition, users have the legal right to revoke their permission at any time, which implies that businesses are obligated to present users with a straightforward mechanism to decline participation in data collecting.

The Act identifies the accuracy and accountability of personal data as another significant concern that should be taken into account. Companies have a responsibility to verify that the data they gather is correct, current, and pertinent to the goals they have set for themselves. In addition to this, they are required to take responsibility for the data they gather by establishing crystal-clear rules and processes for the management of personal information and by being transparent about the data practises they employ. The user has the right to view their personal data, the ability to request that it be modified, and the ability to seek specifics on how the data has been used.

In conclusion, the Bangladesh Data Protection Act, 2022 offers an all-encompassing ethical and legal framework for the collection and use of personal data in IoT and microcontroller-based smart garbage can initiatives. The Act establishes principles for preserving persons' privacy, gaining informed permission, assuring accuracy and responsibility, and providing individuals with the option to govern the data that pertains to them. Companies who are developing and executing projects involving smart trash cans are required to adhere to these standards in order to guarantee that they are gathering and utilising personal data in a manner that is both ethical and responsible. We can earn the trust of consumers and increase the likelihood that these initiatives will be successful in the long run if we put an emphasis on privacy and openness.

National environment policy, 2018 The National Environment Policy, 2018, is an important piece of legislation that serves as a framework for providing rules for the responsible management of Bangladesh's natural resources and the protection of the country's environment. When thinking about the ethical implications of different waste management practises for Internet of Things and microcontroller-based smart trash can projects, these guidelines are absolutely necessary. As a result, it is essential to make certain that these devices are developed and deployed in a sustainable manner so as to leave the smallest possible imprint on the environment.

The possible negative effects on the environment are one of the key ethical issues raised by technological advancements such as smart garbage cans. These devices have the potential to enhance waste management practises; but, in order to function, they need the use of energy and generate electronic trash when they reach the end of their lives. As a result, corporations have a responsibility to guarantee that these products are developed with sustainability in mind by taking the appropriate precautions. This may entail the use of renewable energy sources, the design of gadgets that reduce the amount of energy that they consume, or the incorporation of environmentally friendly materials into the design of the device.

The National Environment Policy, 2018, places an emphasis not only on the necessity of minimising trash output but also on the promotion of recycling. Companies who are designing and implementing smart trash cans have a responsibility to give top priority to environmentally friendly waste management practises in order to lessen the quantity of rubbish that is sent to landfills and to advance the cause of the circular economy. This may entail the creation of equipment that make trash separation easier or the formation of partnerships with local recycling facilities in order to guarantee that garbage is processed and reused in an appropriate manner.

In addition, the policy emphasises the significance of including all relevant stakeholders, especially the communities in which they live, in the procedures for waste management. Businesses have a responsibility to interact with the communities in which they operate and any other relevant stakeholders in order to better comprehend their requirements, amass input, and establish credibility. This can assist guarantee that the practises of waste management are inclusive and equitable, and that they are beneficial to all parties concerned.

Companies might utilise data analytics software to monitor container fill levels while also gathering data on garbage composition and characteristics in order to make waste management practises more efficient, effective, and sustainable. This type of software would optimise the collection routes, save operating costs through predictive maintenance, and allow for improved decision-making about the profitable secondary raw material recovery.

When it comes to creating and executing Internet of Things and microcontroller-based smart garbage bin initiatives in Bangladesh, the National Environment Policy, 2018 offers a crucial foundation for ethical issues that must be taken into account. Companies may guarantee that initiatives are designed and implemented in a responsible and ethical manner by prioritising sustainability, recycling, community engagement, and inclusion. This provides benefits not just to people, but also to the environment and society as a whole. Companies are required to comply to these rules in order to guarantee that these projects will encourage environmentally responsible waste management practises and minimise any negative effects these projects may have on the environment.compromised.

IEEE 610.4-1990 The IEEE 610.4-1990 standard code is a set of rules for the procedures that make up the software life cycle. These standards cover the creation and implementation of Internet of Things and microcontroller-based smart garbage can projects. It is very necessary to give careful consideration to the ethical implications of both creating and utilising the software that runs these devices. The necessity of guaranteeing the dependability, security, and safety of software is emphasised throughout the code.

When it comes to the Internet of Things (IoT) and microcontroller-based smart garbage cans, dependability is one of the key ethical problems that needs to be addressed. These devices are frequently essential parts of waste management systems; as a result, their malfunction might result in damage to the environment, dangers to public health, or financial expenses. As a result, it is very necessary to build software that is dependable and operates in the manner that was intended. At every level of the software development life cycle, comprehensive testing must to be carried out in order to guarantee that the programme in question is both dependable and efficient. Software developers should

guarantee that the software can interact flawlessly with other components of the smart trash can. Additionally, the software should be able to operate under a variety of scenarios, such as when there is a lack of electricity or when there are difficulties with internet access.

The law also tackles the necessity of ensuring the security of software, which is especially important when it comes to the gathering and transmission of sensitive data. A person's garbage disposal habits may be gleaned from the data that is collected by smart trash cans; however, this information must be safeguarded to prevent unauthorised access or use. In order to protect their customers' personal information and avoid data breaches, businesses need to employ stringent security policies. This involves the use of encryption techniques to safeguard the transfer of data across networks, the storage of data on servers in a secure manner, and the implementation of steps to authenticate users.

Last but not least, the code emphasises the need of protecting the security of software in Internet of Things and microcontroller-based smart garbage cans. In the event that these gadgets malfunction or were not developed with safety in mind from the beginning, they may provide potential health hazards. As a result, software engineers are obligated to make safety concerns a top priority throughout the entirety of the software development process, beginning with the design phase and continuing through testing and deployment. For instance, the software should be built to prevent the garbage cans from being overfilled, hence avoiding any accidents caused by leakage. In addition, user warnings and alerts need to be built into the programme so that users are informed in the event that there is a potential risk.

In conclusion, IEEE Standard 610.4-1990 offers a complete framework for ethical issues to be taken into account during the process of creating and implementing software for Internet of Things (IoT) and microcontroller-based smart garbage bin projects. We are able to guarantee the development and execution of these projects in an ethical and responsible manner if we place a high priority on dependability, security, and safety. Because of this, the hazards that are often connected with the use of these devices will be reduced, while the advantages that they provide to users, waste management systems, and society as a whole will be increased. Companies are required to follow these requirements in order to guarantee that the software they supply to power intelligent garbage cans is dependable, secure, and safe.

IEEE 1221-1993 The IEEE 1221-1993 standard code is a set of principles for establishing and implementing software quality assurance processes. These rules may be found in the standard code. It is necessary to address the ethical implications of building and utilising software that drives these devices while working on Internet of Things (IoT) and microcontroller-based smart garbage can projects. The necessity of ensuring that software is of a high quality, dependability, and efficiency is emphasised throughout the code.

When it comes to the quality of the software used in Internet of Things and microcontroller-based smart garbage cans, one of the key ethical concerns is privacy. These devices are expected to carry out their intended functions and adhere to all applicable rules and regulations regarding safety, security, and privacy. As a result, it is very necessary to create software that is of a high quality and is tested extensively in order to guarantee that it will perform appropriately. This can entail making use of agile

approaches, automated testing, and continuous integration as some of the best practises in software development.

In addition to this, the code addresses the necessity of ensuring the dependability of software, which is particularly important when considering the essential parts of waste management systems. Any error in the programme might potentially result in damage to the environment, hazards to public health, or financial consequences. As a result, businesses have a need to adhere to industry standards while developing software in order to guarantee the dependability of their wares and ensure that they operate as designed. For instance, businesses need to perform exhaustive testing and debugging before deploying any new software in order to identify any potential problems.

In conclusion, the code emphasises how critical it is to test and validate the efficacy of the software used in Internet of Things and microcontroller-based intelligent garbage cans. These devices need to be efficient in order to accomplish their goals, which may include lowering the amount of trash generated or enhancing the methods by which waste is managed. As a result, it is critical to build software that not only satisfies the requirements of users and other stakeholders but also is congruent with the objectives of the project. In this regard, it may be necessary to undertake user research and collect feedback in order to guarantee that the software performs as expected and is user-friendly.

In conclusion, the IEEE 1221-1993 standard offers a complete framework for ethical issues to be taken into account during the process of creating and implementing software for Internet of Things (IoT) and microcontroller-based smart garbage bin projects. We are able to guarantee the development and execution of these initiatives in a manner that is both ethical and responsible if we place a premium on quality, dependability, and efficacy. Because of this, the hazards that are often connected with the use of these devices will be reduced, while the advantages that they provide to users, waste management systems, and society as a whole will be increased. Companies are required to follow these rules in order to guarantee that the software they supply to power smart garbage cans is of a high quality, is dependable, and is functional.

ISO 15270:2008 The ISO 15270:2008 standard is a set of rules for sustainable development in organisations, with a specific emphasis on the management of environmental elements and impacts. These guidelines may be found in the standard. When thinking about the ethical implications of different waste management practises for Internet of Things and microcontroller-based smart trash can projects, these guidelines are absolutely essential. It places a strong emphasis on lowering the amount of trash produced, encouraging recycling, and limiting the negative effects that garbage has on the surrounding ecosystem.

The possible negative effects on the environment are one of the key ethical issues raised by technological advancements such as smart garbage cans. These devices have the potential to enhance waste management practises; but, in order to function, they need the use of energy and generate electronic trash when they reach the end of their lives. As a result, it is very necessary to make certain that these devices are developed and deployed in a sustainable manner in order to reduce the impact that they have on the environment. In order to accomplish this goal, businesses need to design their products such that they use the least amount of energy possible, are simple to recycle or dispose of after their useful lives are over, and utilise materials that have a low negative impact

on the environment.

The ISO 15270:2008 standard places a strong emphasis on the significance of minimising trash creation and increasing recycling rates. Companies who are designing and implementing smart trash cans have a responsibility to give top priority to environmentally friendly waste management practises in order to lessen the quantity of rubbish that is sent to landfills and to advance the cause of the circular economy. This may entail the creation of equipment that make trash separation easier or the formation of partnerships with local recycling facilities in order to guarantee that garbage is processed and reused in an appropriate manner. These kinds of collaborations need to take into account the full value chain and work towards the end goal of establishing a closed-loop system in which recyclable trash is converted into useful goods.

In addition to this, the standard emphasises the need of including stakeholders in the processes that are utilised to manage trash. Businesses have a responsibility to interact with the communities in which they operate and any other relevant stakeholders in order to better comprehend their requirements, amass input, and establish credibility. This can assist guarantee that the practises of waste management are inclusive and equitable, and that they are beneficial to all parties concerned. The engagement of stakeholders may entail the creation of awareness campaigns or the organisation of education programmes to promote environmentally responsible methods of garbage management.

When it comes to creating and executing Internet of Things and microcontroller-based smart garbage can projects, the ISO 15270:2008 standard offers an essential foundation for ethical issues that should be taken into account. Businesses have the capacity to guarantee that the projects will be created in a responsible and ethical manner if they place a priority on topics such as sustainability, recycling, engagement in the community, and diversity. Because of this, the hazards that are often connected with the use of these devices will be reduced, while the advantages that they provide to users, waste management systems, and society as a whole will be increased. Companies have a responsibility to make compliance with these standards a top priority in order to encourage environmentally responsible waste management practises and reduce any negative effects on the environment.

1.3 Systematic Overview/Summary of the proposed project

Our proposed project is an innovative solution designed to reduce plastic waste and encourage responsible waste disposal practices through the incentive of reward points. It aims to collect the disposed plastic bottles in a single respective bin from which the plastic waste will be transported timely and safely to plastic recycling plants without causing harm to the environment or living beings. By promoting responsible waste disposal practices and ensuring the proper transport of plastic waste to recycling plants, we significantly reduce the environmental footprint associated with plastic pollution. This aligns with broader sustainability goals by preserving ecosystems and reducing the harm caused to the environment and living beings.

Beyond its environmental impact, our project actively engages the society in fostering responsible behaviors. Through the incentive of reward points, we encourage individuals to take ownership of waste management. By raising awareness and providing a user-friendly mobile app, we empower users to actively participate in creating a cleaner

and more hygienic environment. This promotes a sense of collective responsibility and community engagement.

In a political context, our project aligns with government initiatives and policies aimed at environmental conservation and sustainable waste management. Collaborations with local authorities and environmental agencies can further enhance its impact by garnering political support and alignment with regulatory frameworks.

Using image processing and machine learning, the system accurately identifies plastic bottles, streamlining their disposal. The system integrates IoT technology, recording bottle weights as virtual currency to incentivize users. A waste threshold has been defined to prevent waste overflowing to the surrounding environment. We have also created a mobile app to enable users to track and redeem reward points. Overall, this project embodies a commitment to a cleaner, more sustainable future.

1.4 Conclusion

The project titled "Design and Implementation of an Incentive-Based Smart Plastic Bottle Disposal System" places a strong emphasis on promoting responsible waste disposal practices. In light of the ongoing industrial revolution and growing concerns regarding industrial waste and its obstructive environmental impacts, we have defined the objectives of our project. In its execution, we have carefully considered the constraints we anticipate encountering and the strategies to address them. Additionally, we have established the standards and codes that will guide our work. Furthermore, we have conducted a comprehensive review of existing literature to gain insights into prior research efforts in this field.

2 Project Design Approach [CO5, CO6, PO-C, PO-B]

2.1 Introduction

In this bankruptcy, we embark on an thrilling adventure to explore the arena of multiple layout processes for creating a clever trash bin! Throughout this chapter, we will delve into the fascinating realm of innovation, discussing how numerous design strategies can make a contribution to the improvement of an wise and efficient waste control gadget.

The number one objective of this bankruptcy is to pick out, describe, and analyze a range of layout methods to be had for building smart trash containers. By doing so, we goal to equip you with the knowledge and insight needed to make knowledgeable choices whilst starting up to design your very personal progressive trash bin.

To kick things off, we can dive headfirst into the intricate venture of identifying more than one layout strategies. Through substantial research and evaluation, we are able to discover an array of methodologies, frameworks, and ideas that have demonstrated potential within the realm of smart waste management.

Following this identity phase, we are able to continue to carefully describe each of the selected design processes. We will get to the bottom of their distinguishing traits, standards, and features, imparting you with a complete expertise of ways they can be applied to the design of a clever trash bin.

Finally, inside the analysis degree, we will critically compare each design approach's strengths, barriers, and suitability in the context of growing an shrewd waste control answer. By analyzing their respective blessings and disadvantages, we aim to facilitate a selection-making process that aligns with your undertaking's goals, assets, and constraints.

Through this chapter's based exploration, we aim to provide you with a properly-rounded view of the more than one layout techniques available for creating a clever trash bin. Whether you are an aspiring inventor, an environmental enthusiast, or an expert within the field, we hope that this bankruptcy empowers you to craft an revolutionary, powerful, and sustainable solution for waste disposal. Together, permit's reimagine the destiny of trash boxes, making a high quality effect on our environment one layout approach at a time!

2.2 Identify multiple design approach

When it comes to designing a smart trash bin, there are numerous objectives that we can pursue to enhance its functionality and efficiency. In this section, we will explore five key objectives and examine multiple design approaches for achieving each one. Let's dive in and discover the exciting possibilities!

1. User Identification:

Objective: Implement a system that can identify and authenticate users interacting with the smart trash bin.

Design Approaches:

- **RFID/NFC Tagging:** Integrate radio-frequency identification (RFID) or near-field communication (NFC) tagging to associate individual users with their trash disposal activities.
- **Mobile App Integration:** Leverage smartphone applications to enable users to connect with the smart trash bin and personalize their interactions.

2. Plastic and Non-plastic Identification:

Objective: Develop a mechanism to identify and separate plastic waste from non-plastic waste for proper recycling and disposal.

Design Approaches:

- **Sensor-based Differentiation:** Implement sensors that can detect specific properties unique to plastic, such as density, heat conductivity, or electromagnetic response.
- **Machine Learning Classification:** Train machine learning models using labeled datasets to classify waste items as plastic or non-plastic based on various attributes.

3. Waste Weight Measurement:

Objective: Incorporate a system to measure the weight of the disposed waste accurately.

Design Approaches:

- **Load Cells:** Utilize load cells integrated into the trash bin to measure the weight of the waste as it is thrown in.
- **Motion Sensors:** Detect the motion caused by disposing of waste and infer the weight by analyzing the velocity and acceleration patterns.

4. Trash Level Measurement:

Objective: Design a method to measure and monitor the trash bin's level to optimize waste collection processes.

Design Approaches:

- **Ultrasonic Sensors:** Deploy ultrasonic sensors to measure the distance from the top of the trash bin to the trash pile and estimate the fill level.
- **Infrared Sensors:** Utilize infrared sensors to detect the presence and volume of waste inside the trash bin.

5. User Reward System:

Objective: Implement a system that incentivizes users to participate in responsible waste disposal practices.

Design Approaches:

- **Points-based System:** Assign users points for each correct disposal action and reward them with incentives such as discounts or coupons based on accumulated points.
- **Monetary-based Reward System:** Reward users with real money after the successful waste dumping.

By exploring these multiple design approaches for achieving each objective, we open the door to innovation and creativity in developing a smart trash bin that aligns with specific project goals, available resources, and desired user experiences. The possibilities are vast, and the choice of design approach ultimately depends on the unique requirements and priorities of the project. Let's continue our exploration in the following sections and discover the potential and implications of these design approaches in more detail!

2.3 Describe multiple design approach

2.3.1 Design Approach 1

Flowchart

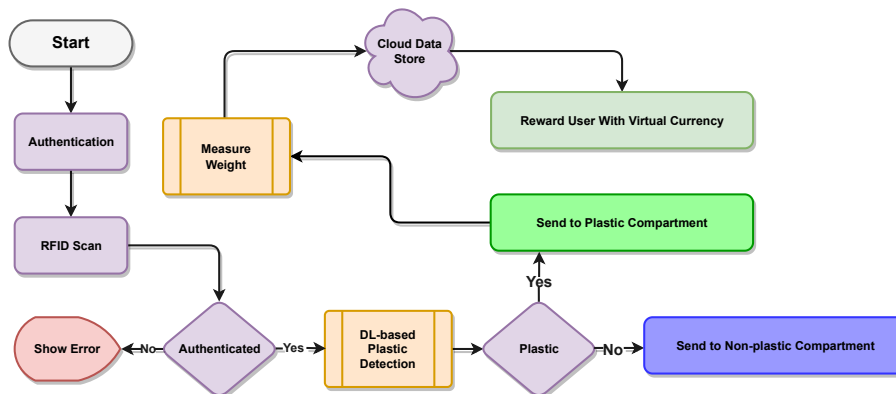


Figure 2: Design approach 1 flowchart.

Initially, the user will come to the bin and will be authenticated. To authenticate himself, he will use an Radio Frequency Identification (RFID) scanner to scan his ID card. Following successful identification, the user will put the trash into the scanning sheet of the bin. When the user throws debris into the bin, an IR sensor determines if the debris is made of plastic or not. The bin will not open its valve if it is not made of plastic. For explanatory purpose, the plastic detection technique has been illustrated in Figure 3 which describes the detection process. If it is determined to be plastic, the valve will open and a conveyor will transport the object to a weighing sensor. The sensor will weigh it, and utilizing Internet of Things (IoT) technology, it will save that data against that specific user as virtual currency in the cloud. The user will be able to see that incentive on the mobile app. Later on, the user may utilize that reward point to do things like buy a product at a discount, exchange anything for these virtual currencies, or withdraw raw money.

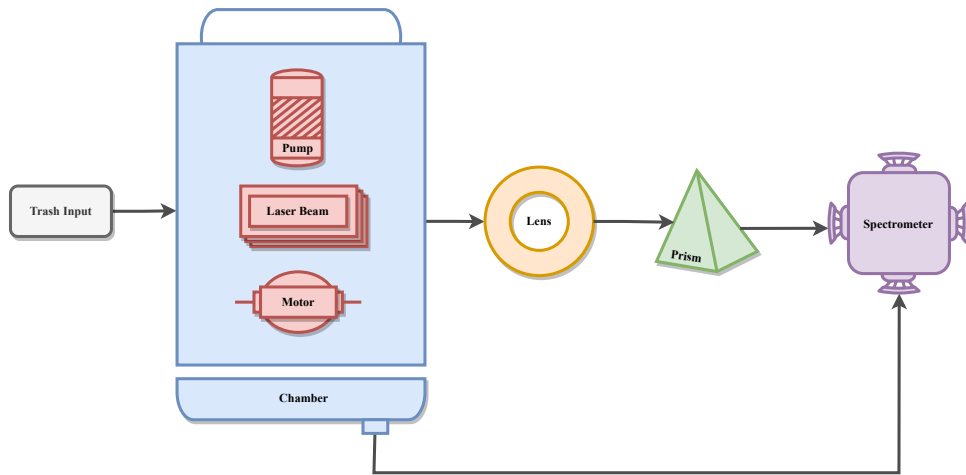


Figure 3: Design approach 1 plastic bottle detection diagram.

As we can see in Figure 3, we are utilizing the laser spectrometer to detect the plastic bottle. Initially, we are providing the unknown object to the scanner. Then it will pass through a laser beam. In this stage, while the bottle is being scanned, a motor will keep rotating the plastic bottle for detection purposes. Also, a pump has been used to make the chamber airtight. After that, the reflected ray coming from the bottle will go through a focal lens, which will go through a prism. At the end, the ray will be processed by a spectrometer, which will provide a final result indicating whether the object is plastic or not [9].

In terms of waste collection, the bin will alert the garbage collector through central server when it exceeds any threshold. They will be able to go to the trash using Google Maps, and using the proper authentication mechanism, they will be able to take the garbage out and the bin will immediately reset.

CAD design

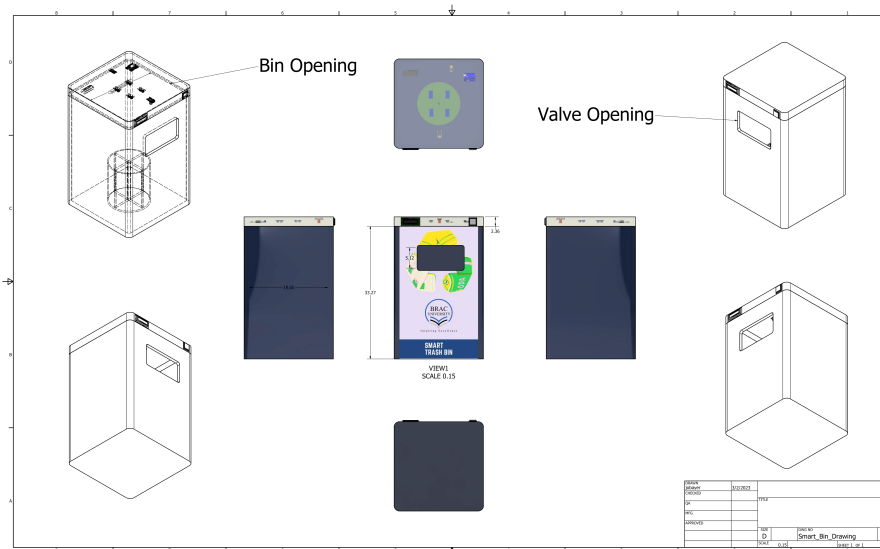


Figure 4: Design approach 1 – CAD design.

2.3.2 Design approach 2

Flowchart

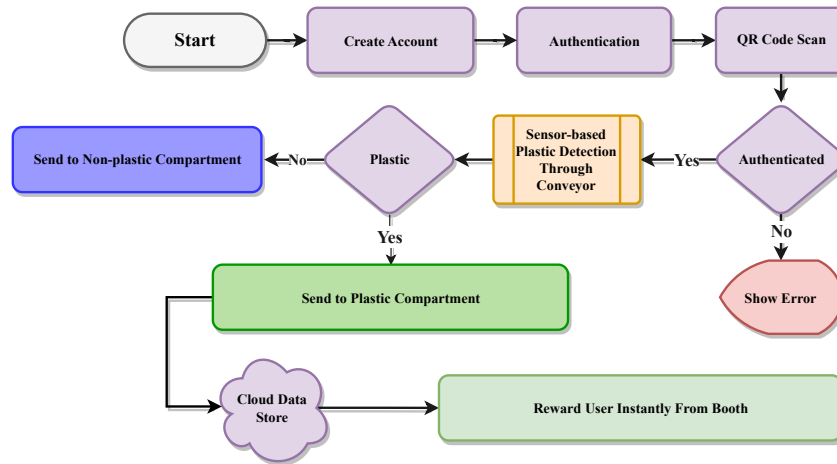


Figure 5: Design approach 2 illustration.

In this design approach, first the user will create an account in our app. By creating an account, they will get a unique Quick Response (QR) code to identify themselves. To throw waste into the bin, they have to approach the bin and position the QR code in front of the camera attached to it. The camera will scan the QR code and will check whether the user account exists in the cloud. If the user does not exist in our database, he/she will not be able to throw waste into the bin. On the other hand, if the user is authenticated properly, the trash bin will ask the user to put the waste into a sheet located beneath the camera. Then the camera will scan the waste and will predict the shown object to be plastic according to our trained machine learning algorithm. If the object is predicted to be a plastic bottle, the valve will open and let the user put their waste into the bin. For explanatory purpose, the plastic detection technique has been illustrated in Figure 6 which describes the detection process. After putting the waste into the bin, the user will be rewarded with something valuable from the rewarding vending machine located beside the bin.

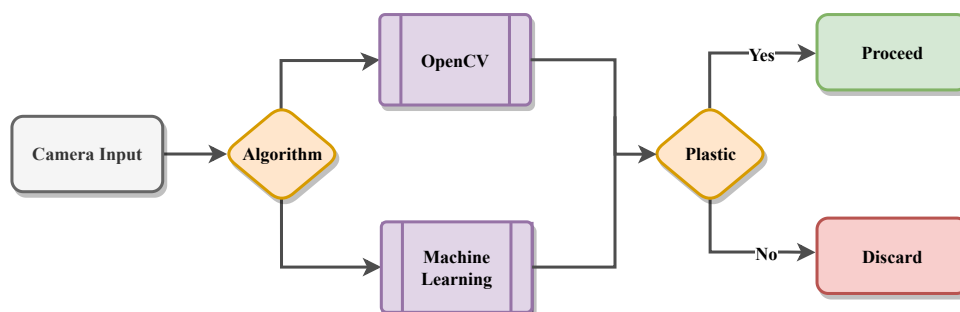


Figure 6: Design approach 2 plastic bottle detection diagram.

Here in Figure 6, first of all, we are taking image as an input to our plastic detection module. We can either prefer *OpenCV* or any machine learning image detection algorithm like *CNN*. It depends on our system components like microcontroller, power limitations

and few other criteria. In case of *OpenCV* library, if the object's properties match with a typical bottle, then it is identified as a plastic. Whereas in case of machine learning, if the input object is predicted to be a plastic according to our trained model, then it is identified as a plastic bottle. If in any cases, the bottle is not identified as a plastic, it is discarded and an error will be shown to the user. Otherwise, the bottle will be processed further into our bin.

The garbage collection procedure will remain the same as in design approach 1.

CAD design

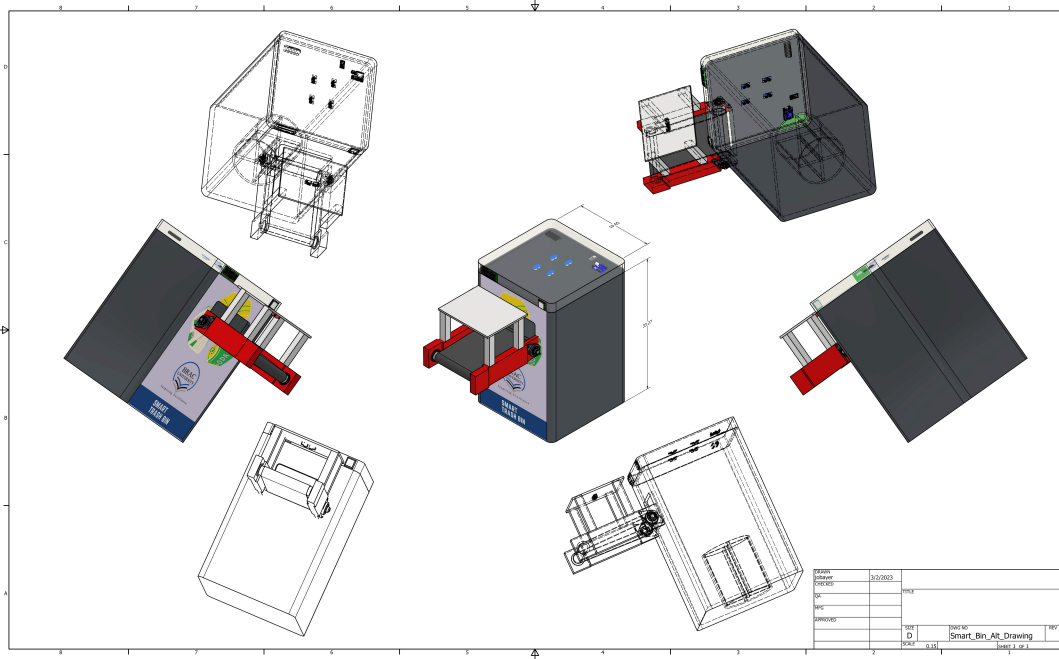


Figure 7: Design approach 2 – CAD design.

2.4 Analysis of multiple design approach

Table 4: Internal and external parameters of a smart trash bin.

Factor	Parameters	Design Approach	
		Design 1	Design 2
Internal	Size & Shape	Bulky	Compact
	Weight	Higher	Lower
	Materials	Fragile	Sturdy
	Sensors	Much	Less
	Battery	High Powered	Low Powered
External	Maintenance	High	Low
	Pedestrian Traffic	Equal	Equal

Table 5: Analysis of multiple design approaches based on efficiency.

Parameters	Design Approach	
	Design 1	Design 2
Capacity	10 Kg	10 Kg
Waste Monitoring	Ultrasonic	Ultrasonic
Odor Control	Gas Detector	Gas Detector
Waste Detection	Image Processing	Inductive Sensor
Connectivity	WiFi	WiFi
Monitoring Interface	Mobile App	Mobile App
Power Source	Rechargeable Battery	Direct Power

Table 6: Analysis of multiple design approaches based on usability.

Parameters	Design Approach	
	Design 1	Design 2
Accessibility	Sensor-based lid opening	Sensor-based lid opening
Feedback Mechanism	OLED display	OLED display
Maintenance	Easy to replace & clean	Difficult to replace & clean
Durability	Strong and durable built	Normal built
Price	Affordable	A bit costly

Table 7: Analysis of multiple design approaches based on manufacturability.

Parameters	Design Approach	
	Design 1	Design 2
Assembly Complexity	Moderate	High
Component Integration	Fewer components, relatively simpler	More components, complex integration
Manufacturing Process	Manual assembly	Manual assembly
Scalability	Scalable	Scalable
Production Time	Shorter period	Longer period

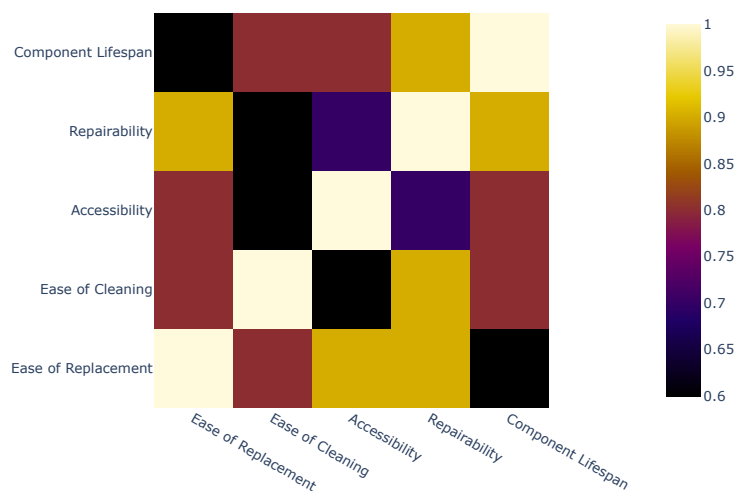


Figure 8: Analysis of multiple design approaches based on maintainability.

Table 8: Analysis of multiple design approaches based on impact.

Impact on	Design Approach	
	Design 1	Design 2
Life	Simplifies waste disposal process	Promotes conscious consumerism and waste reduction
Environment	Improves waste management and recycling	Focuses on waste-to-energy conversion
Weather	Weather-resistant design	Climate-sensitive features
Culture	Values cultural preferences in design	Requires adaptation to smart waste systems
Community	Encourages community participation through rewards	Encourages community participation through rewards

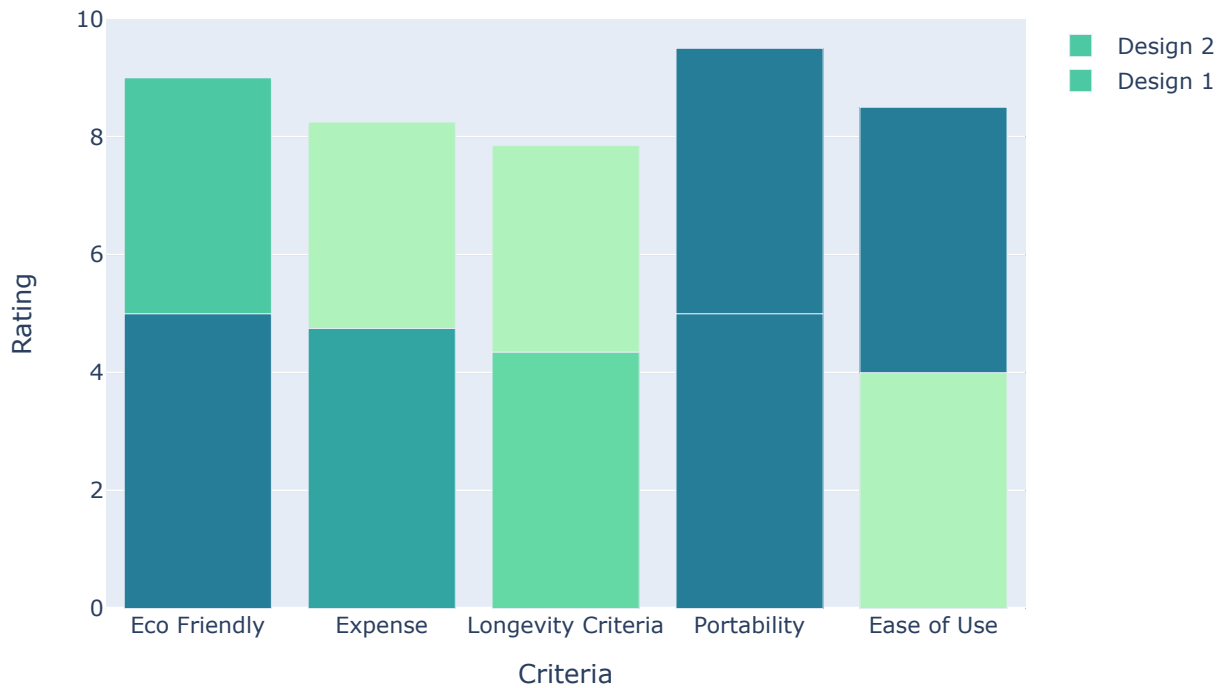


Figure 9: Analysis of multiple design approaches based on sustainability.

Table 9: Analysis of multiple design approaches based on estimated cost.

Component		Budget (BDT)	
		Design 1	Design 2
Hardware	Bin	1000	1000
	RFID	1500	–
	Camera	1000	1200
	Motor	2500	5000
	Load Cell	300	300
	US	400	400
	MCU	1800	2500
	Battery	2970	4590
	Display	650	650
	Bearing	–	800
	Coveyor	–	1000
	PVC	1500	1500
	Rod	300	300
	Wire	100	100
	LED	30	30
	Boost Converter	–	250
	Capacitive Sensor	–	340
	Inductive Sensor	–	390
	Software	Cloud Storage	500
Map API		1000	1000
Play Console		2900	2900
Others	Transportation	500	500
Total		18950	25250

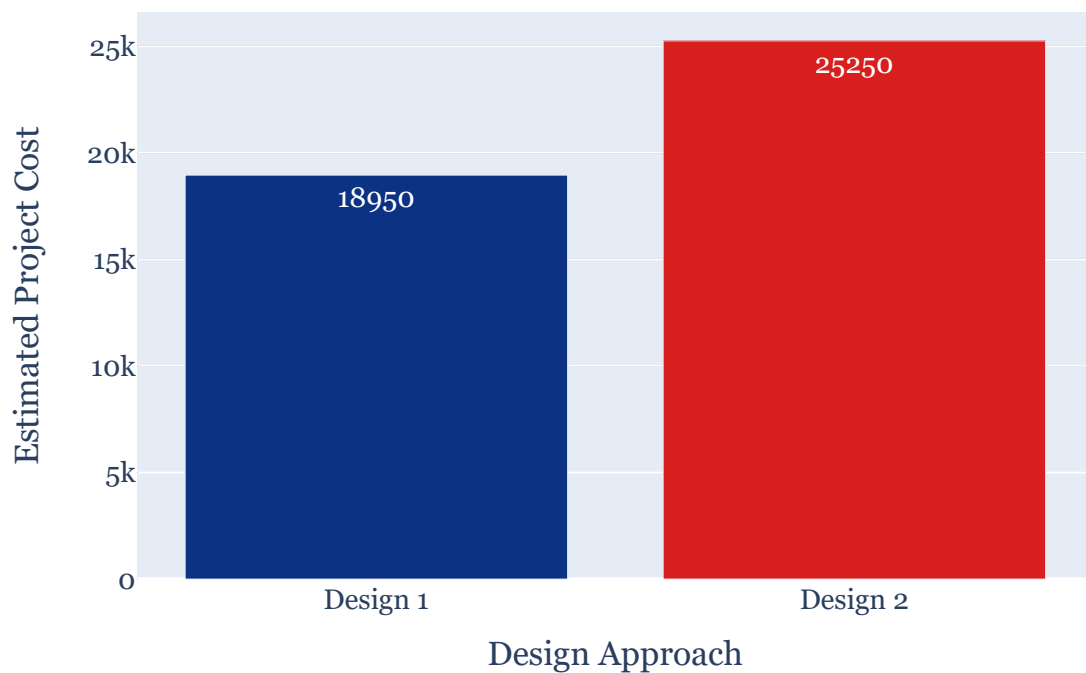


Figure 10: Design 1 & 2 estimated cost analysis.

Table 10: Qualitative analysis of multiple design approaches.

Parameters	Design Approach	
	Approach 1	Approach 2
Odor Detection	Yes	No
Disposable Compartment	Yes	Yes
Fire Detection	Yes	No
Weight Measurement	Yes	Yes
Automated Operation	Yes	Yes
Transparency	Yes	No

2.5 Conclusion

In this chapter, we delved into the exploration of numerous layout techniques for the improvement of a smart trash bin. Our primary aim was to discover and examine capacity design strategies that could beautify the functionality and effectiveness of the bin.

Throughout the bankruptcy, we launched into a detailed exploration of different design procedures. We targeted on expertise the underlying principles, technologies, and methodologies related to each technique. By offering comprehensive descriptions, we aimed to offer a complete evaluation of the possibilities and challenges offered through every layout method.

Moreover, we conducted an in-intensity evaluation of two precise layout techniques, carefully comparing their strengths, weaknesses, and potential implications. This evaluation furnished us with valuable insights regarding the feasibility, viability, and capability impact of those procedures.

By reading those design processes and their analysis, we gained a deeper expertise of the key elements to do not forget while designing a clever trash bin. These elements consist of technological issues, person alternatives, fee-effectiveness, environmental impact, and market reputation.

Our exploration and analysis on this chapter serve as a foundation for the subsequent tiers of our research and improvement manner. Armed with this know-how, we are nicely-gear'd up to make knowledgeable decisions and continue with designing a smart trash bin that embodies innovation, functionality, and consumer satisfaction.

3 Use of Modern Engineering and IT Tools [CO9, PO-E]

3.1 Introduction

Modern engineering and IT tools are integral in creating virtual simulations of our project before building them in the real world. We have used a variety of software applications to plan out the system’s mechanical design, electrical circuitry, electronic components, as well as trained and tested hundreds of images for waste identification. In addition to a multitude of online resources, we have used industry-standard programs to better visualise our project. After comparing different options, we have chosen the combination of software that best represents our project virtually.

3.2 Select appropriate engineering and IT tools

In the ever-evolving landscape of engineering and information technology, the significance of selecting appropriate tools cannot be overstated. This is particularly evident in the realm of smart trash bins, where the integration of advanced engineering and IT tools assumes paramount importance. This introductory paragraph seeks to shed light on the vital role played by the careful choice and implementation of tools in various domains, including simulation, CAD design, programming, and mobile application development. By exploring the multifaceted nature of these criteria, it is possible to comprehend how an optimized amalgamation of engineering and IT tools can revolutionize the functionality and efficiency of smart trash bins, thereby creating a more sustainable and intelligent waste management system.

Table 11: Comparative analysis of circuit simulation software.

Criteria	Proteus	MATLAB	Multisim	LTspice	PSpice
Simulation	Mixed-mode	Numerical	Mixed-mode	Mixed-model	Mixed-mode
Component Library	Extensive	Limited	Extensive	Extensive	Extensive
Simulation Accuracy	Good	Good	Good	Excellent	Excellent
Model Availability	Limited	Extensive	Limited	Limited	Extensive
Learning Curve	Moderate	Steeper	Moderate	Moderate	Moderate
Price	Commercial	Commercial	Commercial	Free	Commercial
Analog Simulation	Yes	Limited	Yes	Yes	Yes
Digital Simulation	Yes	Limited	Yes	Yes	Yes
Schematic Capture	Yes	No	Yes	Yes	Yes

Table 12: Comparative analysis of 3D CAD software

Criteria	Autodesk Inventor	SolidWorks	FreeCAD	KiCad
Types	Parametric	Parametric	Parametric	N/A
User Interface	User-friendly	User-friendly	Less intuitive	Less intuitive
Parametric Design	Yes	Yes	Yes	No
Assembly Design	Yes	Yes	Yes	No
Part Library	Extensive	Extensive	Limited	Limited
Price	Commercial	Commercial	Open-source	Open-source
Learning Curve	Moderate	Moderate	Steeper	Moderate
Rendering and Animation	Yes	Yes	Limited	No

Table 13: Comparative analysis of programming languages

Criteria	C++	Java	Python
Paradigm	Multi-paradigm	Object-Oriented	Multi-paradigm
Syntax Clarity	Complex	Clear	Clear, concise
Learning Curve	Steeper	Moderate	Gentle
Performance	High	Moderate	Moderate
Memory Management	Manual	Automatic	Automatic
Community	Large	Large	Large
Development Speed	Slower	Moderate	Faster
ML Support	Growing support	Growing support	Extensive support
Open Source	Yes	OpenJDK	Yes

Table 14: Comparative analysis of programming frameworks

Criteria	TensorFlow Lite	OpenCV
Framework Type	ML Inference	Computer Vision
Language Support	C++, Python, and more	C++, Python, and more
Platform Compatibility	Cross-platform	Cross-platform
Ease of Use	High-level API	High-level & low-level APIs
Real-time Processing	Suitable	Suitable
Open Source	Yes	Yes

Table 15: Comparative analysis of mobile app development platforms

Criteria	Android Studio	Ionic	iOS (Native)	Flutter
Language	Java, Kotlin	HTML, CSS, JS	Swift, Obj-C	Dart
Performance	Excellent	Moderate	Excellent	Good
Cross-Platform	No	Yes	No	Yes
App Store Deployment	Play Store	App Stores	App Store	App Stores
Cost	Free	Free	Free	Free
Performance Optimization	Native	Hybrid	Native	Native

Following a comprehensive analysis of the requirements for simulation, CAD design, programming, and mobile application development within the context of smart trash bins, a judicious selection of individual tools has been determined. The culmination of this evaluation process has yielded a refined set of specific engineering and IT tools that will be utilized in the development and implementation of the smart trash bin system. These carefully chosen tools have been identified based on their demonstrated suitability, compatibility, and effectiveness in addressing the unique challenges and objectives associated with each respective domain. Through this meticulous approach to tool selection, the aim is to ensure optimal functionality, performance, and user experience in the realization of an efficient and intelligent waste management solution.

1. Circuit simulation
 - Proteus
 - Matlab Simulink
2. CAD design
 - Autodesk Inventor
 - SolidWorks
3. Programming language
 - Python
4. Programming framework
 - TensorFlow Lite
 - OpenCV
5. Mobile application platform
 - Android Studio

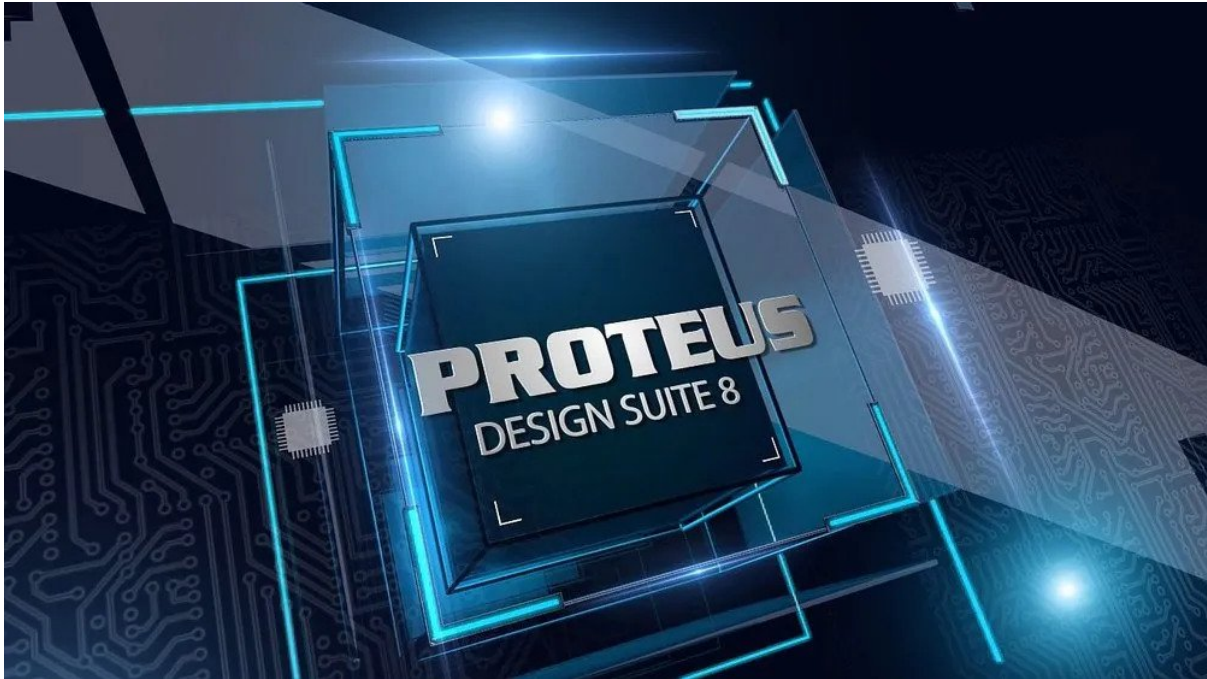
3.3 Use of modern engineering and IT tools

3.3.1 Circuit simulation

3.3.2 Proteus

Proteus is predominantly used for simulation and trying out of microcontroller-based totally designs and digital circuits. It gives a whole set of gear for designing and evaluating diverse analogue and digital circuits. Proteus enables designers to simulate and validate their designs prior to constructing the hardware, thereby retaining time and resources.

Proteus presents schematic seize, PCB format design, and debugging capabilities further to circuit simulation. The software program supports a whole lot of microcontrollers and permits users to put in writing and check firmware code in the software itself. Proteus also can be used for virtual instrumentation, allowing designers to construct individualised person interfaces with which to engage with their designs.



Proteus has a number of advantages over other comparable software products on the market. Among the main advantages are:

- **User-friendly interface:** Proteus's interface is basic and intuitive, making it trustworthy to apply for both amateur and superior users.
- **Versatility:** Proteus offers a sizable selection of additives and models, making it a flexible instrument for designing and simulating plenty of circuit types.
- **Real-time simulation and debugging:** Proteus allows designers to conduct actual-time simulation and debugging of their designs, which could help identify mistakes and decorate the general efficacy of the circuit.
- **Integration with other tools:** Proteus integrates well with different software program programs, consisting of MATLAB and Simulink, permitting designers to amplify its capacities.

Advantages

1. **Ease of use:** The interface of Proteus is easy and user-pleasant, making it simple to pick out up and positioned to apply straight away. This is one of the software's strongest selling points.
2. **Wide range of components:** Proteus is a flexible tool for creating and simulating many kinds of circuits since it comes with a vast selection of components and models to choose from. Proteus also comes with a wide range of components.
3. **Real-time simulation and debugging:** Real-time simulation and debugging: Proteus gives designers the ability to do real-time simulation and debugging of their designs, which may assist in locating flaws and enhancing the designs' overall performance.

4. **Integration with other tools:** Integration with other tools: Proteus connects effectively with other software tools like MATLAB and Simulink, which allows it to increase its capabilities in a number of different ways.

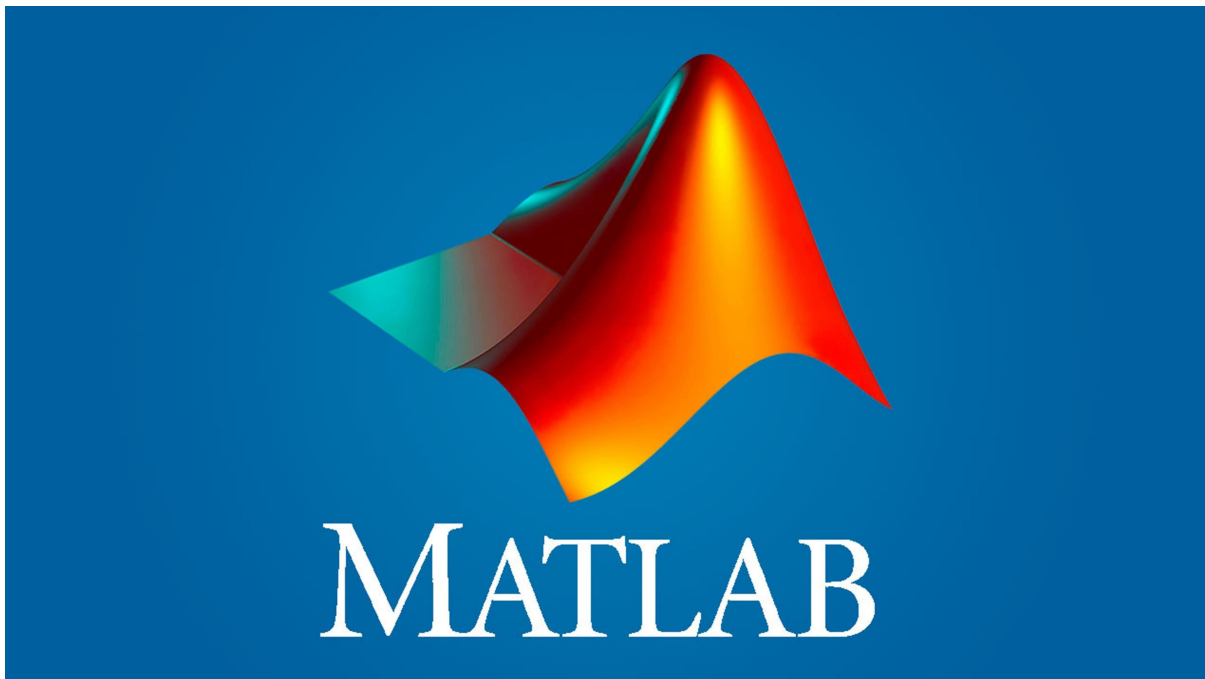
Disadvantages

1. **Cost:** The cost of using Proteus is higher than the cost of using alternative software solutions that perform comparable functions that are currently on the market.
2. **Limitations of free version:** The free edition of Proteus has several restrictions on the amount of components and models that may be utilised in a design. These restrictions are imposed by the software's developers.
3. **Occasional instability:** Occasional instability: While running a simulation, the Proteus programme may, on rare occasions, become unstable or crash, which may be quite irritating for the program's users.

In general, Proteus is a sophisticated and adaptable tool that can be used to build and simulate electrical circuits as well as designs that are based on microcontrollers. Before deciding whether or not Proteus is the appropriate tool for their particular applications, users should first carefully assess their requirements and weigh the benefits and drawbacks of using the software.

3.3.3 Matlab

MATLAB is a powerful programme that is often used in the solution of intricate engineering issues. It is especially useful for solving issues requiring numerical analysis, the visualisation of data, and simulations. Several of the following are particular applications of MATLAB that can be found in engineering:



- **Signal processing:** MATLAB's built-in capabilities for filtering, analysing, and

visualising signals make it helpful for signal processing applications including audio and picture processing.

- **Control systems:** MATLAB may be used to build and test control systems, which has applications in a broad number of industries such as robotics, aeronautical engineering, and automotive engineering, amongst many others.
- **Finite element analysis:** MATLAB's finite element analysis is excellent for modelling how materials and structures respond when exposed to complicated loads since it has methods for solving partial differential equations (PDEs).
- **Optimization:** MATLAB has a wide range of optimisation techniques, which may be used to locate the optimum values of design parameters for complicated systems. This can be accomplished via optimisation.

MATLAB is superior to many other software programmes that are often used in the engineering industry in a number of ways. Some examples of this are as follows:

- **User-friendly interface:** MATLAB's syntax is straightforward and easy to understand, making it simple to pick up and put to use even for those who have no prior knowledge with programming.
- **Large community:** A lot of people use MATLAB, both professionally and in academia, therefore there are many of tutorials and forums where we may ask questions and get answers if we get stuck.
- **Versatility:** MATLAB's versatility allows it to be used for a diverse array of applications, ranging from simple computations to intricate modelling and simulations.

MATLAB is a software programme that, like any other, has both positive and negative aspects.

Advantages

1. **Powerful built-in functions:** Built-in functions that are very powerful MATLAB contains a large number of pre-built functions that may be used for typical tasks, which saves time and effort when developing custom code.
2. **Easy data visualization:** Simple representation of data MATLAB's charting capabilities make it simple to produce high-quality representations of data, which may be shown in a variety of formats.
3. **Active development:** MATLAB is constantly being updated with new features and enhancements to existing ones.

Disadvantages

1. **Cost:** MATLAB may be rather pricey, particularly when used for business purposes.
2. **Limited customization:** There is a limit to the amount of customisation that can be done with MATLAB. Although it has a large number of built-in functions, it may be challenging to alter existing functions or add new features.

3. **Steep learning curve:** The learning curve for MATLAB is somewhat steep because, despite its user-friendly interface, becoming adept in the software's more complex functions may require a significant amount of time and effort.

3.3.4 CAD design

3.3.5 Autodesk Inventor



Autodesk Inventor is a totally powerful programme that allows engineers remedy hard design demanding situations. It is a 3-D CAD programme that offers engineers and architects the capacity to increase specific virtual prototypes of goods or additives, simulate how they may behave in a whole lot of situations, and make any required changes before the layout is finalised.

Autodesk Inventor presents users with a wide type of equipment and abilities, which allows them to construct complicated designs in a well timed manner whilst keeping a high degree of accuracy. These equipment offer talents for motion analysis and rendering, as well as parametric modelling, meeting modelling, sheet metal fabrication, and sheet metal manufacturing. Additionally, the software can combine with numerous different software programmes, which paves the manner for easy collaboration between various organizations of people.

When compared to other software program, Autodesk Inventor has a number of blessings that set it apart. The simplicity of its operation is one of the primary benefits that it has. The programme includes an intuitive graphical consumer interface, which makes it simple for novices to discover ways to use and navigate. In addition, Autodesk Inventor gives users with a whole range of tools and abilities, which makes it viable for designers and engineers to build complicated designs in a well timed manner even as preserving excessive degrees of accuracy. In addition to that, it has fantastically evolved simulation and visualisation competencies, that are very essential for the manner of planning and trying out complicated engineering tasks.

Advantages

1. **User-friendly interface:** Interface that is pleasant to users Autodesk Inventor's interface is designed to be user-friendly, making it simple for users to navigate the programme and use its many tools and capabilities. This is very helpful for novices who are just getting started with engineering design software and 3D modelling tools.
2. **Comprehensive set of tools and features:** Tools and features that cover the whole product development cycle Autodesk Inventor provides its users with a com-

prehensive collection of tools and features that cover the entire product development cycle, beginning with the first ideation of an idea and ending with the creation of the finished product. Tools such as sophisticated modelling tools, assembly management tools, simulation tools, visualisation tools, and technical documentation tools are included among these tools.

- 3. Integration with other software programs:** Other software, including as AutoCAD, Fusion 360, and Vault, may be smoothly integrated with Autodesk Inventor because to its excellent integration capabilities. This makes it possible for users to effortlessly import and export data across various software systems, which streamlines processes and reduces the likelihood of mistakes occurring.
- 4. Advanced simulation and visualization capabilities:** Users of Autodesk Inventor have the ability to simulate real-world situations, test designs for stress, strain, and motion, and assess the performance of their designs before the designs are produced. Users are able to generate lifelike renderings and animations because to the software's excellent visualisation features, which are also included in the package.
- 5. Ability to create 3D models and simulations:** Users of Autodesk Inventor have the ability to construct three-dimensional models of their goods and run simulations of how those things would behave in the real world. Because of this, engineers and designers are better able to spot possible problems early on in the design process, which saves both time and the expenses involved with physical prototypes.
- 6. Technical documentation tools:** Tools for the creation of technical documentation Autodesk Inventor provides a variety of tools for the creation of technical documentation including drawings, bills of materials, and exploded views. These technologies contribute to ensuring that all relevant parties have access to information that is both correct and up to date on the product design.
- 7. Large online community for support and resources:** Autodesk Inventor offers a significant online community of users who work together to provide help and resources for one another. We may obtain advice and direction on how to use the programme by accessing this community's online tutorials, blogs, and discussion forums, which are all available online.

Advantages

- 1. High cost of ownership:** Autodesk Inventor is a premium software, thus it comes with a hefty price tag and a high total cost of ownership. Because of this, it may be challenging for individuals and smaller enterprises to be able to purchase the programme.
- 2. Steep learning curve for complex designs:** Autodesk Inventor offers a user-friendly interface; nonetheless, mastering the programme may take a lot of time and effort, especially when working on complicated designs. The steep learning curve is due to the product's ability to handle complex designs. This could provide a challenge for those who are just starting out or have just a little bit of experience working with 3D modelling and engineering design software.

3. **Can be resource-intensive, requiring high-end hardware:** Autodesk Inventor is a powerful piece of software that, in order to function without hiccups, calls for high-end hardware. Users who need to update their hardware in order to make full use of the programme may incur extra expenses as a result of this need.
4. **Limited compatibility with non-Autodesk software:** It may have limited compatibility with software that is not produced by Autodesk. Although Autodesk Inventor interacts effectively with other software programmes produced by Autodesk, it may have limited compatibility with software that is not produced by Autodesk. This might be a drawback for users that depend on many software applications.
5. **Some features may not be as robust as other similar software programs for specialized tasks:** It is possible that certain features are not as sturdy as those found in other software programmes that are comparable and designed for performing specialised tasks: Although Autodesk Inventor provides its users with a comprehensive set of tools and features, some users may discover that certain features of the software are not as powerful as those offered by other specialised software programmes that are designed to perform particular tasks. However, this is a common tradeoff with a software application that can be used for a variety of purposes, such as Autodesk Inventor.

3.3.6 SolidWorks



SolidWorks is a 3D computer-aided design (CAD) programme that is frequently utilised in the tools required to solve complicated engineering problems. Engineers are given the ability to easily develop complicated components and assemblies, and they are also given the ability to simulate real-world situations in order to analyse how their designs will operate under a variety of different settings. SolidWorks includes tools for producing precise drawings, modelling the behaviour of assemblies under a variety of stress circumstances, and constructing complicated geometry. Because of these properties, it is an excellent tool for the design of intricate mechanical systems.

SolidWorks is superior than competing software because to its intuitive user interface, strong simulation capabilities, and comprehensive feature set. It provides a comprehensive set of tools for the design of everything from basic components to intricate assemblies. Because of its simulation capabilities, engineers are able to test their ideas and make accurate predictions about how those systems would behave in the actual world. Because SolidWorks works well with other software and integrates well with other software, it is simple to transfer data to and from other CAD programmes and CAM systems.

Advantages

1. **User-friendly interface:** SolidWorks features an interface that is easy to use and navigate, making it accessible to users with varying levels of expertise, including novices.
2. **Powerful simulation capabilities:** SolidWorks has significant simulation capabilities, which allow for the study of complicated assemblies and the prediction of how they will act under real-world situations. These capabilities make it possible to analyse and anticipate how the assemblies will behave in the real world.
3. **Large community of users:** SolidWorks has a big and lively network of users, and those customers often collaborate and alternate useful facts with each other on the way to get the maximum out of the programme. This may be useful for finding answers to issues as well as learning new competencies.
4. **Robust feature set:** SolidWorks has a complete function set, which incorporates a large form of equipment and talents for the layout of the whole thing from easy components to tricky assemblies. These abilities encompass sheet steel layout, weldments, pipe and tubing, and extra.
5. **Integration with other software:** SolidWorks connects successfully with other CAD software program as well as CAM systems, which makes it simple to transfer facts from one programme to some other.

Disadvantages

1. **Expensive:** One of the maximum significant drawbacks of using SolidWorks is that it's far instead highly-priced. When as compared to different CAD software, it is able to be quite steeply-priced, which might also make it unfeasible for sure users or for smaller corporations to purchase it.
2. **Requires powerful computer:** SolidWorks desires a fairly speedy laptop to work well, which may be a trouble for certain users who do no longer have get right of entry to to high-performance hardware. Because of this requirement, some users may additionally discover it tough to utilise SolidWorks.
3. **Limited flexibility:** SolidWorks may not be the right option for other varieties of layout paintings consisting of structure or commercial layout due to its restrained flexibility. SolidWorks is an extremely good device for mechanical layout, but it may now not be the pleasant desire for different varieties of layout work. Because of this, its adaptability and usability are restricted for sure applications.
4. **Steep learning curve:** Although SolidWorks is a user-friendly programme, it does have a steep learning curve, which can be particularly challenging for people who have not previously worked with computer-aided design (CAD) software. Because of this, it might be difficult for new users to get started with the programme and become adept in its use.
5. **Reliance on updates:** SolidWorks depends heavily on frequent software updates to guarantee compatibility and maintain operation. This may be annoying for customers who do not want to regularly upgrade their programme since SolidWorks relies so largely on these updates.

3.3.7 Programming language

3.3.8 Python

Python is a famous programming language this is utilised in many tools for fixing difficult engineering troubles. Data analysis, system learning, and scientific computing are simply few of the various applications that employ it. Python comes with a massive set of gear and frameworks that streamline the development procedure and make it easy to construct complicated fashions and simulations. These benefits make Python an attractive alternative for programmers. Signal processing, the layout of control structures, and optimisation are just some of the engineering jobs that may be done the use of Python.

Python is advanced to other software in phrases of its person-friendliness, versatility, and value-effectiveness. It capabilities a straightforward syntax that is straightforward to select up and recognise, which makes it approachable for beginner customers as well as those with more understanding. Engineers are able to tailor their approaches to fulfill their person necessities way to Python's high diploma of adaptability and the availability of a large quantity of libraries tailored to sure applications. Python is a programming language that isn't best freely usable but additionally open-supply, which makes it a reasonably-priced desire for both people and groups.

Python's ease of use, adaptability, and robust user network are simply some of the numerous benefits of the usage of this programming language. Python is not as fast as compiled languages, it does not have integrated guide for multithreading, and it does not carry out as well as other programming languages in positive styles of packages. These are just some of the drawbacks of the use of Python.

Advantages

1. **Easy to learn:** Python's syntax is straightforward and easy to understand, making it a language that is simple to learn and simple to use for programmers of all experience levels, from novices to seasoned pros.
2. **Adaptable:** Python is an adaptable language that can be used for a broad variety of applications, such as scientific computing, machine learning, web development, and automation.
3. **Large community of users:** A huge and active user community Python has a large and active user community, which implies that there are numerous resources accessible for learning the language and obtaining support with it.
4. **Open-source:** Python is a free programming language that is also available under an open-source licence. Because of this, it is a cost-effective choice for both people and enterprises.
5. **Cross-platform compatibility:** Compatibility with numerous operating systems and platforms Python can operate on a number of different operating systems, and programming developed in Python is readily portable to a number of different platforms.

Disadvantages

1. **Slower execution speed:** Python is an interpreted language, which means that its execution pace can be slower than that of compiled languages inclusive of C or C++. This is because of the truth that Python does not have a digital device. This may be a drawback for a few forms of packages, specially those who need for excessive-overall performance computation.
2. **Weak support for multithreading:** Python's help for multiple threads isn't always almost as robust as that provided via other languages, which includes Java. This is despite the truth that Python does provide a few aid for many threads.
3. **Lack of built-in functionality:** Python's absence of some built-in features that are available in other languages Despite the fact that Python offers numerous libraries and frameworks to make development simpler, Python is lacking in certain built-in capabilities. For example, it does not offer native support for GUI development.
4. **Limited applicability in certain fields:** Despite its versatility, Python may not be the greatest option for certain fields, such as high-performance computing or real-time embedded systems.
5. **Dependency management challenges:** Managing dependencies in Python may be difficult, especially when working on big projects or with several versions of Python.

3.3.9 Programming framework

3.3.10 TensorFlow Lite

TensorFlow Lite is a lightweight shape of the famous device mastering library TensorFlow. It turned into made for cell and embedded devices. It is used to use system studying fashions on gadgets with limited processing electricity and reminiscence, like smartphones, capsules, and Internet of Things (IoT) devices. TensorFlow Lite gives a set of equipment and APIs that make it clean to construct system mastering fashions and practice them on a wide variety of gadgets.

TensorFlow Lite is better than different programmes due to how nicely it really works, how flexible it's far, and how easy it is to use. It we could programmers make complicated models and run them in real time on cell and embedded devices with excessive-overall performance system gaining knowledge of reasoning. TensorFlow Lite is likewise very bendy. It works with many different kinds of fashions and frameworks and has an smooth-to-use interface that makes the improvement process less complicated.

Advantages

1. **High performance:** TensorFlow Lite offers high-performance machine learning inference on mobile and embedded devices, so engineers can build complicated models and run them in real time.
2. **Flexibility:** TensorFlow Lite is very flexible and can be used with many different kinds of models and frameworks. This lets programmers change the way they work to fit their needs.

3. **Easy-to-use interface:** TensorFlow Lite has an easy-to-use interface that makes the development process simpler and makes it easy for both new and experienced coders to use.
4. **Large community of users:** TensorFlow Lite has a large and busy community of users, which means there are a whole lot of approaches to find out about the device and get help with it.
5. **Cross-platform compatibility:** TensorFlow Lite works on Android, iOS, and Raspberry Pi, amongst different platforms. This makes it clean to apply machine mastering fashions on a wide variety of devices.

Disadvantages

1. **Complexity:** TensorFlow Lite can be hard to use, in particular for those who are just starting out with device mastering and don't know plenty approximately it.
2. **Difficult to learn:** Learning TensorFlow Lite takes loads of time and paintings because we must study both the TensorFlow code and the APIs that TensorFlow Lite makes use of.
3. **Limited support for certain platforms:** TensorFlow Lite doesn't paintings nicely on all platforms. It works on many systems, however it might not be the high-quality desire for systems or gadgets with restricted running energy or reminiscence.
4. **Problems with converting models:** It can be hard to change models from other machine learning tools to TensorFlow Lite, especially when they have complicated designs or are big.
5. **Difficulties with debugging:** It can be hard to debug TensorFlow Lite models, especially when they have complicated structures or use big datasets.

3.3.11 OpenCV

OpenCV, which stands for 'Open Source Computer Vision', is a computer vision and machine learning software library that is open-source and is utilised in complicated technical problem-solving technologies. It includes a broad variety of algorithms for image and video processing, feature identification, object recognition, and many other applications. OpenCV is put to use in a wide variety of applications, such as robots, augmented reality, facial recognition, medical imaging, and autonomous cars, to name a few.

OpenCV excels in comparison to other software in terms of its adaptability, performance, and user-friendliness. Because it is an open-source library, users do not have to pay to make use of it, and it can be customised to meet the requirements of a wide variety of applications. In addition, OpenCV offers a comprehensive library of well-documented application programming interfaces (APIs) and methods, which makes it simpler to design and apply computer vision algorithms. Last but not least, OpenCV has a high level of performance and is compatible with a wide range of hardware platforms, from traditional desktop PCs to mobile devices.

The adaptability, performance, and vibrant user community of OpenCV are three of the program's many strong points. OpenCV has a high learning curve, it only offers limited

support for specific categories of applications, and it may have compatibility difficulties with other kinds of libraries and frameworks. These are some of the OpenCV's drawbacks.

Advantages

1. **Adaptability:** OpenCV is a versatile library that may be put to use in a wide variety of applications, ranging from simple image processing jobs to in-depth computer vision systems.
2. **Performance:** OpenCV is capable of running on a diverse array of hardware platforms and has a high level of performance, which enables it to do real-time video processing and analysis.
3. **An active community:** Because OpenCV has such a huge and active community of users, there are a great deal of resources accessible for learning about the library and obtaining assistance with it.
4. **A diverse set of functionalities:** OpenCV offers a diverse set of algorithms and functions for the processing of images and videos, as well as for the identification of features and objects, among other things.
5. **Available at no cost and with open source:** OpenCV is a library that is available at no cost and with open source, making it available to both people and enterprises.

Disadvantages

1. **A steep learning curve:** Learning OpenCV may be difficult, especially for novices who are not acquainted with the basics of computer vision.
2. **Limited support for certain applications:** Despite the fact that OpenCV is a sturdy library, it's far feasible that it is not the right alternative for a few sorts of applications, consisting of machine learning or deep getting to know, for which specialised libraries or frameworks can be extra suitable.
3. **Problems with compatibility:** Using OpenCV along side other libraries or frameworks might from time to time bring up compatibility issues, that could make the improvement procedure greater tough.
4. **Inadequate documentation:** Although OpenCV includes a massive range of utility programming interfaces (APIs) and functions, some sections of the library can also have insufficient documentation, which may additionally make it extra hard to use.
5. **Speed constraints:** Despite its excellent stage of pace, OpenCV does have sure overall performance restrictions in relation to operating with large datasets or complicated algorithms.

3.4 Mobile application platform

3.4.1 Android Studio

Android Studio is an Integrated Development Environment (IDE) especially designed for Android app improvement. It is the authentic improvement platform for growing Android packages. Android Studio gives builders with a complete set of gear and resources to streamline the app improvement method.



Advantages

1. **Official Development Environment:** Android Studio is the legitimate IDE for Android app development, sponsored by means of Google. This guarantees that builders have get admission to to the cutting-edge capabilities and updates in the Android environment.
2. **Rich Set of Tools:** It gives a rich set of development tools, such as an emulator, code editor, and graphical person interface (GUI) layout tools. These gear simplify the improvement process and decorate productivity.
3. **Powerful Emulator:** Android Studio consists of a distinctly configurable emulator that allows builders to test their apps on various virtual Android devices, assisting become aware of compatibility troubles.
4. **Intelligent Code Editor:** The code editor in Android Studio is characteristic-rich, with code finishing touch, debugging, and actual-time errors checking. It supports more than one programming languages, consisting of Java and Kotlin.
5. **Easy Integration:** Android Studio seamlessly integrates with popular version manage systems like Git and offers help for non-stop integration and shipping (CI/CD) pipelines.

6. **Android Jetpack:** Android Studio includes Android Jetpack, a fixed of libraries, gear, and architectural guidance that simplifies Android app development, making it extra modular and maintainable.

Disadvantages

1. **Resource Intensive:** Android Studio may be useful resource-intensive, requiring a powerful pc with massive memory and processing energy, which won't be best for all developers.
2. **Learning Curve:** While it gives a wealthy set of capabilities, Android Studio has a mastering curve, specifically for novices who're new to app improvement.
3. **Large Download Size:** The initial download size of Android Studio can be quite large, which may be a concern for developers with limited internet bandwidth.
4. **Platform Limitation:** Android Studio is primarily intended for Android app development, so it may not be the best choice if you need to develop for other platforms like iOS.
5. **Code Complexity:** Developing for Android can be complex, as it requires dealing with various device configurations and screen sizes, which can lead to code complexity.

3.5 Conclusion

For the purpose of simulating system circuitry, building a 3D model of our system, and selecting the programming language and framework for image processing, we had researched a variety of software applications capable of performing these tasks. After thoroughly analyzing the advantages and disadvantages of each and every option, we finalized our selection based on reliability of results, software versatility and compatibility, availability of built-in features, and data visualization abilities, alongside various other criteria.

4 Optimization of Multiple Design and Finding the Optimal Solution [CO5, CO6, CO7, PO-C, PO-B, PO-D]

4.1 Introduction

In this bankruptcy, our focus revolves around the quest for the top of the line layout method for the development of a smart trash bin. The purpose is to discover the maximum appropriate and effective design approach that maximizes capability, usability, and consumer delight.

To obtain this objective, we can delve into the exploration and evaluation of two particular design methods. These procedures have shown promising capacity in improving the skills of clever trash containers, but they also bring on distinct benefits and demanding situations. By accomplishing a radical analysis and evaluation of those techniques, we can strive to decide which choice aligns exceptional with our goals and necessities.

Throughout our have a look at, we will study every layout method in phrases of its underlying concepts, technological requirements, implementation complexities, and anticipated results. We will look at their respective strengths and weaknesses, thinking about elements consisting of consumer enjoy, price-effectiveness, protection, and environmental impact. This complete evaluation will permit us to make an informed selection while choosing the most appropriate layout technique.

Furthermore, we will explore the market landscape and accumulate insights from capacity users or stakeholders to recognize their possibilities, desires, and expectancies. By incorporating consumer remarks, market trends, and industry standards, we aim to design a clever trash bin that not only meets functional requirements but also aligns with consumer expectations, making sure great adoption and popularity.

Overall, this chapter serves as a essential step in our design journey, as we embark at the exploration and assessment of two design tactics for a smart trash bin. By carefully thinking about the blessings, challenges, and user perspectives related to each technique, we are able to in the long run decide the top of the line layout approach that maximizes the bin's functionality, usability, and overall effectiveness.

4.2 Optimization of multiple design approach

4.2.1 Optimization Metrics

We have carefully selected the five optimization options for the smart trash bin after thorough consideration and analysis. Our aim was to strike a balance between incorporating enough features to maximize effectiveness and performance while avoiding overload or unnecessary complexity. Each option addresses a specific aspect of the bin's functionality and aligns with the objective of achieving optimized waste management. By focusing on these areas, we aim to create a smart trash bin that not only meets basic waste disposal needs but also goes beyond by providing enhanced usability, efficiency, sustainability, flexibility, and user engagement.

1. Optimization for optimal bin usability

2. Time-efficiency optimization
3. Optimization in terms of energy efficiency
4. Optimization in terms of mobility
5. Optimization in terms of enhanced encouragement methodology

Optimization for optimal bin usability: It is important to prioritize the usability of the trash bin to ensure that it is easy to use and convenient for individuals disposing of waste. By optimizing bin usability, we can encourage more people to properly dispose of their trash, leading to cleaner environments and improved waste management overall.

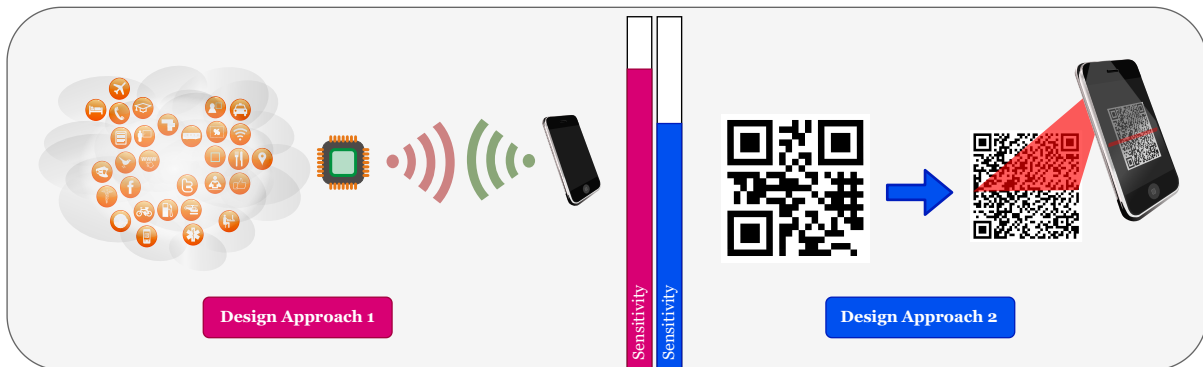


Figure 11: Graphical representation of usability optimization.

Comparing the two methods of user access, RFID scan appears to be the most beneficial out of the two. RFID scanners are generally faster and more convenient, enabling quick access such that users are not hampered by longer waiting times. This is because in the case of RFID, users simply need to bring their ID card close to the scanner, and it can read the information without requiring a camera to focus on a QR code, which could in turn be time-consuming. Moreover, RFID tags and cards are often more durable and resistant to wear and tear compared to printed QR codes, making them suitable for long-term usage. RFID can offer enhanced security features as well, such as encryption and authentication, while QR codes are typically less secure as they can be easily replicated or shared.

Optimization in terms of time-efficiency: Time-efficiency is crucial in waste management processes. By optimizing the smart trash bin for time-efficiency, we can streamline the waste collection and disposal process, saving time for both users and waste management personnel. This optimization leads to increased productivity and more efficient operations.

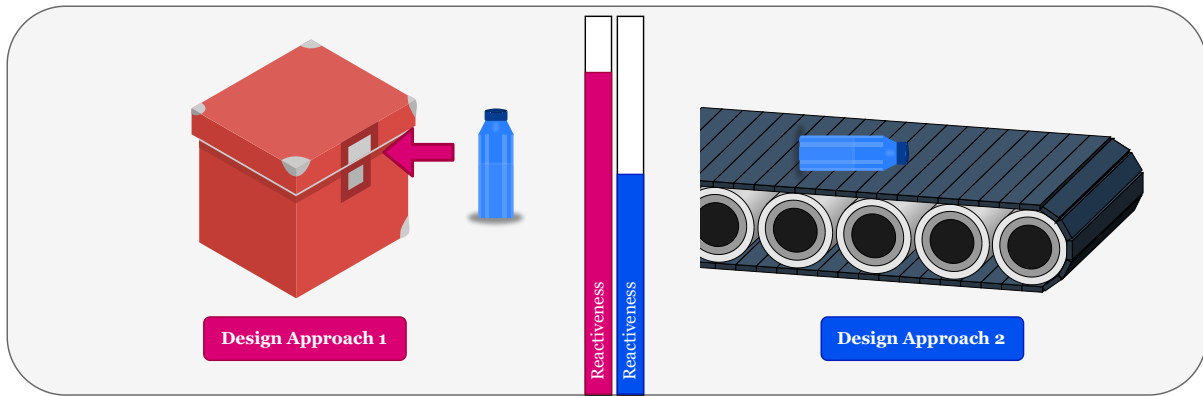


Figure 12: Graphical representation of time optimization.

Placing the piece of trash manually onto the rotating lid is more advantageous in contrast to placing it on a conveyor belt to be carried to the corresponding waste compartment, due to reasons such as energy efficiency, lower operating costs, simplicity and reliability, quieter environment along with little to no waiting time. A rotating lid typically requires minimal to no electrical energy, as it relies on gravity and simple mechanical components for the trash to fall into the compartment, whereas conveyor belt systems require motors and other electrical components to move trash, which can consume significant energy over time. Conveyor belt systems also require further maintenance, electricity, and potential repairs, all of which can add to the operational expenses. Its initial setup cost is very high as well compared to a rotating lid. The manual disposal method is simple and relies on basic mechanical principles as well, making it less prone to technical malfunctions and breakdowns compared to conveyor systems. Conveyor belt systems also generate more noise due to motorized components and moving conveyor belts. Lastly, it would also take more time for the conveyor to transport the waste to the compartment as opposed to simply "dropping" the waste into the appropriate compartment.

Optimization in terms of energy efficiency: Energy efficiency is a key consideration in the design of smart trash bins to promote sustainability. By optimizing for energy efficiency, we can reduce the environmental impact associated with the bin's operation, resulting in lower energy consumption and carbon emissions. This optimization aligns with the goal of achieving sustainable waste management practices.

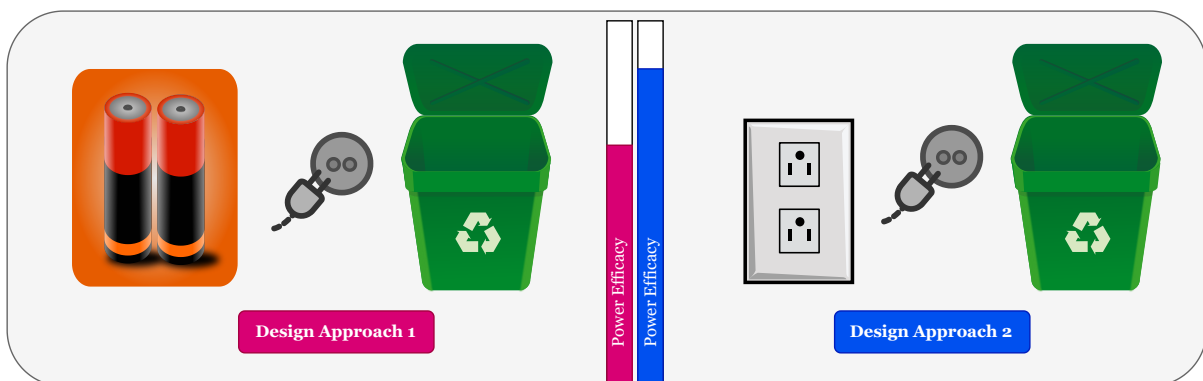


Figure 13: Graphical representation of energy optimization.

Using DC power supply to power the system offers several benefits over AC power supply. First of all, there is no need for the energy to be converted from AC to DC, meaning that less energy is wasted in the conversion process. DC power also experiences lesser voltage drop over long distances compared to AC power. As we are powering small devices at lower voltages, DC voltage is a safer option than AC voltage, reducing the risk of electric shock which is imperative as user interaction is involved. As DC power is the standard for batteries, it is also easier to integrate battery backup systems with DC-powered smart trash bins.

Optimization in terms of mobility: Mobility optimization enables the smart trash bin to be easily relocated to areas with higher waste generation or specific waste management requirements. This flexibility allows for efficient waste collection and disposal in various settings, such as events, festivals, or busy public spaces. Optimizing mobility ensures that the trash bin can adapt to changing needs and improve waste management effectiveness.

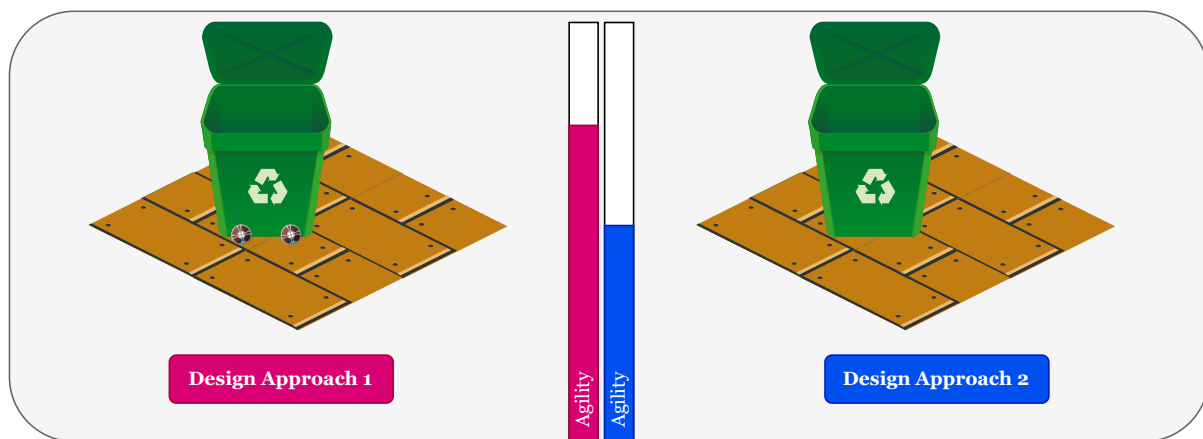


Figure 14: Graphical representation of mobility optimization.

Adding wheels to a smart waste bin offers several advantages over a bin with no wheels, making it a more versatile and user-friendly solution. The most apparent advantage is that wheels make the bin easy to move around, allowing sanitation workers to transport heavy loads of waste by instead effortlessly rolling it to the collection point without needing to strain themselves. Wheels also make it easier to clean the area around and underneath the bin. They can be quickly relocated to different areas which require waste collection. Wheels also allow bins to be stacked or nested when not in use, therefore saving space as well. Finally, the ability to quickly move and position bins with wheels can save time in waste collection and disposal processes, making the overall system more efficient.

Optimization in terms of enhanced encouragement methodology: This option focuses on incorporating motivational and educational elements in the smart trash bin's design to encourage responsible waste disposal habits. By optimizing the encouragement methodology, such as integrating rewards systems or educational prompts, we create a more engaging and interactive experience for users. This optimization fosters community participation and increases awareness of sustainable waste management practices.

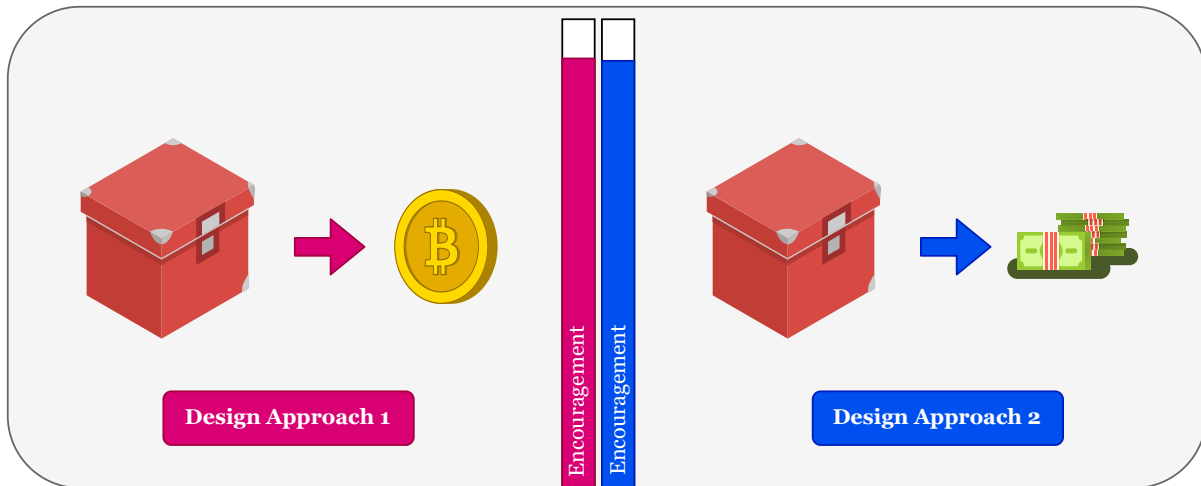


Figure 15: Graphical representation of encouragement optimization.

Offering virtual currency as a reward appears to be a better incentive compared to instant cash reward. Virtual currency rewards can be tailored to suit the preferences and interests of the target audience. Participants may have the flexibility to choose from a range of rewards, such as discounts, vouchers, or donations to charitable causes, making the program more appealing to a diverse group of users. On the other hand, instant cash rewards can be susceptible to theft or fraud while virtual currency rewards are typically distributed electronically, reducing the risk of unauthorized access or misuse. Virtual currency rewards also encourage sustained engagement with proper waste disposal practices. Unlike one-time cash rewards, participants may continue to participate over an extended period to accumulate virtual currency for larger rewards. Waste management programs can also partner with a variety of businesses or organizations to offer virtual currency rewards, promoting local businesses or charitable causes and enhancing the overall community impact.

4.2.2 Optimization Through Functional Verification

The process of optimization through functional verification is an essential stage in the creation of any system, and the development of our smart garbage bin project is no different. The functional verification procedure has been broken down into the following three subsystems for the purpose of ensuring that our system operates as expected:

- **Authentication subsystem:** This component is in charge of verifying the identities of users before allowing them to interact with the intelligent garbage bin. It has features like RFID-based and QR code based authentication, for example.
- **Compartment and storage subsystem:** This subsystem is responsible for managing the smart trash bin's physical components, such as the compartments where garbage is placed as well as the bin's overall capacity for holding waste. In addition to that, it comes with features such as an automated waste compactor and a warning system for when the trash bin is full.
- **Bottle detection subsystem:** This subsystem is in charge of determining whether or not a bottle has been placed in the intelligent garbage bin and then segregating it from the other sorts of rubbish that have been deposited there. It

is able to precisely identify bottles via the use of sensors and machine learning techniques.

By segmenting our step for functional verification into these three subsystems, we will be able to completely test and verify each component of our intelligent garbage bin, so guaranteeing that it performs as expected and with maximum effectiveness.

Authentication subsystem

Password-based simulation in Proteus – circuit diagram

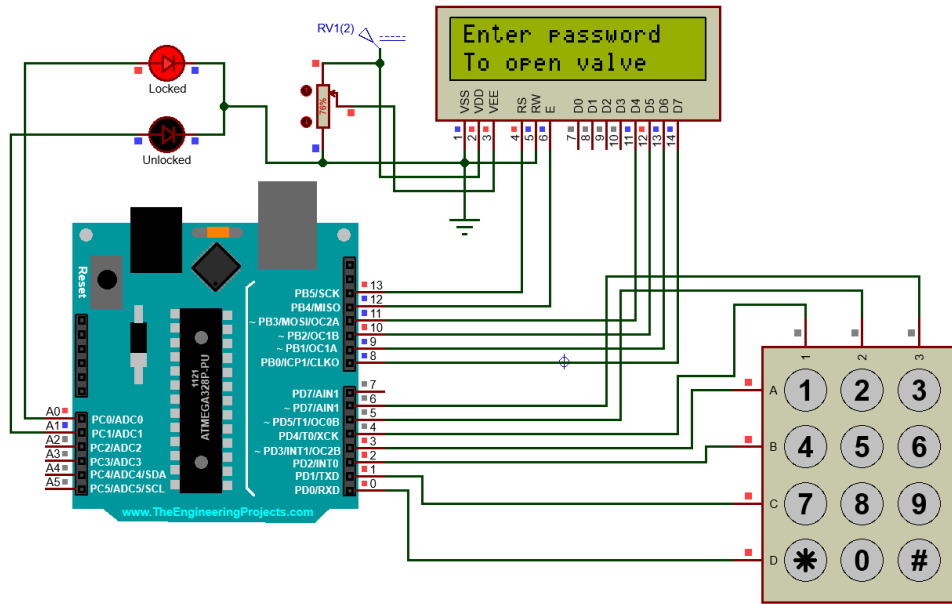


Figure 16: Password-based authentication simulation in Proteus – initial setup.

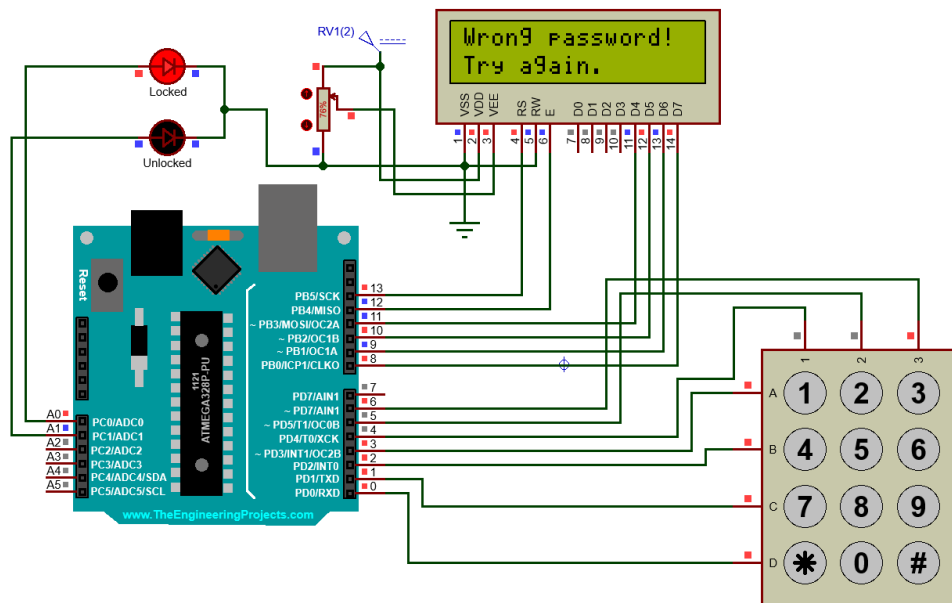


Figure 17: Password-based authentication simulation in Proteus – wrong password input.

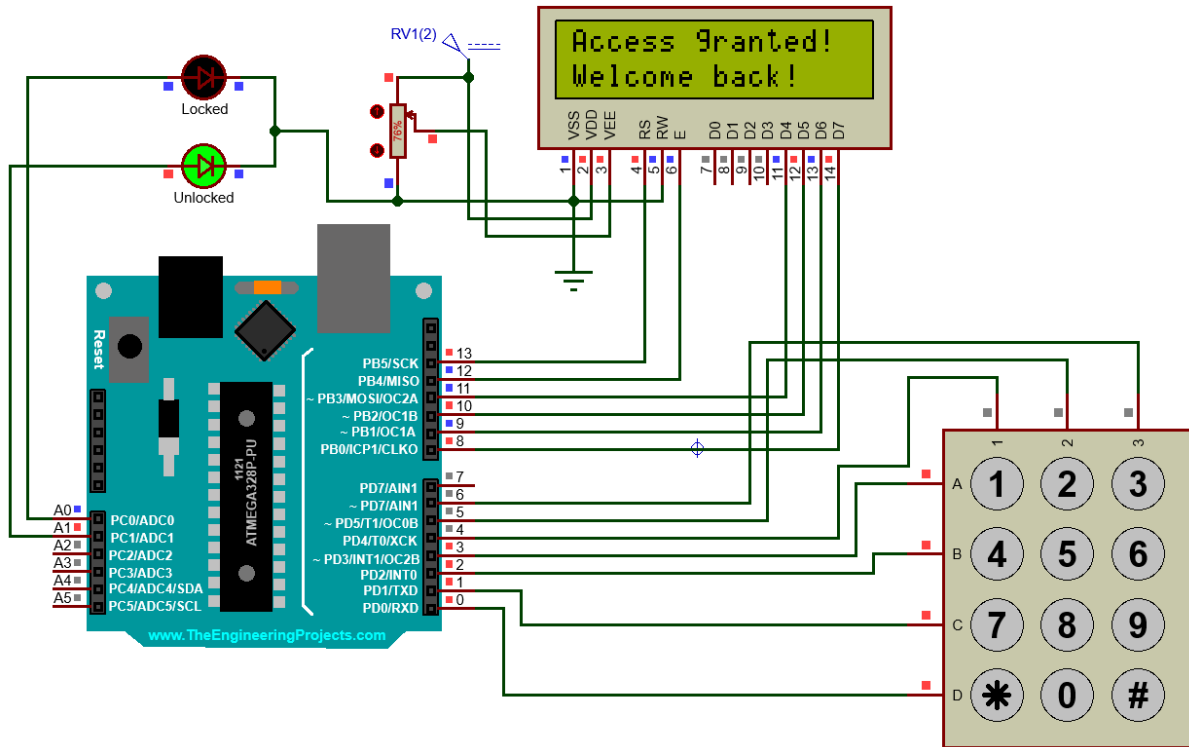


Figure 18: Password-based authentication simulation in Proteus – right password input.

RFID-based simulation in Proteus – circuit diagram

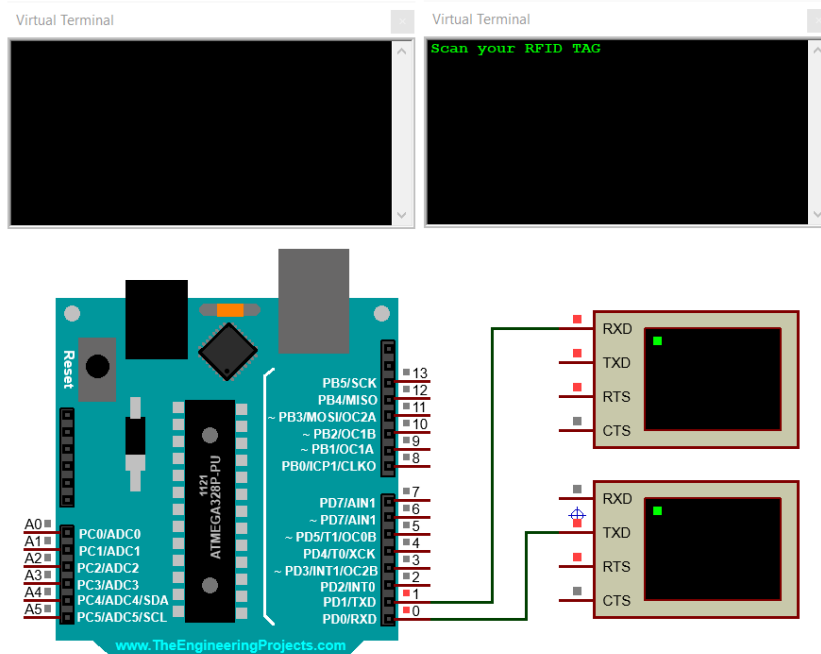


Figure 19: RFID-based authentication simulation in Proteus – initial setup.

Compartment and storage subsystem

Proteus-based simulation

Within the confines of this circuit, our primary goal was to recreate the project on a component-by-component basis. The simulation of waste level, motor control, an LED indication, and user interface design with an LCD display have all been addressed in this lesson. A microcontroller was utilised to assist in the accomplishment of each one of these features. Because we wanted our simulation to be as straightforward as possible, we settled on using an Arduino Nano.

A microcontroller was outfitted with an ultrasonic sensor, and this was done so that the waste level could be simulated. We connected the ground pin of the ultrasonic sensor to a ground terminal, the trigger pin of the ultrasonic sensor to pin 7, the echo pin of the ultrasonic sensor to pin 8, and the +5V pin to a voltage source. We also attached a potentiometer to the input pin that was designated as 'TestPin' so that any change in the ultrasonic sensor may be triggered by it. We connected a voltmeter in parallel with the potentiometer so that we could monitor the changes in voltage as they occurred.

The next thing we did was make the assumption that the user continually added more plastic bottles to the trash bin. As a result, the motor will maintain its constant rotation for the entirety of the simulation. However, there is a requirement that must be met before the motor bin be rotated. If there is less than 25% waste material in the bin, it will not spin. If there is more than 25% waste material in the bin, it will revolve.

In addition, we utilised one LED display and one LCD display in order to make the overall design user-friendly and straightforward. When the percentage of trash reaches or falls below 25%, the LED light will begin to illuminate. In addition to that, we are displaying the name of our bin (which, in this instance, is 'Smart Bin') on the first line of the LCD display. The present state of the trash level is displayed on the second line of the information.

This circuit, in a nutshell, imitates a smart trash bin by controlling the rotation of the motor based on the amount of waste that is present in the trash bin. The ultrasonic sensor determines the level of waste, and the motor will only turn when the level is greater than or equal to 25%. Additionally, a user-friendly feedback system consisting of an LED indicator and an LCD display provides real-time information regarding the status of the waste level. In general, this simulation highlights how microcontrollers may be utilised to construct solutions that are both efficient and easy to understand for problems that arise in everyday life.

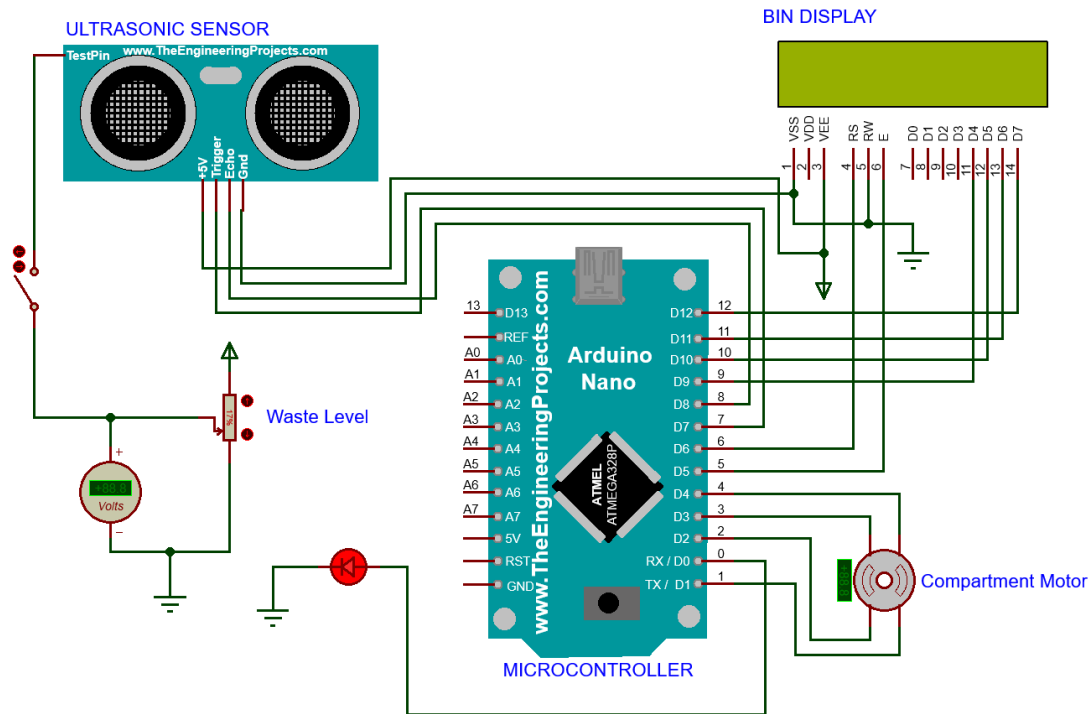


Figure 20: Proteus simulation of compartment and storage subsystem – when the system is turned off (ultrasonic sensor does not process data, compartment motor does not rotate and the LED and LCD are turned off).

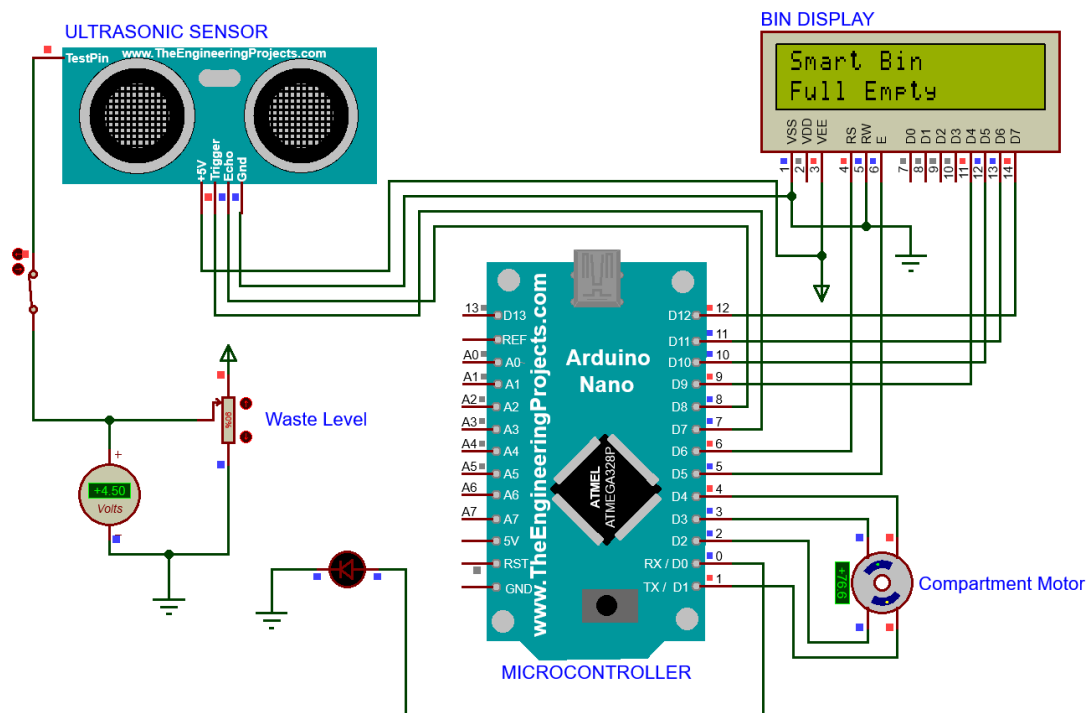


Figure 21: Proteus simulation of compartment and storage subsystem – when the system is turned on but the bin is full empty and are ready to receive wastes from the users.

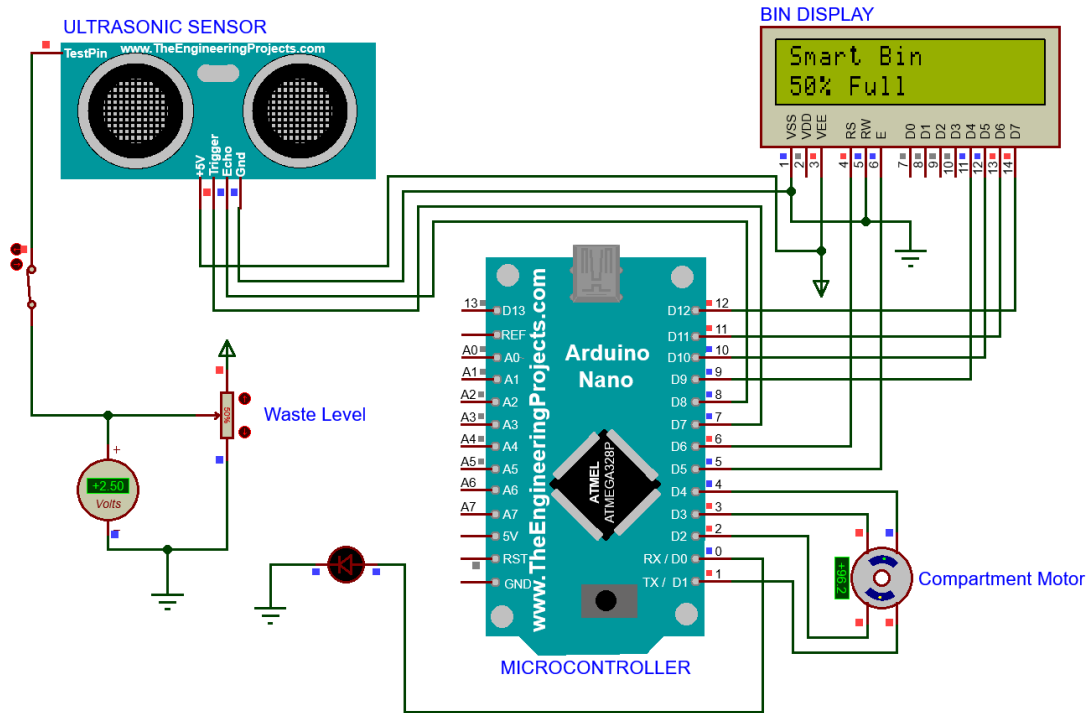


Figure 22: Proteus simulation of compartment and storage subsystem – when the system is turned on but the bin is 50% full and are still able to receive wastes from the users.

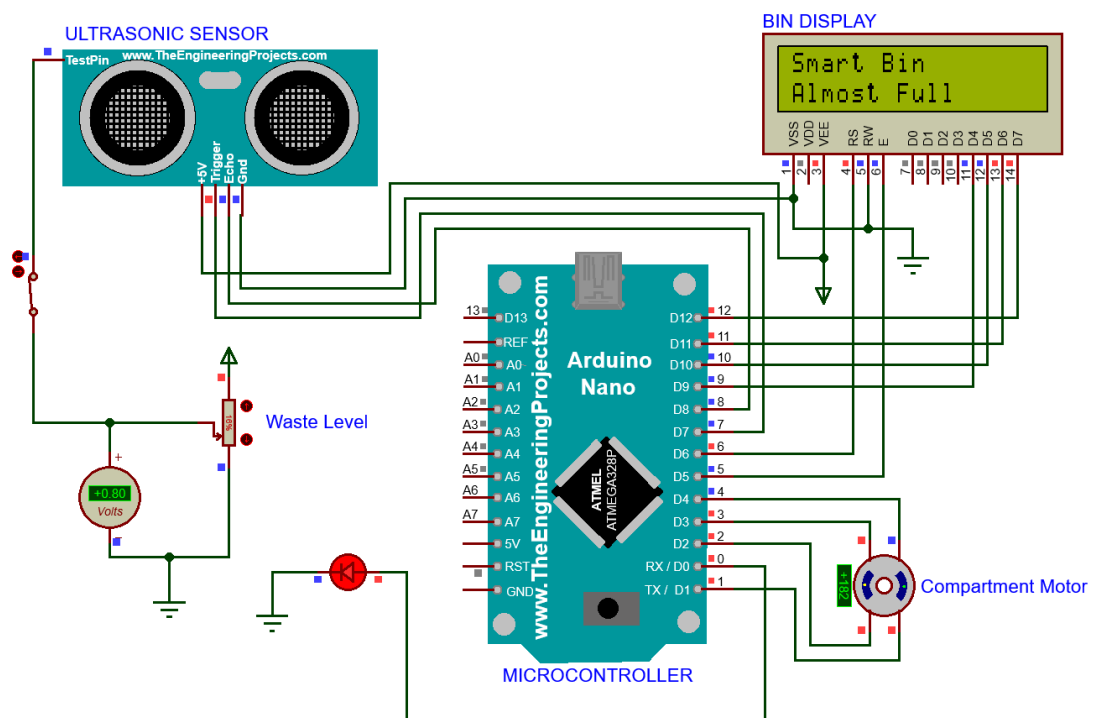


Figure 23: Proteus simulation of compartment and storage subsystem – when the system is turned on but the bin is almost full and are not able to receive anymore wastes from the users.

Complexity estimation & system verification

Compartment calculation

To calculate angular velocity, we need to know two pieces of information:

- The angle through which the object has rotated
- The time taken for that rotation

Angular velocity is defined as the rate at which an object rotates or revolves around a central point, typically measured in radians per second (rad/s) or degrees per second (°/s). Mathematically, angular velocity can be expressed as:

$$\omega = \frac{\Delta\theta}{\Delta t}$$

where ω is the angular velocity, $\Delta\theta$ is the change in angle over time, and Δt is the time taken for that change in angle.

With respect to our specific scenario,

- The net angular displacement, $\Delta\theta$, the change in angle over time is $\frac{\pi}{2}$.
- Δt , the time taken for that change in angle is 2 s

$$\omega = \frac{\Delta\theta}{\Delta t} = \frac{\pi}{4} \text{ rad/s} \quad (1)$$

To find the angular acceleration of a rotating object, we need to know its moment of inertia, the torque acting on it, and any external forces or friction. We can use the following formula to calculate the angular acceleration:

$$\alpha = \frac{\Delta\omega}{\Delta t}$$

Where α is the angular acceleration in radians per second squared (rad/s²), $\Delta\omega$ is the difference between the final and initial angular velocities in radians per second (rad/s) and Δt is the time taken for that change in angle.

Regarding our situation,

- The net angular velocity, $\Delta\omega$ is $\frac{\pi}{4}$ rad/s
- Δt , the time taken for that change in angle is 2 s

$$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{\frac{\pi}{4}}{2} = \frac{\pi}{8} \text{ rad/s}^2 \quad (2)$$

The moment of inertia (I) of a rotating square-shape object depends on its mass distribution and geometry. For a solid square rotating about its central axis, the moment of inertia can be calculated using the formula [18]–[20]:

$$I = \frac{1}{6} \cdot M \cdot a^2$$

Where I is the moment of inertia, expressed in kgm^2 , M is the mass of the square box in kilogram (kg) and a is side length of the square box (m).

With respect to our specific scenario,

- The mass of the square box, M is 3.5 kg
- The side length of the square box, a is 0.43 m

$$\begin{aligned} I &= \frac{1}{6} \cdot M \cdot a^2 \\ &= \frac{1}{6} \cdot (3.5 \text{ kg}) \cdot (0.43^2 \text{ m}^2) \\ &= 0.1078 \text{ kgm}^2 \end{aligned} \tag{3}$$

The torque (τ), expressed in Newton meter (Nm) acting on a rotating object is related to its moment of inertia (I) and angular acceleration (α) by the formula:

$$\tau = I \cdot \alpha$$

This formula, known as Newton's second law for rotation, states that the torque applied to an object is equal to its moment of inertia multiplied by its angular acceleration.

In the situation that we are considering,

$$\begin{aligned} \tau &= I \cdot \alpha \\ &= 0.1078 \text{ kgm}^2 \cdot \frac{\pi}{8} \text{ rad/s}^2 \\ &= 0.0423 \text{ Nm} \end{aligned} \tag{4}$$

To calculate the energy consumption of a cylindrical compartment rotating with a load, we might need to know some additional facts:

- Mass of the load (kg)
- Side length of the compartment (m)
- Angular velocity of the compartment (rad/sec)

Once we've this statistics, we can use the subsequent formulation to calculate the power consumption:

$$Power = \frac{1}{2} \cdot I \cdot \omega^2 = \tau \cdot \omega$$

Where:

- I = Moment of inertia of the rotating system (which includes the load and the compartment itself)

- ω = Angular velocity of the rotating system
- τ = Torque of the system
- ω is the angular velocity of the system

$$\begin{aligned}
 P &= \tau \cdot \omega \\
 &= 0.0423 \cdot \frac{\pi}{4} \\
 &= 0.0332 \text{ W} \\
 &= 0.000797 \text{ kWh}
 \end{aligned} \tag{5}$$

The formula for calculating RPM (revolutions/minute):

$$\text{RPM} = \frac{60 \times \text{Power}}{2\pi \times \text{Torque}} \tag{6}$$

where:

- RPM = Revolutions per minute
- Power = Measured power in watts
- Torque = Measured torque in Newton meters
- $\pi = 3.14159$

This formulation relates the rotational speed of an item to the power carried out to it and the torque had to keep that pace. It assumes that the object is rotating at a consistent velocity and that the torque required to keep that pace is regular.

In the situation that we are considering,

$$\begin{aligned}
 \text{Speed in RPM} &= \frac{60 \times \text{Power}}{2\pi \times \text{Torque}} \\
 &= \frac{60 \times 0.0332}{2\pi \times 0.0423} \\
 &= 7.49 \text{ RPM} \\
 &= 7.5 \text{ RPM}
 \end{aligned} \tag{7}$$

Lid calculation

To calculate angular velocity, we need following information:

- Rotating angle of the object
- Rotational time

Angular velocity is defined according to the rate at which an item rotates or revolves around a primary factor, normally measured in radians consistent with 2nd (rad/s) or levels consistent with degree/second (°/s). Mathematically, angular speed can be expressed as:

$$\omega = \frac{\Delta\theta}{\Delta t}$$

where ω is the angular velocity, $\Delta\theta$ is the change in angle over time, and Δt is the time taken for that change in angle.

In our case,

- The net angular displacement, $\Delta\theta$, the change in angle over time is $\frac{\pi}{2}$
- Δt , the time taken for that change in angle is 2 s

$$\omega = \frac{\Delta\theta}{\Delta t} = \frac{\frac{\pi}{2}}{2} = \frac{\pi}{4} \text{ rad/s} \quad (8)$$

To find the angular acceleration of a rotating object, we need to recognize its second of inertia, the torque acting on it, and any outside forces or friction. We can use the subsequent system to calculate the angular acceleration:

$$\alpha = \frac{\Delta\omega}{\Delta t}$$

Where α is the angular acceleration in radians per second squared (rad/s^2), $\Delta\omega$ is the difference between the final and initial angular velocities in radians per second (rad/s) and Δt is the time taken for that change in angle.

Regarding our situation,

- The net angular velocity, $\Delta\omega$ is $\frac{\pi}{4}$ rad/s
- Δt , the time taken for that change in angle is 2 s

$$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{\frac{\pi}{4}}{2} = \frac{\pi}{8} \text{ rad/s}^2 \quad (9)$$

The moment of inertia (MOI) of a rectangular object rotating on one of its axis passing through the x-axis depends on the dimensions of the object and its mass distribution.

Assuming that the rectangular object has sides of length h and w, and is rotating about the x-axis passing through its center of mass, then the MOI can be calculated as [18]–[20]:

$$I = \frac{1}{12} \cdot M \cdot (h^2 + w^2)$$

Where:

- I is the moment of inertia of the object
- M is the mass of the object

This formula assumes that the rectangular object is uniform in density and has a constant thickness. If the object is not uniform in density or has varying thickness, then the MOI will depend on the specific mass distribution.

With respect to our specific scenario,

- The mass of the rectangular object, M is 3 kg
- The height of the object, h is 0.30 m
- The width of the object, w is 0.20 m

$$\begin{aligned}
 I &= \frac{1}{12} \cdot M \cdot (h^2 + w^2) \\
 &= \frac{1}{12} \cdot 3 \cdot (0.30^2 + 0.20^2) \\
 &= 0.0325 \text{ kgm}^2
 \end{aligned}
 \tag{10}$$

The torque (τ), expressed in Newton meter (Nm) acting on a rotating object is related to its moment of inertia (I) and angular acceleration (α) via the formulation:

$$\tau = I \cdot \alpha$$

This components, called Newton's second regulation for rotation, states that the torque applied to an object is same to its second of inertia increased with the aid of its angular acceleration.

In the situation that we are considering,

$$\begin{aligned}
 \tau &= I \cdot \alpha \\
 &= 0.0325 \text{ kgm}^2 \cdot \frac{\pi}{8} \text{ rad/s}^2 \\
 &= 0.0127 \text{ Nm}
 \end{aligned}
 \tag{11}$$

The torque exerted by a force is described because the fabricated from the pressure and the perpendicular distance from the pivot to the line of action of the pressure. Mathematically, we can express this as:

$$F = \frac{\tau}{R} \tag{12}$$

where τ is the torque, F is the force in Newton (N), and R is the perpendicular distance from the pivot to the line of action of the force in meter (m).

So, it can be said that,

- The perpendicular distance from the pivot to the line of action, R is 0.225 m

$$\begin{aligned}
 F &= \frac{\tau}{R} \\
 &= \frac{0.0127}{0.075} \text{N} \\
 &= 0.1693 \text{N}
 \end{aligned}
 \tag{13}$$

To calculate the strength intake of a square item rotating with a load, we'd need some extra information:

- What is the mass of the load (in kilograms)?
- What is the radius of the lid (in meters)?
- What is the angular velocity of the lid (in radians per second)?

Once we have this information, we can use the following formula to calculate the power consumption:

$$Power = \frac{1}{2} \cdot I \cdot \omega^2 = \tau \cdot \omega$$

Where:

- I is the moment of inertia of the rotating system (which includes the load and the compartment itself)
- ω is the angular velocity of the rotating system.
- τ is the torque of the system
- ω is the angular velocity of the system

$$\begin{aligned}
 P &= \tau \cdot \omega \\
 &= 0.0127 \cdot \frac{\pi}{4} \\
 &= 0.00997 \text{W} \\
 &= 0.00024 \text{kWh}
 \end{aligned}
 \tag{14}$$

The formula for calculating RPM (revolutions per minute) using power and torque is [21]:

$$RPM = \frac{60 \times Power}{2\pi \times Torque} \tag{15}$$

where:

- RPM is the revolutions per minute
- Power is the measured power in watts
- Torque is the measured torque in Newton meters
- π is a mathematical constant equal to approximately 3.14159

This formula relates the rotational speed of an object to the power applied to it and the torque needed to maintain that speed. It assumes that the object is rotating at a constant speed and that the torque required to maintain that speed is constant.

In the situation that we are considering,

$$\begin{aligned} \text{Speed in RPM} &= \frac{60 \times \text{Power}}{2\pi \times \text{Torque}} \\ &= \frac{60 \times 0.00997}{2\pi \times 0.0127} \\ &= 7.496 \text{ RPM} \end{aligned} \quad (16)$$

Conveyor calculation

To find the torque of the conveyor belt, we need to know the roller radius, frictional force and the external force working on it. We can use the following formula to calculate the torque:

$$\begin{aligned} \text{Torque}_{req} &= (\text{Frictional force} + \text{External force}) \times \text{Roller radius} \\ &= [(\mu \times w \times g) + (w \times g)] \times r \end{aligned}$$

Where μ is the coefficient of friction between the belt and the rollers or pulleys, w is the weight of the load in kilogram (kg), g is the gravitational acceleration in meter per second squared (m/s^2) and r is the radius of the roller or pulley driving the belt in meter (m).

With respect to our specific scenario,

- Let, the frictional coefficient, $\mu = 0.25$
- The weight of the load, w is 5 kg
- Gravitational acceleration, g is 9.81 m s^{-2}
- Radius of the roller, r is 0.0125 m

$$\begin{aligned} \text{Torque, } \tau &= [(\mu \times w \times g) + (w \times g)] \times r \\ &= [(0.25 \times 5 \times 9.81) + (5 \times 9.81)] \times 0.0125 \\ &= 0.7664 \text{ Nm} \end{aligned} \quad (17)$$

Let,

- Velocity of the conveyor, v is 0.025 m s^{-1}
- Diameter of the roller, D is 0.025 m

$$\begin{aligned} \text{Speed in RPM} &= \frac{V \times 60}{\pi \times D} \\ &= \frac{0.025 \times 60}{0.025\pi} \\ &= 19.098 \text{ RPM} \end{aligned} \quad (18)$$

$$\begin{aligned}
Power &= \frac{2\pi \times RPM \times \tau}{60} \\
&= \frac{2\pi \times 19.098 \times 0.7664}{60} \\
&= 1.5327W
\end{aligned}
\tag{19}$$

Motor calculation

Table 16: Motor performance assessment for three types of motors in accordance with the required specifications.

Parameter	Motor		
	Emax XA2212	Nema 23 23HS5628	MG996
RPM	8250–12020	200	120
Torque (Nm)	0.034	126	0.98
Operating Voltage (V)	8–12	5.6	4.8–7.2
Operating Current (A)	11.9–20.6	2.8	0.1–0.15
Weight (gm)	55	700	55
Unit Price (BDT)	1150	2349	435

Battery calculation

Choosing the appropriate battery for a smart trash bin that requires 7 watts of power depends on a number of factors, including the anticipated utilisation time, size constraints, and budget. Here are some general steps:

- **Required voltage requirement:** The first stage is to determine the voltage requirements of our trash bin. This information should be included in the garbage bin’s specifications or the data sheet for its components.
- **Energy capacity calculation:** Once the voltage requirements have been determined, the energy capacity bin be calculated by multiplying the voltage by the power (7W) and the anticipated utilisation time. For instance, if we expect the garbage bin to operate for 10 hours, it must have a minimum energy capacity of 70 watt-hours (Wh).
- **Select the battery chemistry:** Next, we must select the battery chemistry that meets our requirements the best. Lithium-ion, nickel-metal hydride, and lead-acid batteries are common options. Typically, lithium-ion batteries are the best option for energy-intensive portable applications such as smart garbage bins.
- **Physical size limitation consideration:** Depending at the design of our garbage bin, there may be confined capability for a battery. Choose a battery whose bodily dimensions are well matched with the to be had area.
- **Budget consideration:** Finally, calculate our finances and choose a battery that works inside our price constraints while assembly our overall performance specifications.

By following those methods, we have to be able to select a battery with the required power and strength capacity for our clever trash bin.

To calculate the battery necessities for a given energy, we need to understand the following:

- Power intake of the device in watts
- Battery voltage in volts
- Capacity of the battery in ampere-hours

Once we've got this info, we will use the subsequent components to calculate the battery requirement:

$$\text{Battery capacity (in Ah)} = \frac{\text{Power consumption in Watts} \times \text{Usage time in hours}}{\text{Battery voltage}}$$

For example, if our tool consumes 10 watts of power and we need it to run for 5 hours on a 12V battery, then the specified battery capability will be:

$$\text{Battery capacity} = \frac{10\text{W} \times 5\text{h}}{12\text{V}} = 4.17\text{Ah}$$

This way that we can need a battery with a potential of at least 4.17 Ah to run our gadget for five hours at 10 watts.

However, as we are targeting to operate the bin 24 hours, we will be considering this time duration as the standard operating time.

Graphical analysis

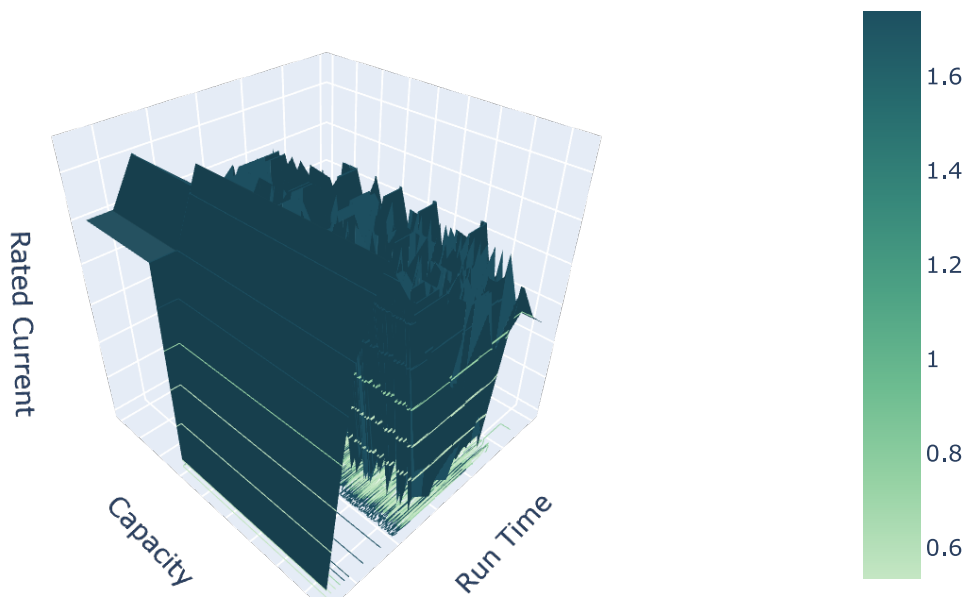


Figure 24: Battery performance multidimensionally analyzed in relation to rated current and runtime.

Design approach 1 From Figure 29, we can see that, in our design 1, we are required about 6.4258W for the whole system and this required power will be our starting point for the battery power requirement calculation. So, for design 1, the calculation for the required nominal current will follow the equation as shown below:

$$\text{Battery capacity in mAh} = \frac{6.4258 \text{ W} \times 24 \text{ h}}{\text{Nominal voltage}} \quad (20)$$

With the help of Equation 20, we have devised Table 17 which helps us to make a clear decision while choosing the appropriate battery.

Table 17: An evaluation of the capacity and performance of batteries in the context of the design of a battery system to meet 24-hour power requirements for design 1.

Parameter	Battery			
	Li 14500	LiPo Eagle	Doublepower	Generic Lead Acid
Battery Material	Lithium	Lithium-Polymer	Lithium-Cobalt-Oxide	Lead Oxide, Sulfuric Acid
Nominal Voltage (V)	3.7	11.1	7.4	4
Nomial Current (mAh)	1300	1000	650	850
Cell Count	1s	3s	1s	–
Calculated Current (mAh)	1263	992.4	651	838
Required Unit	33	14	32	46
Unit Price (BDT)	90	1250	200	80
Total Cost	2970	17500	6400	3680
Physical Dimension	14 × 49 mm	17 × 34 × 72 mm	48 × 26 × 26 mm	27 × 36 × 80 mm

Design approach 2 From Figure 29, we can see that, in our design 1, we are required about 10.2995W for the whole system and this required power will be our starting point for the battery power requirement calculation. So, for design 1, the calculation for the required nominal current will follow the equation as shown below:

$$\text{Battery capacity in mAh} = \frac{10.2995 \text{ W} \times 24 \text{ h}}{\text{Nominal voltage}} \quad (21)$$

With the help of Equation 21, we have devised Table 18 which helps us to make a clear decision while choosing the appropriate battery.

Table 18: An evaluation of the capacity and performance of batteries in the context of the design of a battery system to meet 24-hour power requirements for design 2.

Parameter	Battery			
	Li 14500	LiPo Eagle	Doublepower	Generic Lead Acid
Battery Material	Lithium	Lithium-Polymer	Lithium-Cobalt-Oxide	Lead Oxide, Sulfuric Acid
Nominal Voltage (V)	3.7	11.1	7.4	4
Nomial Current (mAh)	1300	1000	650	850
Cell Count	1s	3s	1s	–
Calculated Current (mAh)	1309	1012	642	846
Required Unit	51	22	52	73
Unit Price	90	1250	200	80
Total Cost	4590	27500	10400	5840
Physical Dimension	14 x 49 mm	17 x 34 x 72 mm	48 x 26 x26 mm	27 x 36 x 80 mm

Power calculation

Design 1

Table 19: Design 1 power consumption breakdown.

Component	Parameter		
	Operating Voltage (V)	Operating Current (mA)	Rated Power (W)
Camera	5	120	0.6
Compartment	–	–	0.1566
LCD	5	120	0.6
Lid	–	–	0.0109
Load Cell	5.5	1.7	0.00935
MCU	5	50	2.5
RFID	3.3	6.5	0.02145
US	5.5	5	0.0275

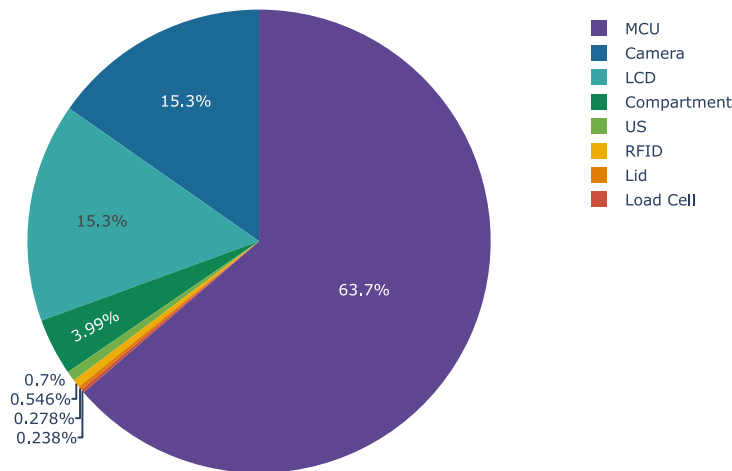


Figure 25: Design 1 power consumption – component-wise distribution

Design 2

Table 20: Design 2 power consumption breakdown.

Component	Parameter		
	Operating Voltage (V)	Operating Current (mA)	Rated Power (W)
Camera	5	200	1
Capacitive Sensor	10	15	0.15
Inductive Sensor	6	300	1.8
Boost Converter	5	2.5	0.0125
Compartment	–	–	0.1566
Conveyor	–	–	1.5327
LCD	5	120	0.6
Lid	–	–	0.0109
Load Cell	5.5	1.7	0.00935
MCU	5	50	2.5
US	5.5	5	0.0275

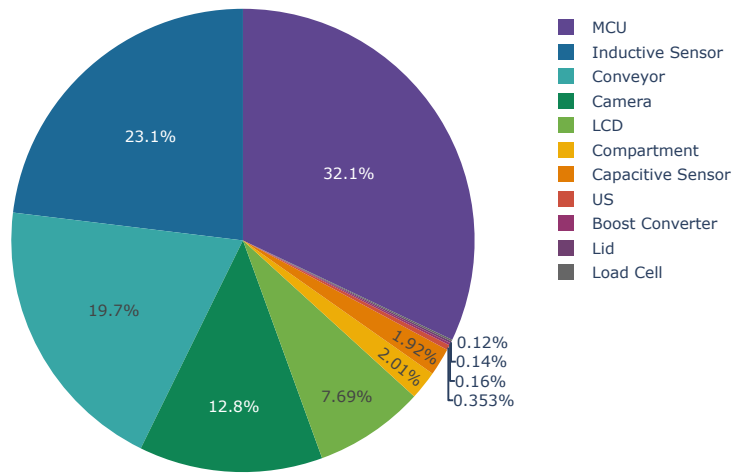


Figure 26: Design 2 power consumption – component-wise distribution

System parametric verification & visualization

Bin lid performance table

Table 21: Torque and Power consumption of bin lid for 10 seconds.

Time (s)	Bin Lid									
	1	2	3	4	5	6	7	8	9	10
Torque (Nm)	0.0556	0.0139	0.0062	0.0035	0.0022	0.0015	0.0011	0.0009	0.0007	0.0006
Power (W)	0.0874	0.0109	0.0032	0.0014	0.0007	0.0004	0.0003	0.0002	0.0001	0.0001

Bin lid performance graph

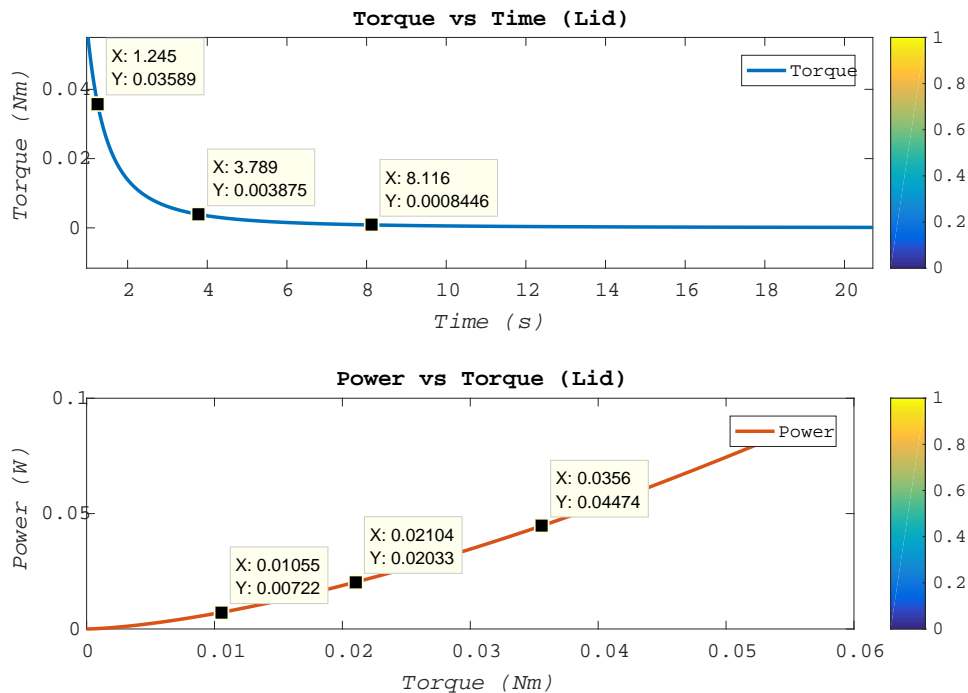


Figure 27: Bin lid parameters performance visualization.

Bin storage compartment performance table

Table 22: Torque and Power consumption of bin storage compartment for 10 seconds.

	Storage Compartment									
Time (s)	1	2	3	4	5	6	7	8	9	10
Torque (Nm)	0.3976	0.0994	0.0442	0.0249	0.0159	0.0110	0.0081	0.0062	0.0049	0.0040
Power (W)	1.2491	0.1561	0.0463	0.0195	0.0100	0.0058	0.0036	0.0024	0.0017	0.0012

Bin storage compartment performance graph

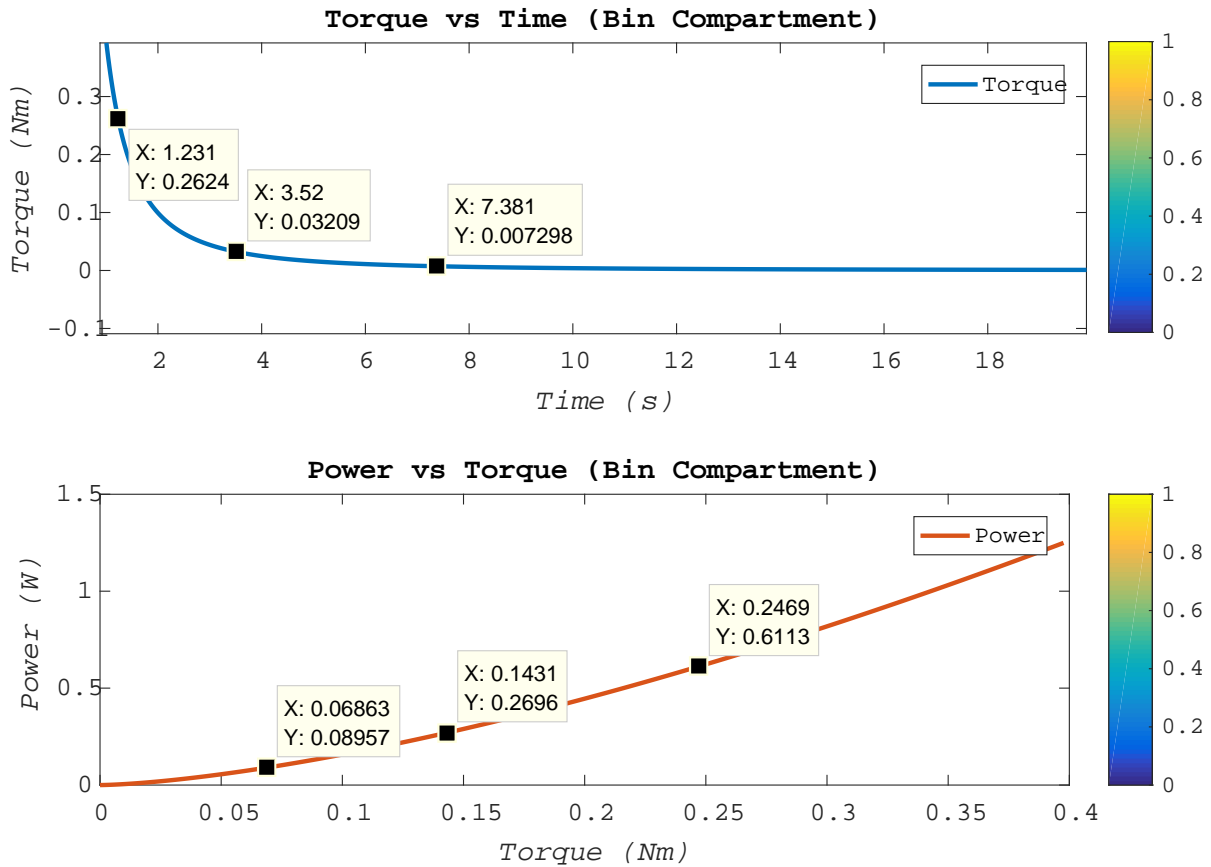


Figure 28: Bin storage compartment parameters performance visualization.

4.3 Identify optimal design approach

4.3.1 System power analysis

Tabular analysis

Table 23: Methods for achieving energy-efficient systems through power-consumption analysis-based optimisation.

Component	Power (kWh)	
	Design 1	Design 2
Camera	0.00022	0.002400
Compartment	0.00092	0.00376
Display	0.00016	0.01440
Lid	0.00092	0.00026
Load Cell	0.00022	0.00930
ESP32	0.00036	0.00036
US	0.00066	0.00066
RFID	0.00036	–
Capacitive Sensor	–	0.00360
Inductive Sensor	–	0.04320
Buck Converter	0.00030	0.00030
Conveyor	–	0.03670
Total	0.00412	0.01149

Graphical analysis

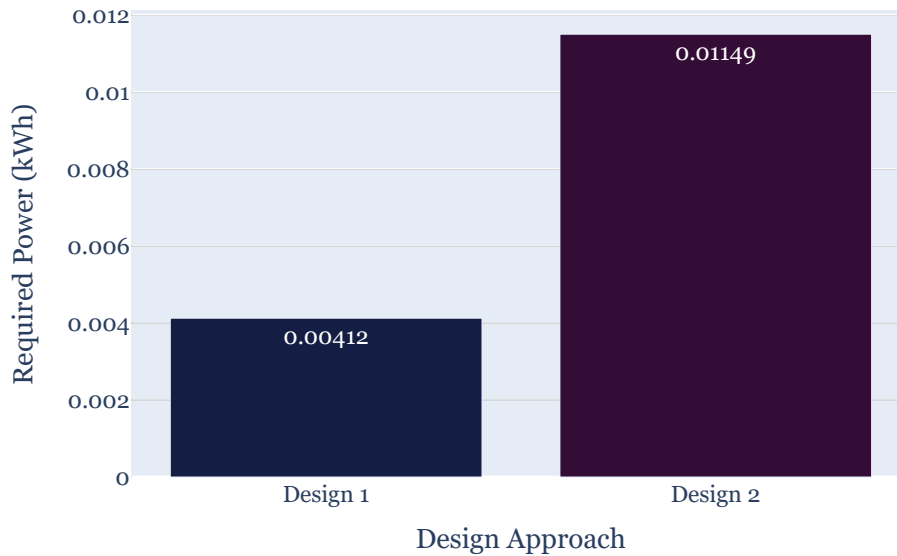


Figure 29: Design 1 and 2 power requirement comparison.

4.3.2 System budget analysis

Tabular analysis

Table 24: Achieving cost effective system through budget analysis-based optimisation.

Components		Design Approach	
		Approach 1	Approach 2
Hardware	Acrylic Sheet	600	600
	Battery	1180	2500
	Battery Charger	200	-
	Buck Converter	222	222
	Buzzer	15	15
	Camera	1000	1200
	Capacitive Sensor	-	1150
	Connector	50	50
	ESP32	650	650
	Flame Sensor	50	50
	Freewheel	240	-
	Gas Sensor	178	178
	Glue Gun	335	335
	Heat Sink	25	25
	Inductive Sensor	-	1132
	LED	50	50
	Load Cell	400	400
	Nema 17	-	1499
	OLED Display	350	350
	PCB	500	500
	Plyer	150	150
	Plywood	250	250
	PVC	1800	2500
	RFID Card	70	-
	RFID Scanner	190	-
	MG996 Servo	830	-
	Soldering Iron	676	676
	Switch	100	100
	TMC2208 Driver	-	512
	Ultrasonic Sensor	200	200
Wire	250	450	
Software	Cloud Storage	500	500
	Map API	1000	1000
	Play Console	2900	2900
Others	Transportation	500	500
	Tools	500	1500
	Misc	500	500
Total		16461	22644

Graphical analysis

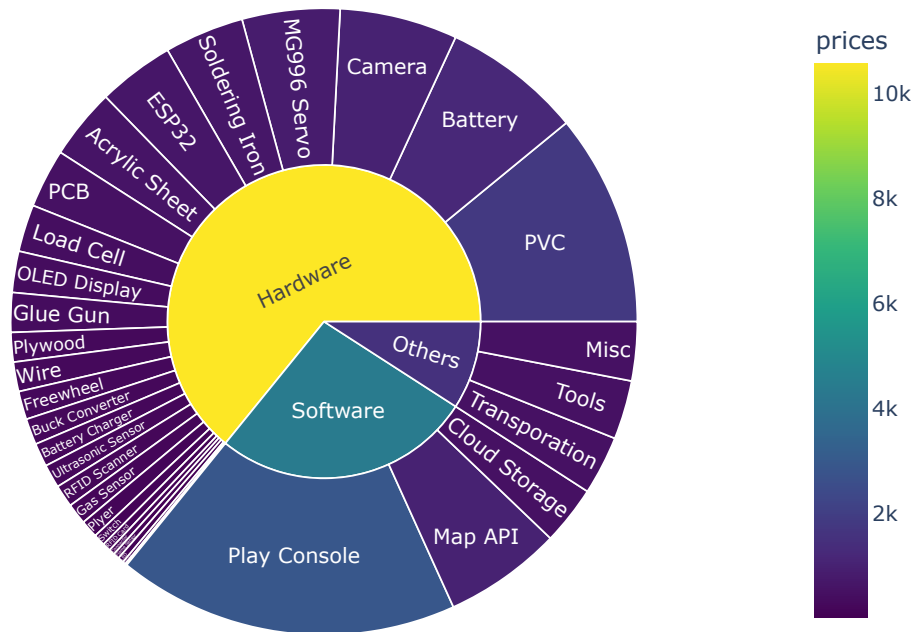


Figure 30: Design 1 budget sunburst breakdown.

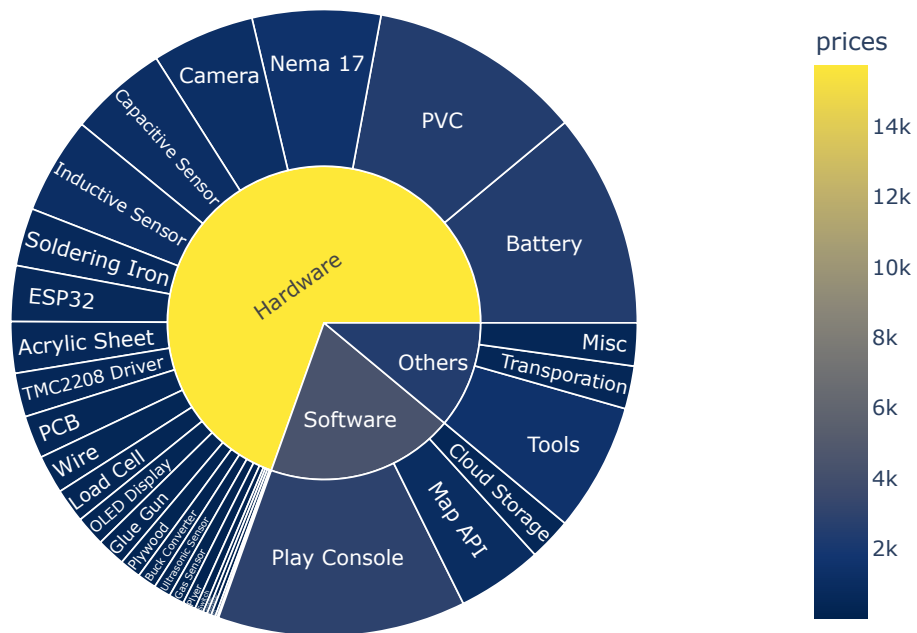


Figure 31: Design 2 budget sunburst breakdown.

4.3.3 System mapping analysis

Design approach 1

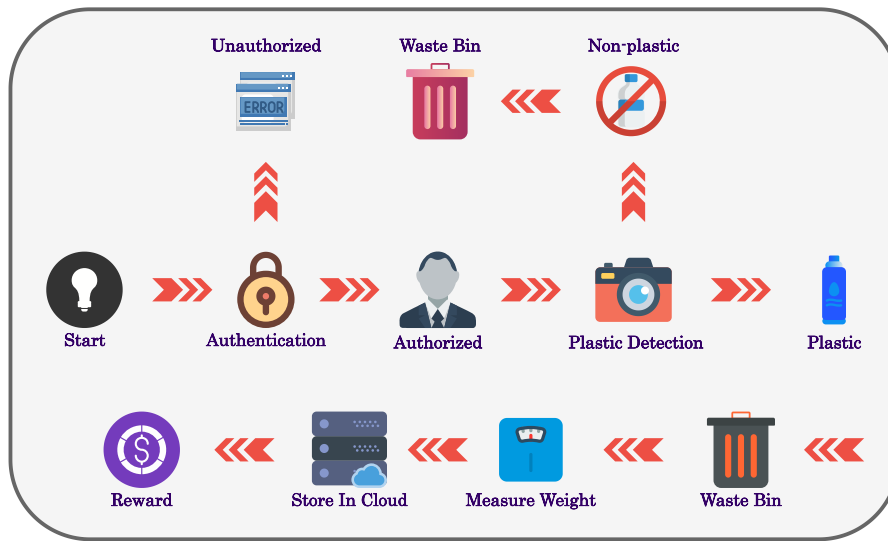


Figure 32: Mapping analysis – design approach 1.

Design approach 2



Figure 33: Mapping analysis – design approach 2.

4.3.4 System ecological analysis

Design approach 1

Table 25: An overview of smart trash bin emissions – a comparative study and carbon footprints table [1], [2].

Component	Manufacturing	Operational	End-of-life
RFID	0.3	0.01	0.05
Camera	0.5	0.12	0.07
Load Cell	0.1	0.03	0.02
PVC	1.0	0.25	0.10
Battery	2.0	0.50	0.20
Sensor	0.2	0.04	0.03
MCU	1.5	0.15	0.08
Total Emissions	5.6	1.10	0.55

The carbon dioxide equivalent (CO₂e) emissions for manufacturing, operational, and end-of-life emissions are listed in this table. The total emissions value represents the aggregate of all emissions from the smart trash bin's RFID, camera, load cell, PVC, battery, sensor, and MCU components.

Table 26: An index table analysis of a smart trash bin's sustainability features and performance for evaluating the environmental impact.

Component	Environmental Impact	Energy Usage	Emissions	Resource Depletion
RFID	Low	Low	Negligible	Low
Camera	Medium	Medium	Low to medium	Low
Load cell	Low	Low	Negligible	Low
PVC	High	Medium to high	High	High
Battery	Medium	Medium	Medium	Medium
Sensor	Low	Low	Negligible	Low
MCU	Low	Low	Negligible	Low

Design approach 2

Table 27: Emission values for a smart trash bin with manufacturing emissions, operational emissions, and end-of-life emissions data for each component [1], [2].

Component	Manufacturing	Operational	End-of-Life
Bearing	0.005	0.002	0.001
Conveyor Belt	0.375	0.150	0.010
Camera	0.025	0.004	0.001
Load Cell	0.007	0.001	0.000
PVC	1.500	1.200	1.500
Battery	5.000	1.800	0.500
Sensor	0.041	0.007	0.003
MCU	0.020	0.005	0.002
Converter	0.015	0.002	0.001
Total Emissions	6.988	3.171	2.018

The carbon dioxide equivalent (CO₂e) emissions for manufacturing, operational, and end-of-life emissions are listed in this table. The total emissions value represents the aggregate of all emissions from the smart trash bin's RFID, camera, load cell, PVC, battery, sensor, and MCU components.

Table 28: An index table analysis of a smart trash bin's sustainability features and performance for evaluating the environmental impact.

Component	Environmental Impact	Energy Usage	Emissions	Resource Depletion
Bearing	Low	Low	Negligible	Low
Conveyor belt	Medium	Medium	Low to medium	Low
Camera	High	High	High	Medium
Load cell	Low	Low	Negligible	Low
PVC	High	Medium to high	High	High
Battery	High	High	High	Medium to high
Sensor	Low	Low	Negligible	Low
MCU	Medium	Medium	Low to medium	Medium
Converter	Medium	Medium	Low to medium	Medium

4.3.5 System comparative analysis

Tabular analysis

Table 29: Optimal design analysis.

Design	Criteria				
	Cost	Design Complexity	Sustainability	Usability	Scalability
Design 1	16461	Simpler	More	Convenient	Scalable
Design 2	22644	More Complex	Less	Less Convenient	Scalable

4.3.6 Final verdict on optimal design

To sum up, in order to find the optimal solution for a smart trash bin project, we conducted an in-depth assessment based on a quartet significant criteria: system power analysis, system budget analysis, system mapping analysis, and system ecological analysis.

By conducting a comprehensive power analysis, we were able to identify the components with the lowest energy needs, optimize data transmission, and select sustainable battery options to reduce power consumption. In conducting a budget analysis, we identified cost-saving opportunities such as the use of open-source software and recycled materials, while also taking into account ongoing maintenance and support costs to ensure the system's long-term viability.

By conducting a system mapping analysis, we evaluated the physical architecture of the smart trash bin system in order to optimize data collection and processing through the placement of sensors in high-traffic areas and the design of an effective centralized management platform. In addition, we used an ecological analysis to reduce the environmental impact of the system by incorporating sustainable materials and practices, such as appropriate battery disposal and waste reduction measures.

We were able to identify the optimal solution for a smart garbage bin project that is not only functional, but also long-lasting and cost-effective. This includes utilizing low-power sensors, open-source software, an efficient system architecture, and eco-friendly materials and practices.

4.3.7 Optimal design – block diagram

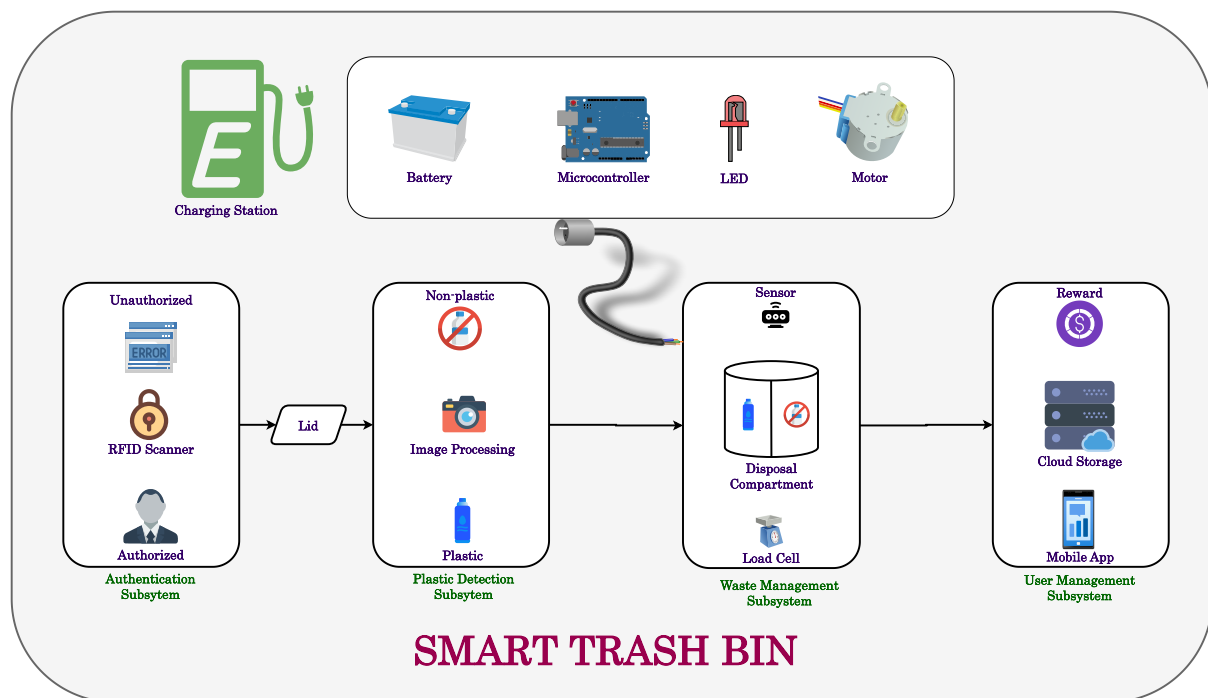


Figure 34: Block diagram of optimal design.

4.3.8 Optimal design – physical model



Figure 35: Developed bin front view.



Figure 36: Developed bin top view.



Figure 37: Developed bin interior view.

4.4 Performance evaluation of developed solution

4.4.1 Quantitative Performance Assessment

Motor Performance Assessment

From section 4.2.2, we come to know that the required power for compartment and lid are 0.000769kWh and 0.00024kWh respectively. From Table 16, we found out that MG996 is the most suitable motor for the compartment and lid operation.

Since the required power for compartment and lid is lower than the maximum power of the motor, it is suitable to use this motor for our project. This means that the motor has enough capacity to provide the power needed by our system.

Furthermore, using a motor with a maximum power higher than the required power adds a safety margin. It ensures that the motor will not operate at its maximum capacity, reducing the risk of overheating or potential damage to the motor.

In summary, the motor with a maximum power of 0.000922 kWh is both suitable and safe to use in our project because it meets the required power and provides a margin of safety.

Graphical Assessment

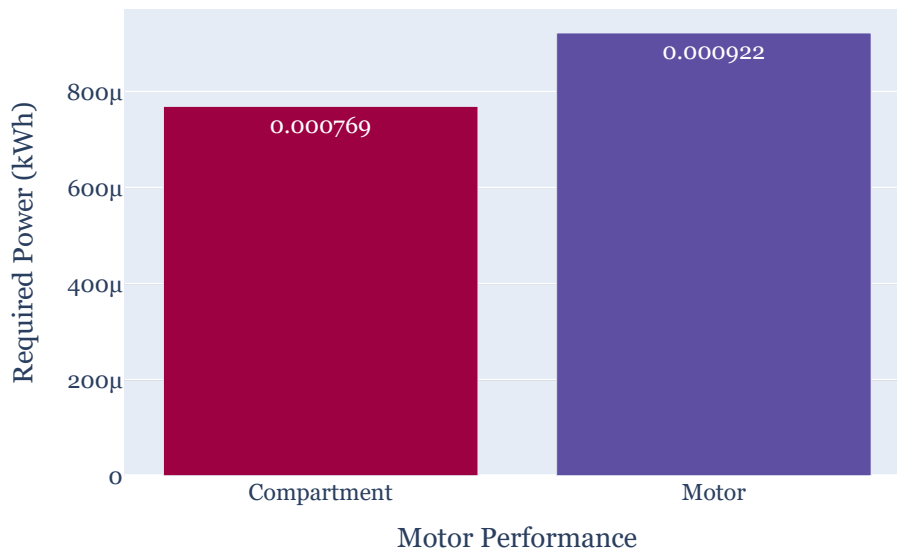


Figure 38: Compartment & Motor power assessment.

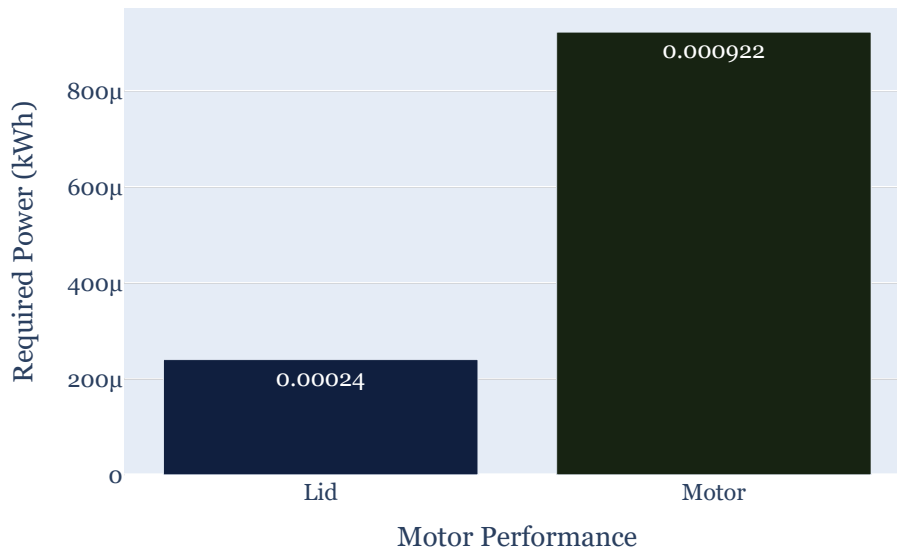


Figure 39: Lid & Motor power assessment.

Battery Performance Assessment

First of all, to assess the battery performance, we need to know the required power for our developed solution so that we can use the appropriate power source for our project.

Table 30: Required power for the developed solution.

Component	Required Power (kWh)
Camera	0.00022
Compartment	0.00092
Display	0.00016
Lid	0.00092
Load Cell	0.00022
ESP32	0.00036
US	0.00066
RFID	0.00036
Buck Converter	0.00030
Total	0.00412

As we can see from the table that the total required power for the whole system is 0.00412kWh. We need such a power source which will provide the required amount of power. From our previous battery analysis portion, we find that li-ion battery will be the best option among other power sources in terms of cost, efficiency and environmental factors.

Now, we will evaluate the battery performance regarding the required output power.
Battery Power Calculation

To calculate the power of our developed system,

$$\begin{aligned}\text{Required current} &= \frac{\text{Battery capacity (Ah)}}{\text{Discharging time (hours)}} \\ &= \frac{27.2\text{Ah}}{12\text{h}} \\ &= 2.26\text{A}\end{aligned}\tag{22}$$

Now, to find out voltage per cell,

$$\begin{aligned}\text{Voltage per cell} &= \frac{\text{Battery total voltage (volts)}}{\text{Number of battery cell}} \\ &= \frac{14.8\text{V}}{4} \\ &= 3.7\text{V}\end{aligned}\tag{23}$$

So, the output power is,

$$\begin{aligned}\text{Output power} &= \text{Required current} \times \text{Voltage per cell} \\ &= 2.26\text{A} \times 3.7\text{V} \\ &= 8.362\text{W} \\ &= 0.2006\text{kWh}\end{aligned}\tag{24}$$

Based on the calculation, the required power for our system is 0.00412 kWh, and the battery we are considering has a maximum power of 0.2006 kWh.

Using a battery with a maximum power capacity of 0.2006 kWh for a system that requires only 0.00412 kWh is more than sufficient. This means that the battery has a significantly higher power capacity than needed for your system, providing a considerable safety margin.

Having a battery with a higher power capacity ensures that it can easily meet the power demands of your system without getting strained or overloaded. It allows the battery to operate comfortably within its capacity limits, reducing the risk of overheating, premature aging, or potential damage to the battery.

Moreover, using a battery with a higher power capacity leaves room for future expandability or accommodating potential power fluctuations in your system. It provides flexibility in case you need to add more components or increase the power requirements in the future.

In summary, the battery with a maximum power capacity of 0.2006 kWh is suitable and safe to use in your project because it exceeds the required power, allowing for a comfortable power supply to your system and providing a safety margin.

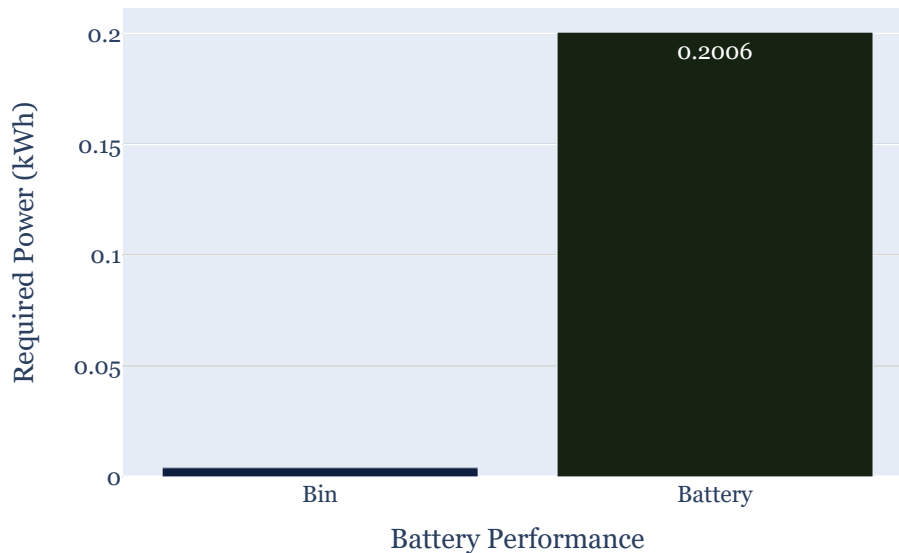


Figure 40: Bin & Battery power assessment.

Battery Charging Rate

In our project, we are using 4 cell Li-ion battery with a capacity of 6.8Ah. So the total power of the battery is 27.2Ah. Also, we are assuming that the bin will be fully charged within 2 hours.

- **In terms of current:**

$$\begin{aligned}
 \therefore \text{Charging rate (Amps)} &= \frac{\text{Battery capacity (Ah)}}{\text{Charging time (hours)}} \\
 &= \frac{27.2\text{Ah}}{2\text{h}} \\
 &= 13.6\text{A}
 \end{aligned}
 \tag{25}$$

- **In terms of power:**

$$\begin{aligned}
 \therefore \text{Charging rate (Amps)} &= \frac{\text{Battery Capacity (Ah)} \times \text{Charging Voltage (V)}}{\text{Charging time (hours)}} \\
 &= \frac{27.2\text{Ah} \times 4.2\text{V}}{2\text{h}} \\
 &= 57.12\text{W} \\
 &= 1.37\text{kWh}
 \end{aligned}
 \tag{26}$$

Battery Discharging Rate

In our project, we are using 4 cell Li-ion battery with a capacity of 6.8Ah. So the total power of the battery is 27.2Ah. Also, we are assuming that the bin run approximately 12h in a day with battery replacement condition in mind.

- **In terms of current:**

$$\begin{aligned} \therefore \text{Discharging rate (Amps)} &= \frac{\text{Battery capacity (Ah)}}{\text{Discharging time (hours)}} \\ &= \frac{27.2\text{Ah}}{12\text{h}} \\ &= 2.26\text{A} \end{aligned} \tag{27}$$

- **In terms of power:**

$$\begin{aligned} \therefore \text{Charging rate (Amps)} &= \frac{\text{Battery Capacity (Ah)} \times \text{Battery Voltage (V)}}{\text{Discharging time (hours)}} \\ &= \frac{27.2\text{Ah} \times 4.2\text{V}}{12\text{h}} \\ &= 9.52\text{W} \\ &= 0.23\text{kWh} \end{aligned} \tag{28}$$

Graphical Assessment

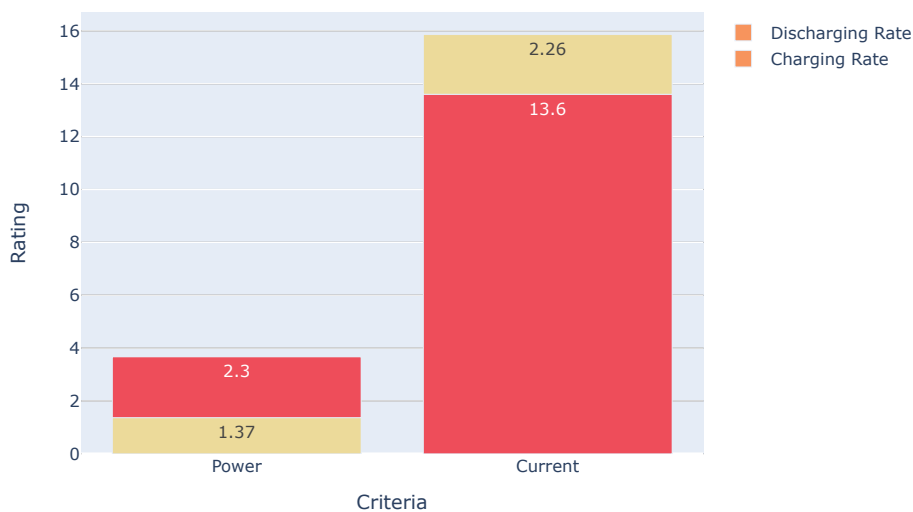


Figure 41: Battery charging & discharging rate assessment.

Project Runtime Assessment

To calculate the runtime of our project, we will need to know two key pieces of information:

- **Battery Capacity:** Determine the capacity of our battery, which is typically measured in watt-hours (Wh) or kilowatt-hours (kWh).
- **Power Consumption:** Determine the average power consumption of our project in watts (W) or kilowatts (kW). This can be done by analyzing the power draw of each component or device in our system and summing up their power requirements.

$$\begin{aligned}
\therefore \text{System runtime} &= \frac{\text{Battery Capacity (kWh)}}{\text{Power Consumption (kW)}} \\
&= \frac{0.2006 \text{ kWh}}{0.04944 \text{ kW}} \\
&= 4.057 \text{ h} \\
&\approx 4 \text{ h}
\end{aligned}
\tag{29}$$

Here we are performing project runtime evaluation with respect to battery performance in different cases of our developed solution:

Table 31: Design Metrics Comparison

Test Case	Run Time		Required Power		Efficiency (%)		Error(%)	
	Theoretical	Actual	Theoretical	Actual	Runtime	Required Power	Runtime	Required Power
1	4h	3.5h	2.06W	2.00W	87.5	97.00	12.50	3.00
2		3.2h		1.95W	80.0	94.60	20.00	5.40
3		3h		1.90W	75.0	92.23	25.00	7.77

Graphical Assessment

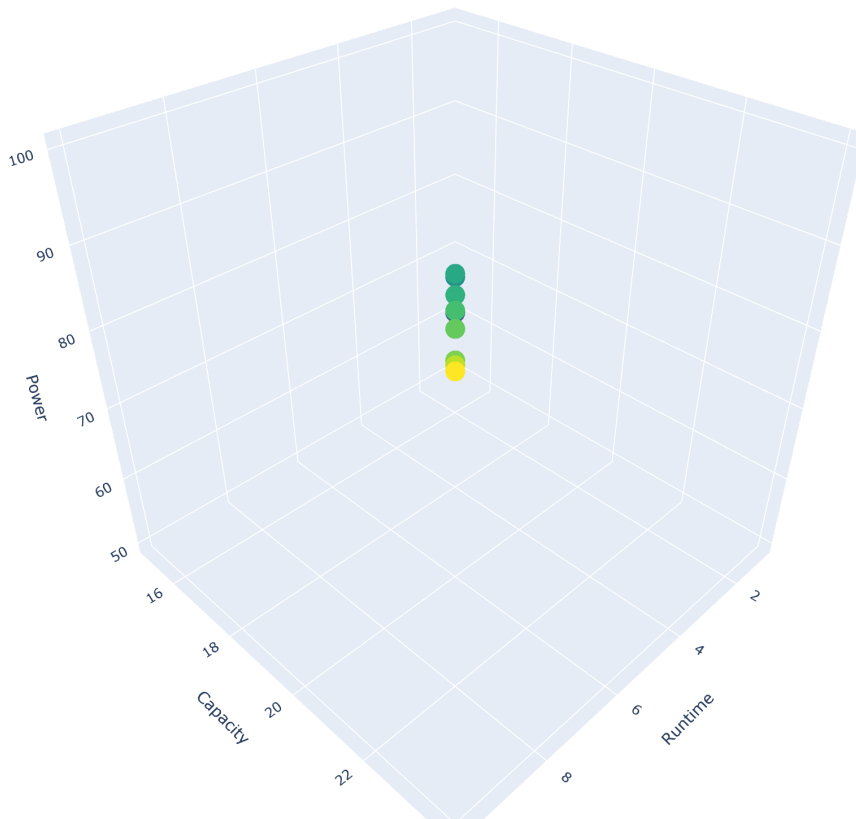


Figure 42: Battery performance multidimensionally analyzed in relation to power consumption and runtime.

4.4.2 Qualitative Performance Assessment

Bottle detection subsystem



(a) Sample Mountain Dew bottle.

(b) Sample Mum water bottle.

(c) Sample CocaCola bottle.

(d) Sample kinley water bottle.

Figure 43: Sample images used to train the image processing models for bottle detection.

Python code for the image processing

```
[1]: import os
os.environ["KMP_DUPLICATE_LIB_OK"]="TRUE"
import cv2
import numpy as np
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten,
    Dense, Dropout
from tensorflow.keras.preprocessing.image import ImageDataGenerator
```

```
[2]: plastic_dir = "data/plastic/"
not_plastic_dir = "data/not_plastic/"
```

```
[3]: datagen = ImageDataGenerator(
    rescale=1./255,
    rotation_range=20,
    width_shift_range=0.1,
    height_shift_range=0.1,
    shear_range=0.1,
    zoom_range=0.1,
    horizontal_flip=True,
    fill_mode='nearest')
```

```
[4]: class_labels = ['plastic', 'not_plastic']
```

```
[5]: model = Sequential([
    Conv2D(32, (3, 3), activation='relu', input_shape=(256, 256, 3)),
    MaxPooling2D((2, 2)),
```

```

Conv2D(64, (3, 3), activation='relu'),
MaxPooling2D((2, 2)),
Conv2D(128, (3, 3), activation='relu'),
MaxPooling2D((2, 2)),
Flatten(),
Dense(128, activation='relu'),
Dropout(0.5),
Dense(1, activation='sigmoid')
])

```

```
[6]: model.summary()
```

Model: "sequential"

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 254, 254, 32)	896
max_pooling2d (MaxPooling2D)	(None, 127, 127, 32)	0
conv2d_1 (Conv2D)	(None, 125, 125, 64)	18496
max_pooling2d_1 (MaxPooling2D)	(None, 62, 62, 64)	0
conv2d_2 (Conv2D)	(None, 60, 60, 128)	73856
max_pooling2d_2 (MaxPooling2D)	(None, 30, 30, 128)	0
flatten (Flatten)	(None, 115200)	0
dense (Dense)	(None, 128)	14745728
dropout (Dropout)	(None, 128)	0
dense_1 (Dense)	(None, 1)	129

=====
Total params: 14,839,105
Trainable params: 14,839,105
Non-trainable params: 0
=====

```
[7]: model.compile(optimizer='adam', loss='binary_crossentropy',
                 metrics=['accuracy'])
```

```
[8]: def process_image(image):
    image = cv2.resize(image, (256, 256))
    image = np.expand_dims(image, axis=0)
    image = np.float32(image)
    return image
```

```
[9]: def convert_to_jpg(image_path):
    img = cv2.imread(image_path)
    if img is None:
        raise ValueError(f"Invalid image file {image_path}")
    filename, extension = os.path.splitext(image_path)
    if extension.lower() == ".jpg":
        return img
    else:
        new_filename = f"{filename}.jpg"
        cv2.imwrite(new_filename, img, [int(cv2.IMWRITE_JPEG_QUALITY), 100])
    return cv2.imread(new_filename)
```

```
[10]: def classify_image(image):
    image = process_image(image)
    prediction = model.predict(image)[0]
    class_idx = int(round(prediction))
    class_label = class_labels[class_idx]
    return class_label
```

```
[11]: plastic_images = []
not_plastic_images = []

for filename in os.listdir(plastic_dir):
    image_path = os.path.join(plastic_dir, filename)
    try:
        image = convert_to_jpg(image_path)
    except ValueError as e:
        print(f"Ignoring file {filename}: {e}")
        continue
    augmented_images = datagen.flow(process_image(image))
    for augmented_image in augmented_images:
        plastic_images.append(augmented_image)
        break

for filename in os.listdir(not_plastic_dir):
    image_path = os.path.join(not_plastic_dir, filename)
    try:
        image = convert_to_jpg(image_path)
    except ValueError as e:
        print(f"Ignoring file {filename}: {e}")
        continue
```

```
augmented_images = datagen.flow(process_image(image))
for augmented_image in augmented_images:
    not_plastic_images.append(augmented_image)
    break
```

```
[39]: import matplotlib.pyplot as plt

image = cv2.cvtColor(plastic_images[4][0], cv2.COLOR_BGR2RGB)

plt.imshow(image)
plt.axis('off')
plt.show()
```



Python code for the image classification

```
[1]: import cv2
import numpy as np
import tensorflow as tf
```

```
[2]: MODEL_PATH = "Model/TFLite/model_unquant.tflite"
interpreter = tf.lite.Interpreter(model_path=MODEL_PATH)
interpreter.allocate_tensors()

labels = ["Coca Cola", "Mountain Dew", "Mum Drinking Water", "Pepsi",
         _"Water Bottle"]
```



```
[3]: input_details = interpreter.get_input_details()
      output_details = interpreter.get_output_details()
```

```
[4]: cap = cv2.VideoCapture(0)
```

```
[ ]: cap.set(cv2.CAP_PROP_FRAME_WIDTH, 640)
      cap.set(cv2.CAP_PROP_FRAME_HEIGHT, 480)
```

```
[13]: while True:
        # Capture frame-by-frame
        ret, frame = cap.read()

        # Preprocess the image
        resized_frame = cv2.resize(frame, (224, 224))
        normalized_frame = resized_frame / 255.0
        input_data = np.expand_dims(normalized_frame, axis=0).astype(np.
        float32)

        # Set the input tensor and invoke the interpreter
        interpreter.set_tensor(input_details[0]['index'], input_data)
        interpreter.invoke()

        # Get the output tensor and extract the predicted class index
        output_data = interpreter.get_tensor(output_details[0]['index'])
        predicted_class_index = np.argmax(output_data)

        # Draw the predicted label on the image
        predicted_class_label = labels[predicted_class_index]
        cv2.putText(frame, predicted_class_label, (50, 50), cv2.
        FONT_HERSHEY_COMPLEX, 1, (255, 0, 0), 2)

        # Display the resulting image
        cv2.imshow('ESP32 Cam', frame)

        # Exit if the user presses 'q'
        if cv2.waitKey(1) & 0xFF == ord('q'):
            break

    cap.release()
    cv2.destroyAllWindows()
```

Test case – system modeling

During this test, we commenced the process of simulating the authentication system by first adding a switch block from Matlab Simulink. After that, we attached the switch to two constants, 0 and 1, that will be activated based on the state that the switch is in at the moment. In order to arrive at a conclusion based on the status of the switch, we compared it to a baseline value of 0. If the value triggered from the switch is more than 0, then the user will be considered authenticated; otherwise, they will not be considered authenticated. If the value triggered from the switch is less than 0, then the user will not be considered authenticated. We built two distinct ways for the user to be notified about the condition of the application. First, we printed the current state by sending it to the Matlab console via an output that was generated by a specialised Matlab function. The next step that we took was to include a display block that demonstrated the current status of the system. Again, we proceeded on the assumption that 0 denotes that the user is not authorised and that 1 denotes that the user is authenticated, and as a result, we printed these values on this display block.

In addition, during the subsequent stage, we included an if-else block in order to determine whether the substance that was going to be emulated was plastic or something else entirely. It is imperative that we keep in mind that in order for this component of the ancillary system to function, the user must first have been authorised in the preceding stage. In this section, just like we did with the authentication system, we included a switch block to imitate the plastic material type. If the switch is activated, it will be assumed that the material in question is plastic; otherwise, it will be assumed that the material in question is not plastic.

If the value in the previous if-else block was 0, the logic will be transferred to the non-plastic block; otherwise, it will be passed to the plastic block. If the value was not 0, the logic will be passed to the plastic block. When any signal is received by the non-plastic block, the display will update to reflect the new information. On the other hand, the value from the if-else block will be transferred to the plastic block if the value is 1. In this section, we added another if-else block, and it was connected to a comparator block so that it could receive the value of the plastic switch's state. If the value that was supplied is larger than 0, then it will be sent on to the final plastic block, which will then send a value of 1 to the display block that is attached to it to indicate that the task was completed successfully. On the other hand, if the comparator registers a value of 0, it will indicate that the item is not plastic and will show this information on the display. This indicates that the test was unsuccessful.

Three different trials of the entire authentication subsystem are illustrated down below: (1) when neither the user nor the material is authenticated [Figure 44], (2) when the user is authenticated but the material is not plastic [Figure 45], and (3) when both the user and the material are authenticated and the material is plastic [Figure 46].

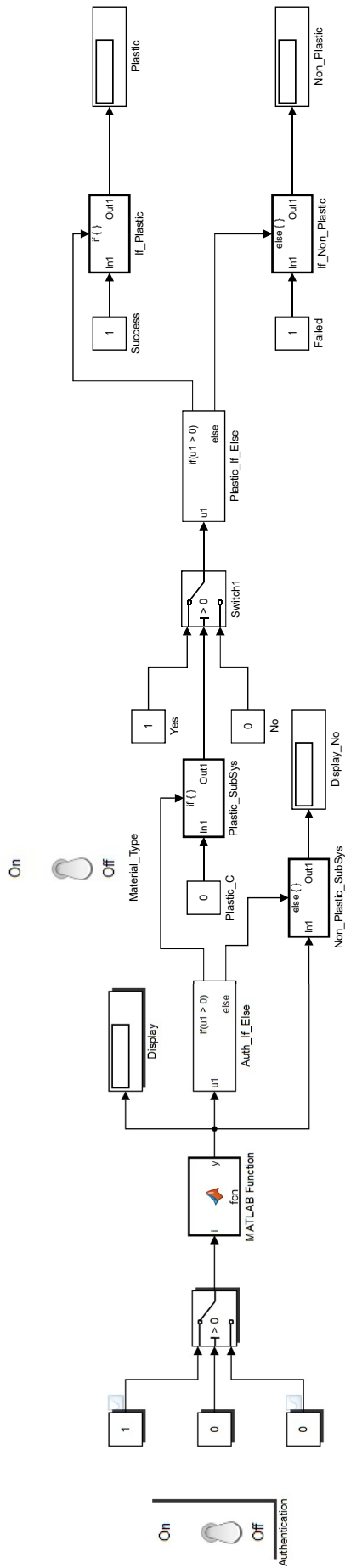


Figure 44: Matlab Simulink trial I – user is not authenticated and material is not plastic.

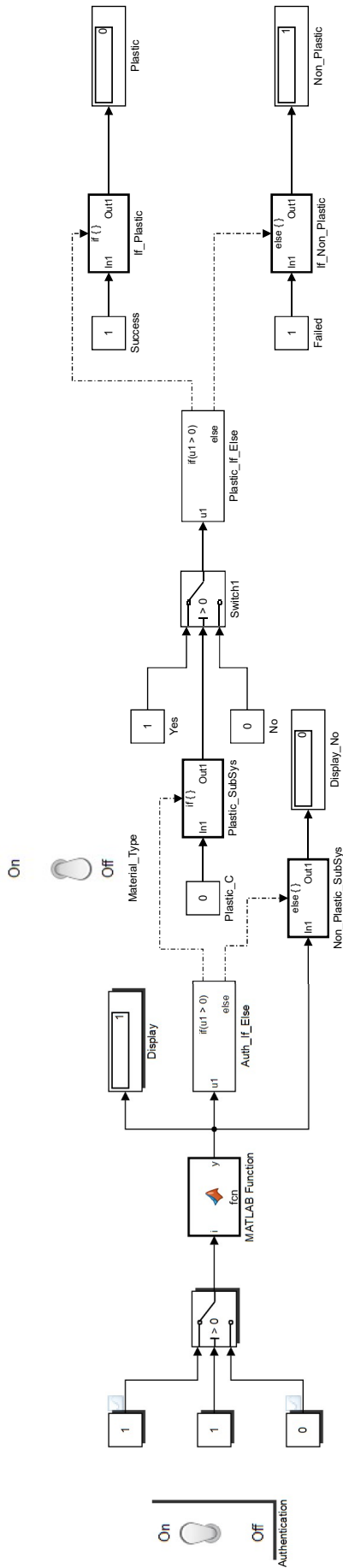


Figure 45: Matlab Simulink trial II – user is authenticated and material is not plastic.

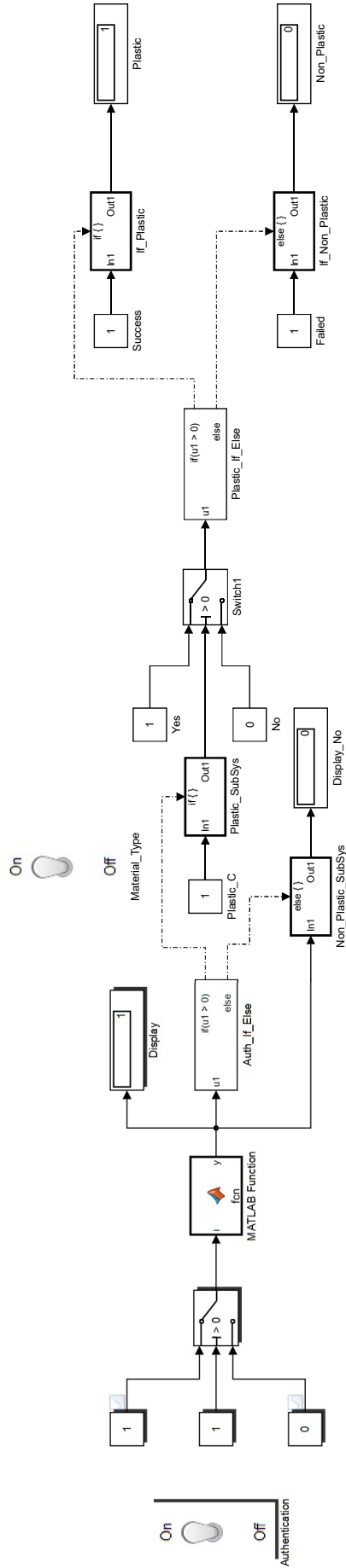


Figure 46: Matlab Simulink trial III – user is authenticated and material is plastic.

Test case – bottle detection

Mum bottle detection

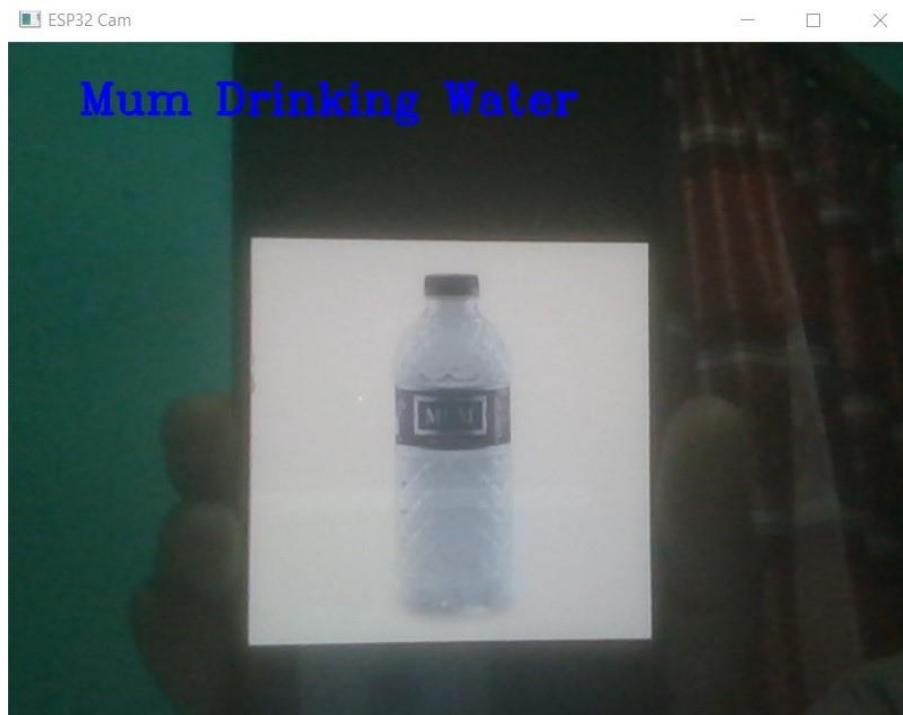


Figure 47: Recognizing Mum plastic bottle using TensorFlow Lite.

Water bottle detection

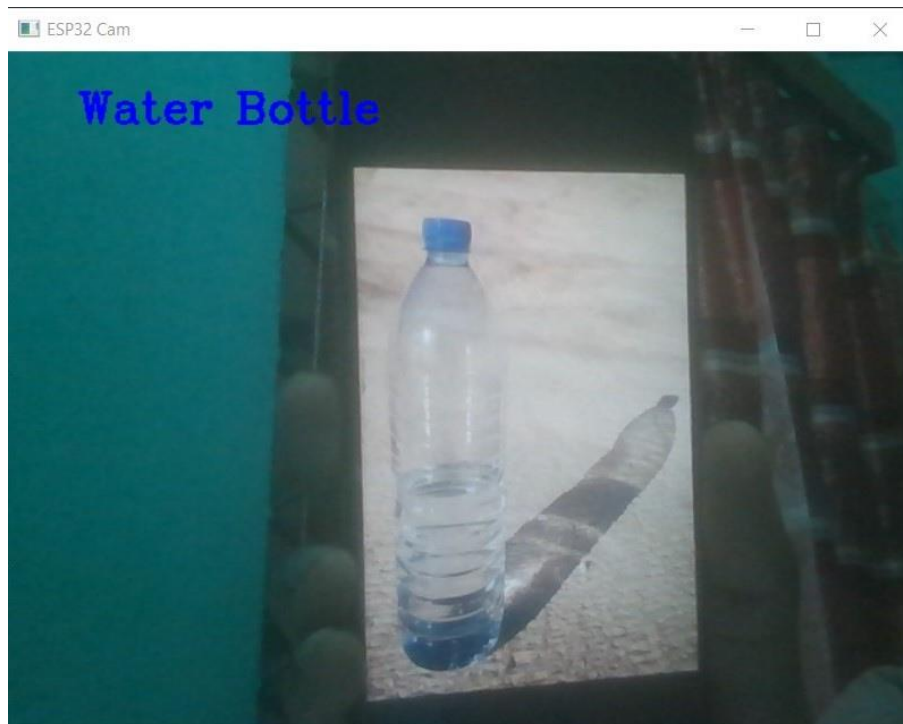


Figure 48: Recognizing plastic water bottle using TensorFlow Lite.

4.5 Conclusion

In conclusion, this section delved into the subject of optimizing a couple of layout design and finding the highest quality solution. We explored a way to approach the optimization manner while multiple design options are to be had. By thinking about different factors along with price, performance, efficiency, and reliability, we outlined techniques for systematically evaluating and comparing distinct design options. Through rigorous evaluation and evaluation, we emphasized the importance of figuring out the greatest design method. This involved using mathematical fashions, algorithms, and selection-making strategies to decide the most favorable answer based totally on particular standards or objectives. After selecting the best design technique, we identified the need to evaluate the overall performance of the developed solution. Through sizable checking out, size, and evaluation, we assessed the solution's effectiveness and efficiency in meeting the preferred desires and necessities.

By following the steps mentioned at some point of this section, groups and people can achieve enormous improvements of their layout design. Optimizing multiple design options lets in for informed decision-making, main to improved performance, value-effectiveness, and overall fulfillment. It is vital to carefully consider the change-offs and boundaries of each design method in the course of the optimization technique, making sure that the selected solution without a doubt aligns with the preferred goals.

Ultimately, through adopting a scientific and thorough method to optimization, one can release progressive solutions, capitalize on opportunities, and power development in numerous domain names, ranging from engineering and era to enterprise and past.

5 Completion of Final Design and Validation [CO8, PO-C]

5.1 Introduction

In this pivotal chapter, we embark on the outcome of our design adventure as we represent the final product design built in hardware. Our minds now shifts toward evaluating the solution to ensure that it not only encompasses all the favored capabilities however also fulfills the power necessities and meets person needs.

With relentless willpower and meticulous making plans, we've transformed abstract principles and thoughts right into a tangible truth. The completion of the very last design signifies a essential milestone in our mission, representing the convergence of creativity, technical knowledge, and interest to element. During the improvement process, we crafted an answer that addresses the unique needs and necessities of our intended users. From the initial layout segment to prototyping and iteration, we have strived to align our efforts with the expectancies and aspirations of the stop-customers.

Our assessment will encompass several aspects, which includes functionality, overall performance, usability, and reliability. Through rigorous checking out and analysis, we will scrutinize every function and make certain that it plays optimally in actual-international eventualities. Furthermore, we are able to assess the energy necessities of our design, making sure that it operates within designated parameters.

5.2 Completion of final design

In this phase, we focus at the crowning glory of the very last design for our smart trash bin project. With the imaginative and prescient of optimizing waste control, the smart trash bin carries diverse subsystems, together with RFID-based authentication, ML and picture processing-based totally plastic bottle detection, waste segmentation with a lid and waste compartment, and a user praise system with virtual currency. Here, we present a task plan and outline the vital steps and tools required to implement the hardware components successfully. By following this roadmap, we aim to create a useful and green smart trash bin that enhances waste disposal practices even as worthwhile customers for his or her eco-friendly efforts.

5.2.1 Project Plan

1. Identification of Hardware Requirements:

- Conduct a thorough analysis of the intended capabilities and functionalities of the smart trash bin.
- Identify the necessary hardware components that will fulfill the requirements of each subsystem.
- Ensure compatibility and integration feasibility of the identified components.

2. System Architecture Design:

- Develop a comprehensive system architecture design that depicts the inter-connection of all subsystems and components.

- Define the communication protocols and interfaces between different subsystems.
- Consider hardware limitations, power requirements, and scalability for future enhancements.

3. Selection of Hardware Tools and Components:

- Research and select appropriate microcontrollers or development boards that can support the identified subsystems.
- Choose RFID readers, cameras, sensors, actuators, and other necessary components based on the project requirements.
- Ensure hardware compatibility and availability of adequate documentation and software libraries for the selected tools.

4. Circuit Design and Prototyping:

- Design the circuit schematic based on the system architecture.
- Utilize circuit design software (e.g., Eagle, KiCad) to create a physical representation of the circuit board.
- Prototype the circuit and test it for functional validation and performance evaluation.

5. Integration of Subsystems:

- Connect the RFID-based authentication subsystem to the microcontroller, ensuring proper communication and data exchange.
- Integrate the ML and image processing-based plastic bottle detection subsystem with the camera and microcontroller.
- Incorporate the waste segmentation subsystem, including the lid and waste compartment, with appropriate sensors and actuators.
- Establish a connection between the user reward subsystem and the microcontroller to track successful waste dumping and virtual currency allocation.

6. Enclosure Design and Manufacturing:

- Develop an enclosure design that accommodates all the integrated hardware components.
- Consider aesthetic appeal, functionality, and durability of the material used for the enclosure.
- Utilize computer-aided design (CAD) software to create a 3D model of the enclosure.
- Manufacture or 3D-print the enclosure based on the CAD model.

7. Software Development:

- Develop firmware for the microcontroller to control the various subsystems, handle data processing, and manage user reward systems.

- Utilize programming languages such as C/C++, Python, or Arduino-specific languages to program the microcontroller.
- Implement machine learning algorithms for plastic bottle detection and image processing.
- Create a virtual currency system and necessary interfaces for user interaction.

8. Testing and Quality Assurance:

- Conduct comprehensive testing of the hardware functionality, including subsystem integration, data accuracy, and user interaction.
- Perform rigorous testing scenarios to validate the performance of individual subsystems and their interactions.
- Ensure compliance with safety standards and regulations.
- Address any issues or bugs identified during testing and make necessary refinements.

9. Documentation and Deployment:

- Create comprehensive documentation, including system architecture, hardware schematics, firmware specifications, and user manuals.
- Provide detailed instructions for the assembly, installation, and maintenance of the smart trash bin.
- Prepare a deployment plan that outlines the steps for deploying the bins in specific locations, considering power supply, connectivity, and user training.

Tools and Resources: - Microcontroller/Development Boards: Arduino, Raspberry Pi, ESP32, etc. - Circuit Design: Eagle, KiCad, Altium Designer. - CAD Software: AutoCAD, SolidWorks, Fusion 360. - Programming Languages: C/C++, Python, Arduino IDE. - Machine Learning Libraries: TensorFlow, OpenCV. - Manufacturing Techniques: 3D Printing, Injection Molding.

5.2.2 Design Adjustments

In the prototype building phase, we realized various changes and adjustments had to be made to ensure the full functionality of the system. First of all, we changed the shape of the compartment from cylindrical to rectangular, to aid the mounting of the high torque motor. The rotating lid was initially planned to be an arc, rotating 90 degrees horizontally to deposit the trash in the respective compartment. However, to simplify our design, we placed a plank shaped lid instead, which would drop down vertically on either side corresponding to the correct trash compartment. Some modifications have been brought to the image dataset as well. We have trained a select few non-plastics as well, like pencils, erasers and small boxes, to identify non-plastic materials. To improve the process of plastic bottle identification, we have trained dynamic images of plastic bottles placed within the system to ensure higher testing accuracy. A light source has also been fitted for the camera to get a better view of the object placed. After trial and error, a stronger motor with much higher torque was fitted in place of the prior servo motor, to

support the load of the bin and associated waste. Freewheel was newly incorporated to ensure the balance and stability of the system. A buzzer was also added as a protective mechanism to alert people nearby if a user happens to perform any fraudulent activity.

5.2.3 Printed Circuit Board design

Schematic

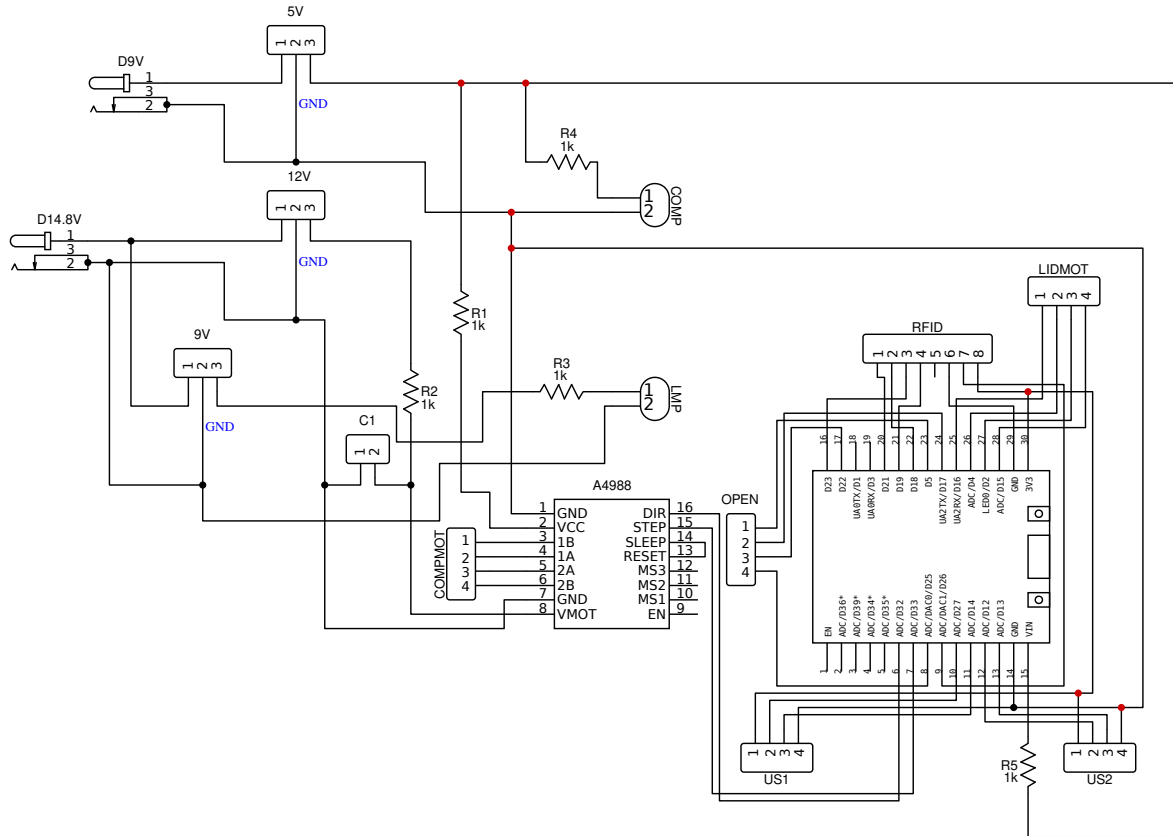
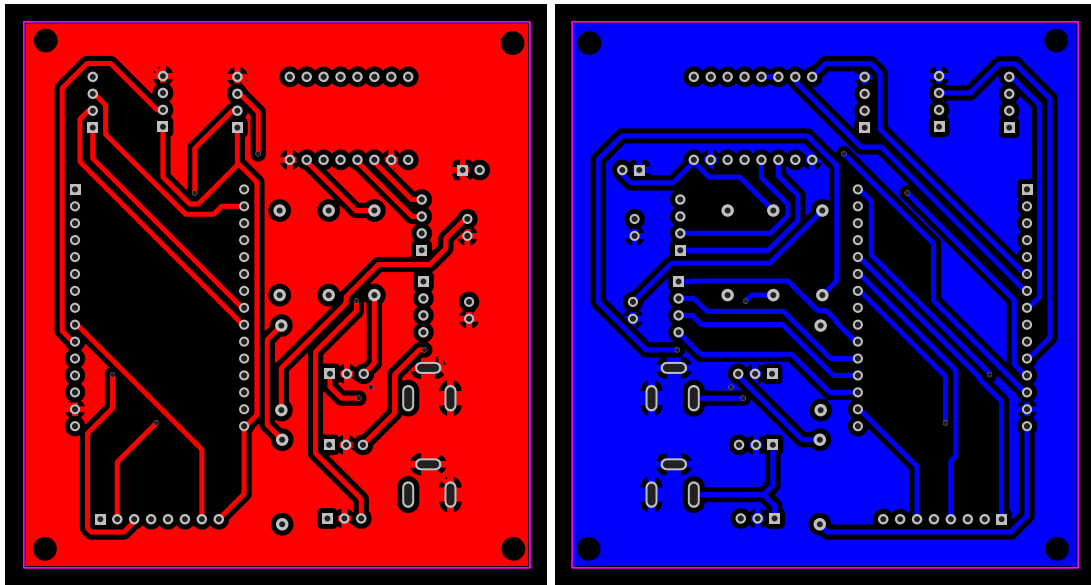


Figure 49: Schematic design for the PCB.

Final output



(a) TopLayer PCB view.

(b) BottomLayer PCB view.

Figure 50: Final PCB design view.

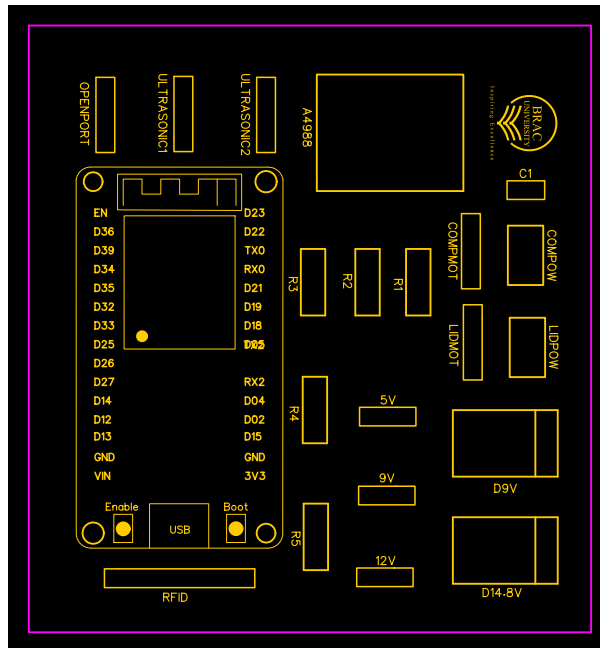
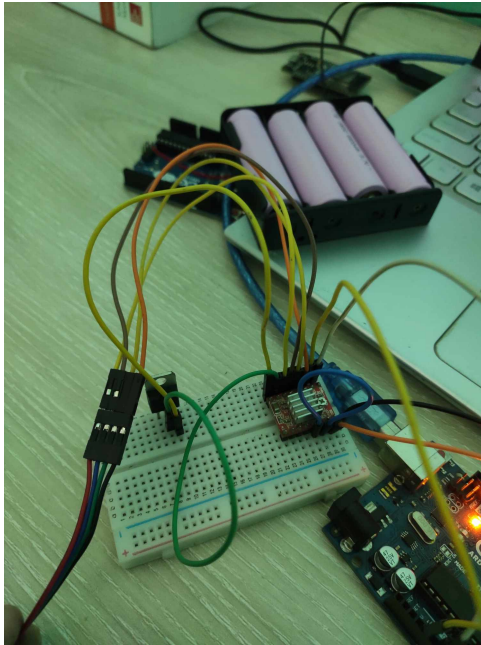


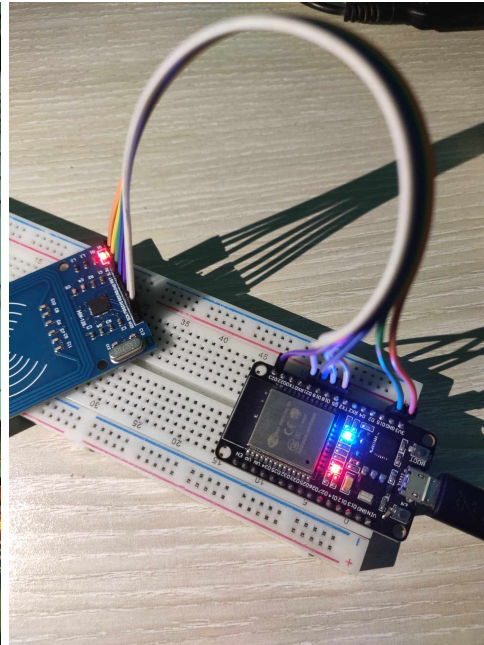
Figure 51: TopSilkLayer PCB view.

5.2.4 Final hardware development

Subsystem-wise bin completion

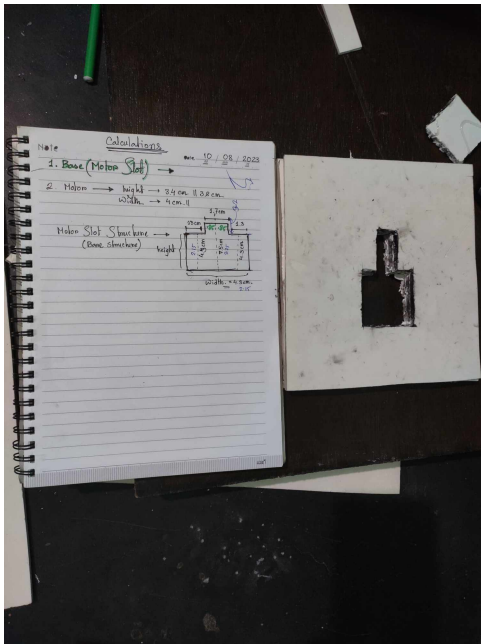


(a) Motor driver testing.

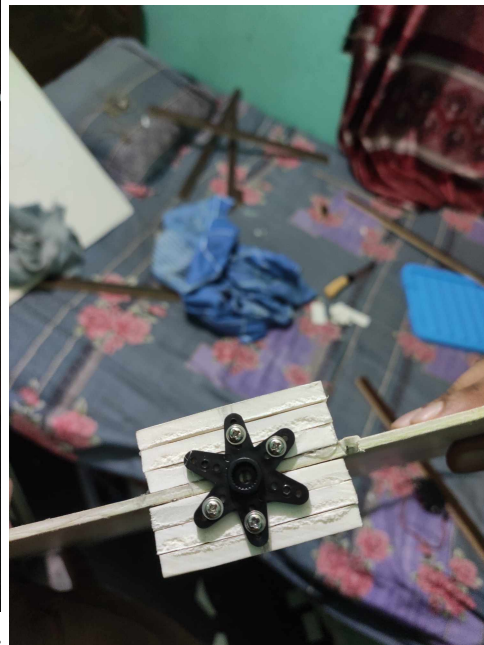


(b) ESP32 & RFID testing.

Figure 52: Phase 1.

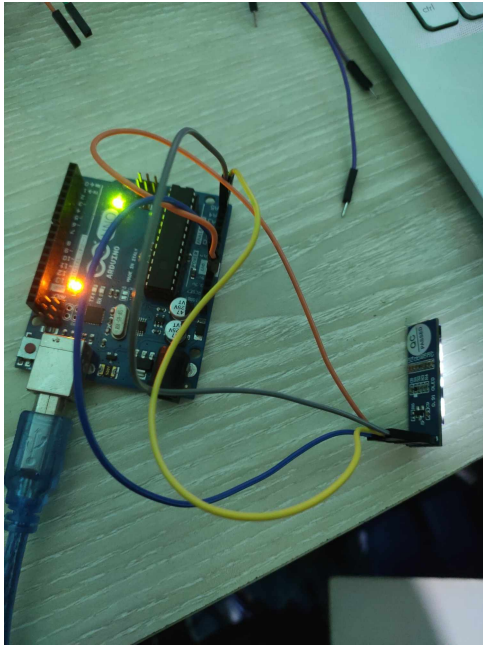


(a) Motor mount measurement for compartment.

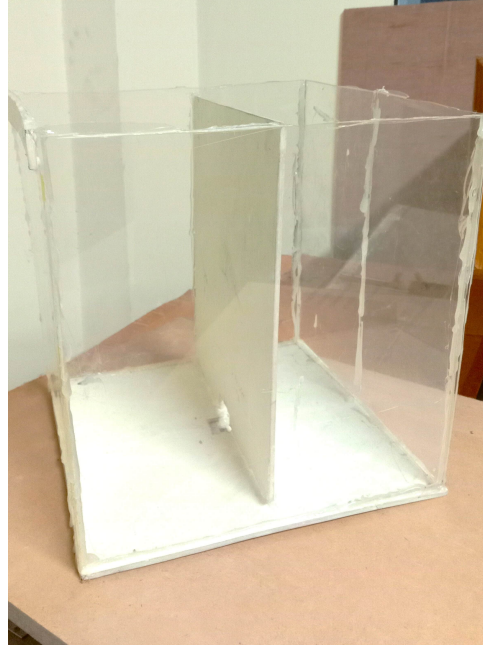


(b) Motor mount setting up for lid.

Figure 53: Phase 2.



(a) Display testing.



(b) Compartment arrangement.

Figure 54: Phase 3.



(a) Compartment mount in main body.



(b) Lid mount in main body.

Figure 55: Phase 4.



(a) Compartment setup – top view. (b) Compartment setup – side view..

Figure 56: Phase 5.

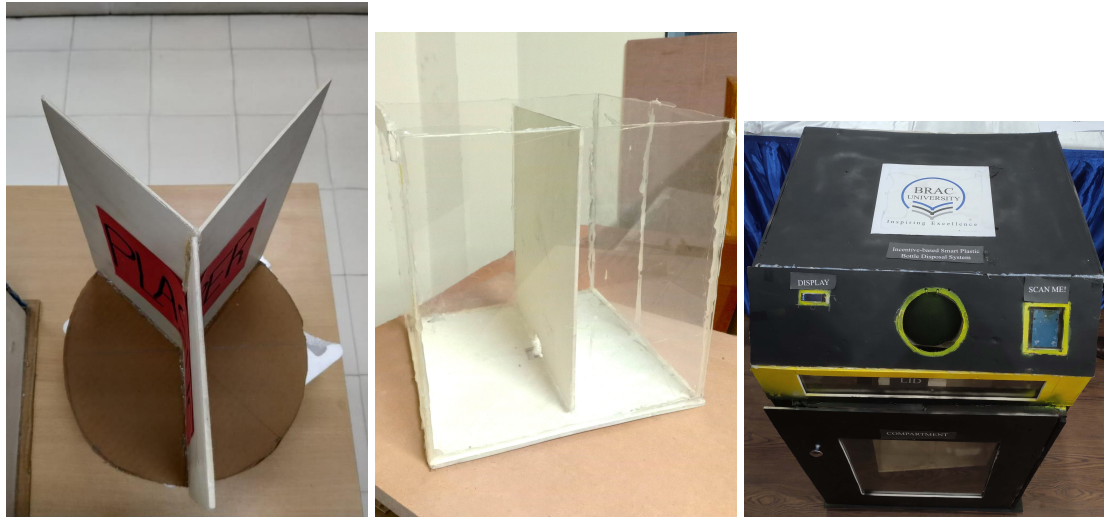
Prototype vs Final Product



(a) Front view of old design

(b) Front view of new design

Figure 57: Front view of the bin design.



(a) Compartment view of old design (b) Compartment view 1 of new design (c) Compartment view 2 of new design

Figure 58: Compartment view of the bin design.



(a) Internal view of old design

(b) Internal view of new design

Figure 59: Internal view of the bin design.

5.3 Evaluate the solution to meet desired need

In this section, we embark on a comprehensive evaluation of our smart trash bin prototype to ensure it meets the desired needs effectively. By subjecting the system to various case studies, we can assess its performance under different loads, authentication systems, feedback mechanisms, and safety features such as fire and toxic gas detection. Additionally, we examine the user rewarding system to encourage and incentivize individuals to actively participate in responsible waste disposal. Through rigorous testing and analysis, our goal is to verify that our solution aligns with the project's goals of enhancing waste management practices. Below we are performing some test cases which are crucial to evaluate the desired need:

5.3.1 Test case 1 – User authentication

Scenario 1 – User not authorized

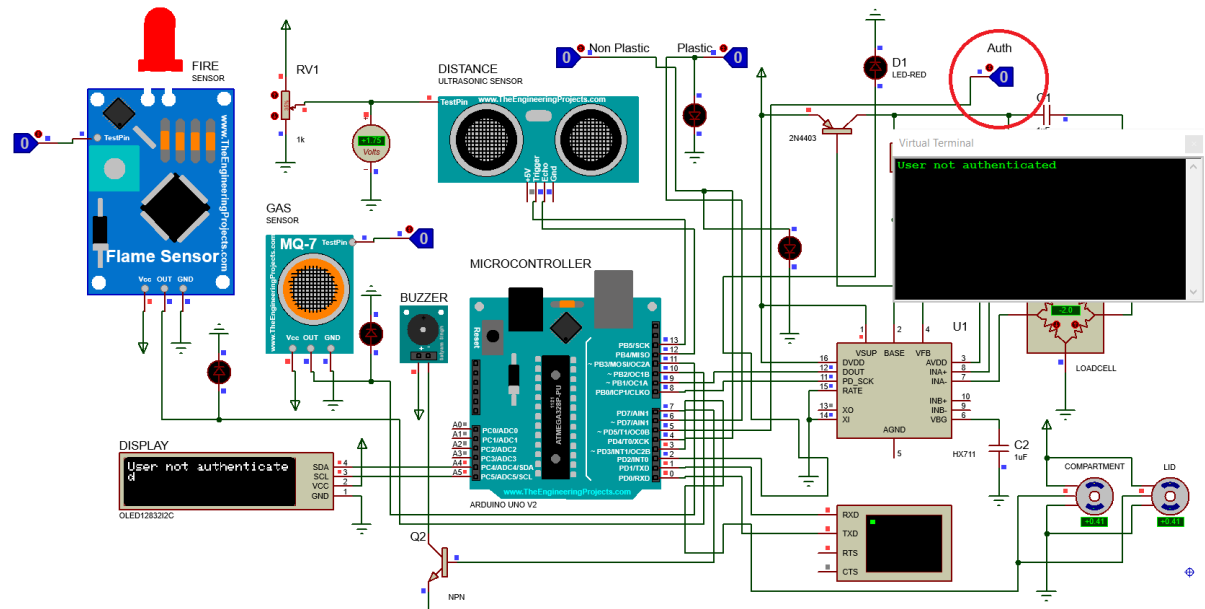


Figure 60: Full circuit representation.

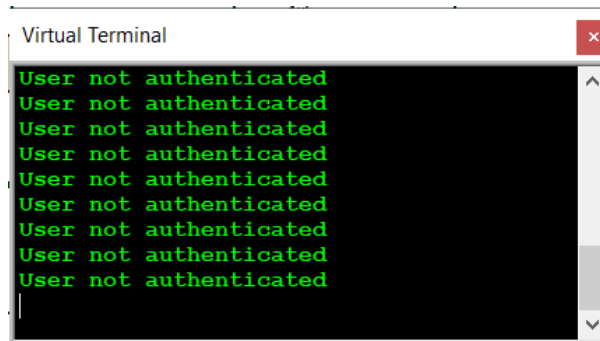


Figure 61: Virtual terminal representation.



Figure 62: Display representation.

Scenario 2 – User authorized

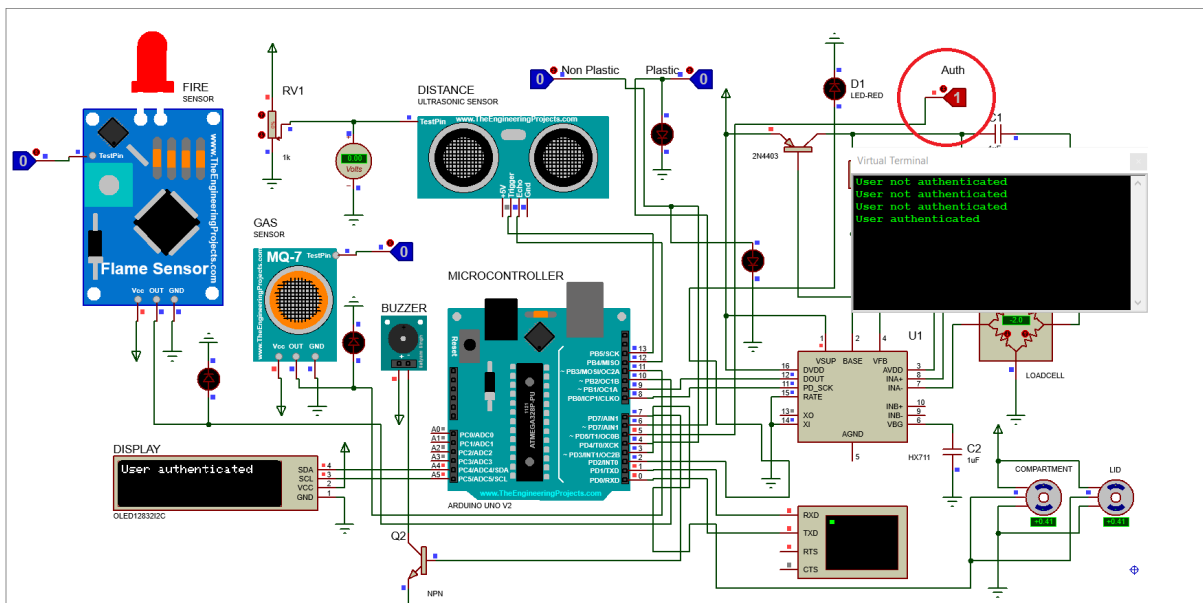


Figure 63: Full circuit representation.

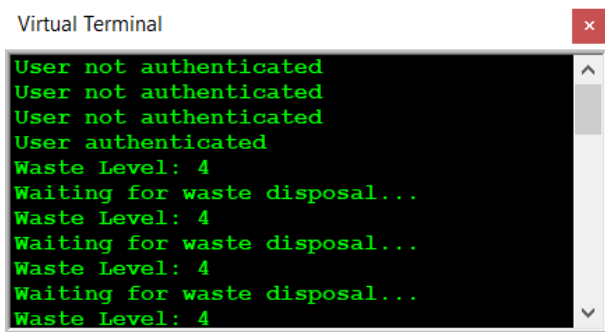


Figure 64: Virtual terminal representation.



Figure 65: Display representation.

Hardware demonstration

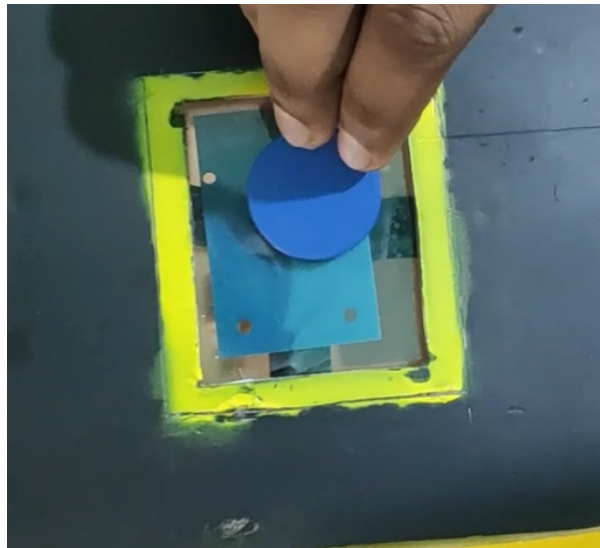


Figure 66: RFID tag placing.

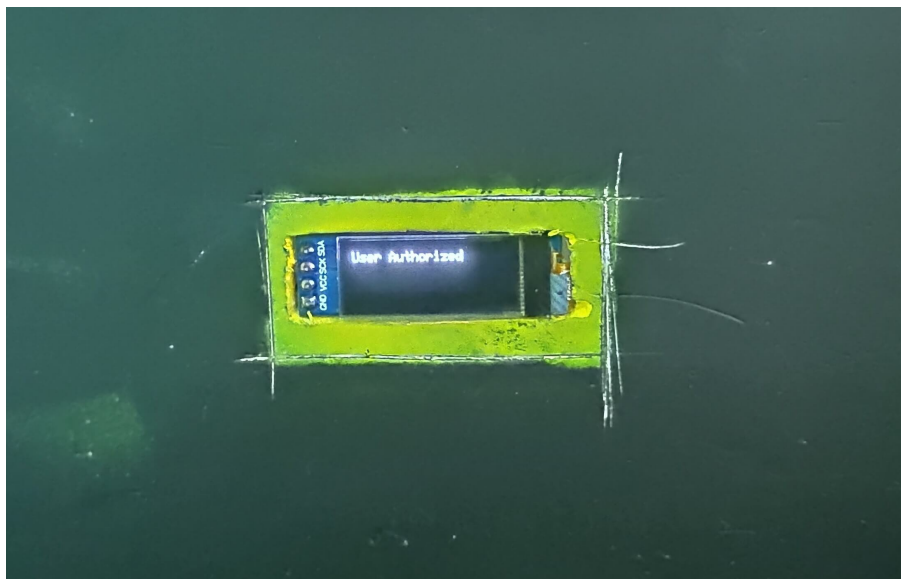


Figure 67: Display showing user authorized.

5.3.2 Test case 2 – Waste detection

Scenario 1 – Plastic detected

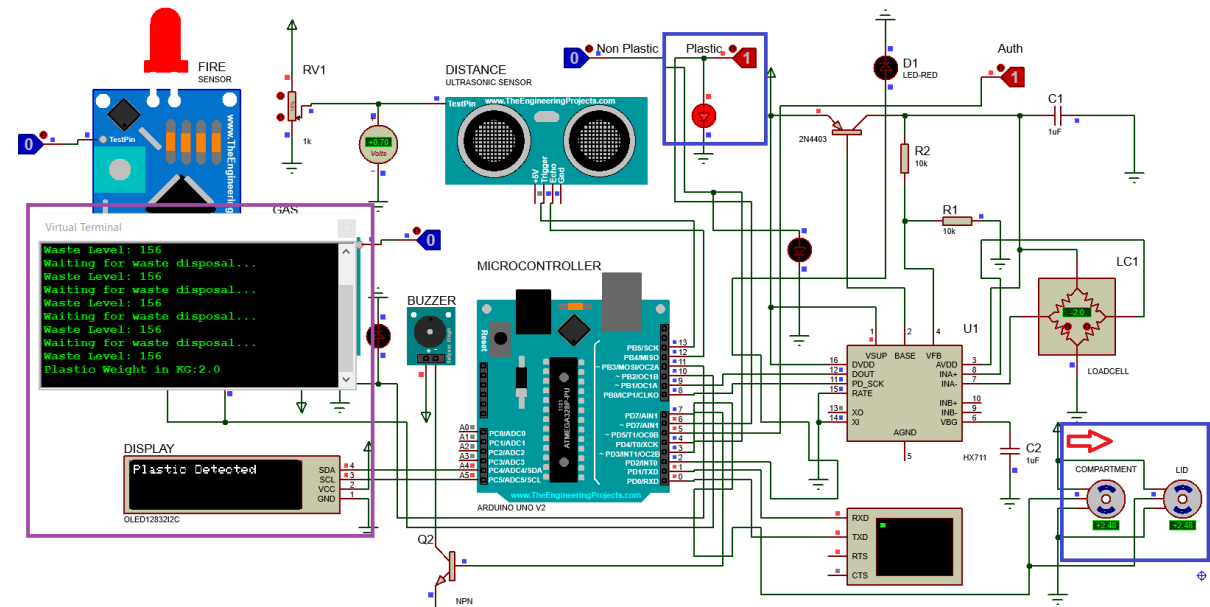


Figure 68: Full circuit representation.

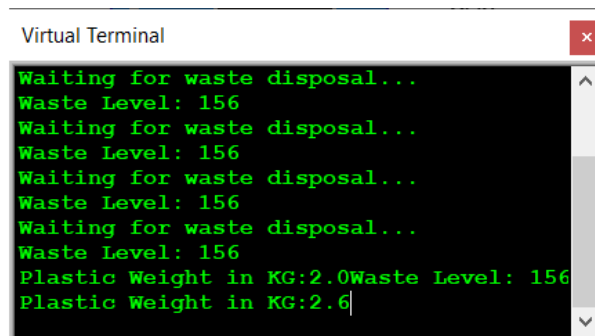
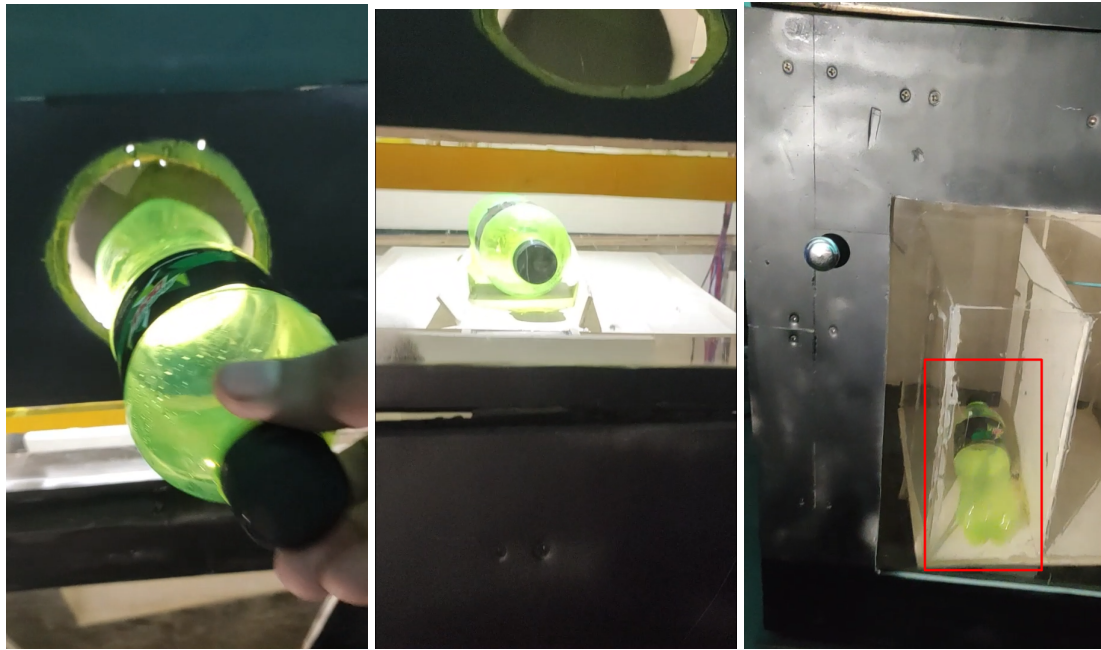


Figure 69: Virtual terminal representation.



Figure 70: Display representation.

Hardware demonstration



(a) Waste entry.

(b) Waste on the lid.

(c) Waste on compartment.

Figure 71: Successful plastic dumping.

Scenario 2 – Non-plastic detected

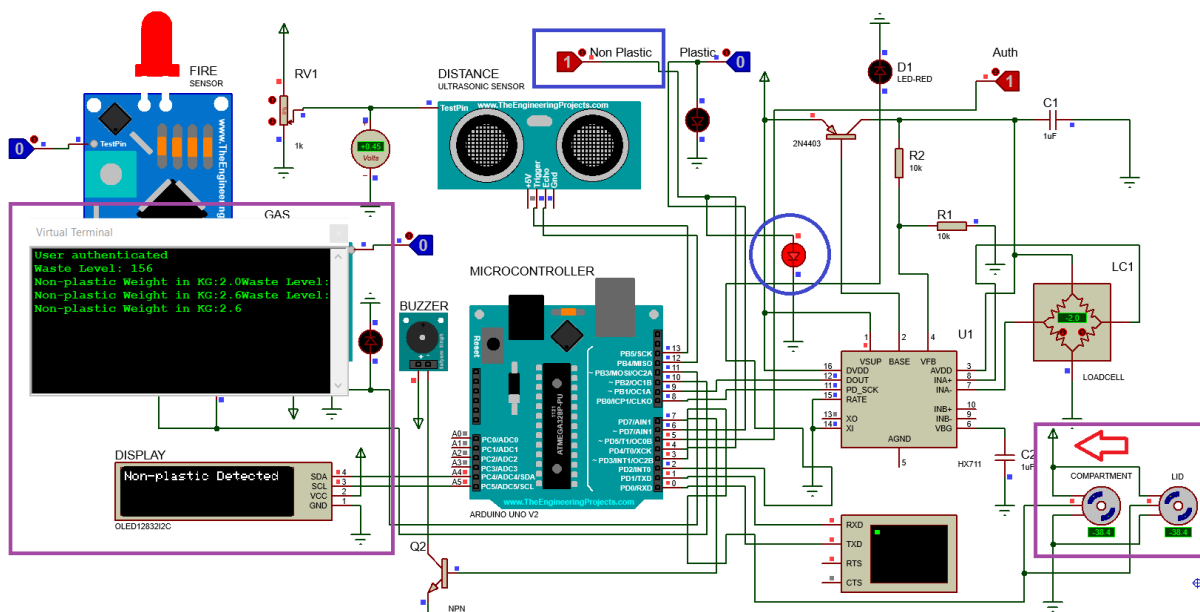


Figure 72: Full circuit representation.

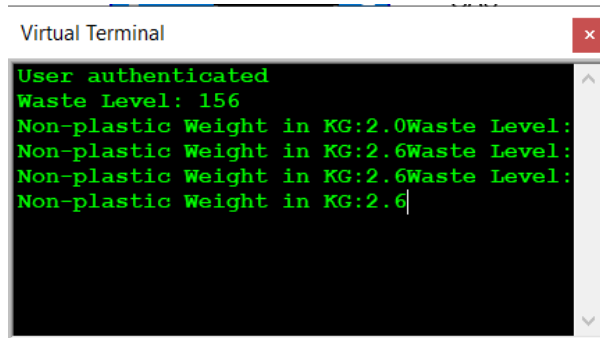
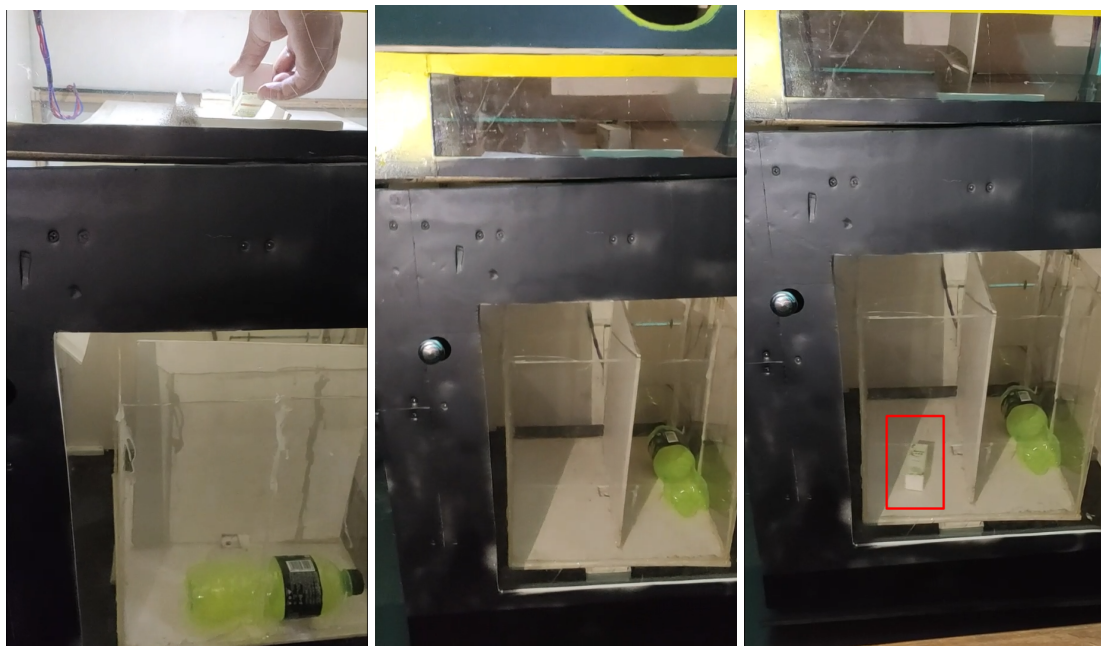


Figure 73: Virtual terminal representation.



Figure 74: Display representation.

Hardware demonstration



(a) Waste entry.

(b) Waste on the lid.

(c) Waste on compartment.

Figure 75: Successful non-plastic dumping.

Scenario 3 – Waste detection mismatch

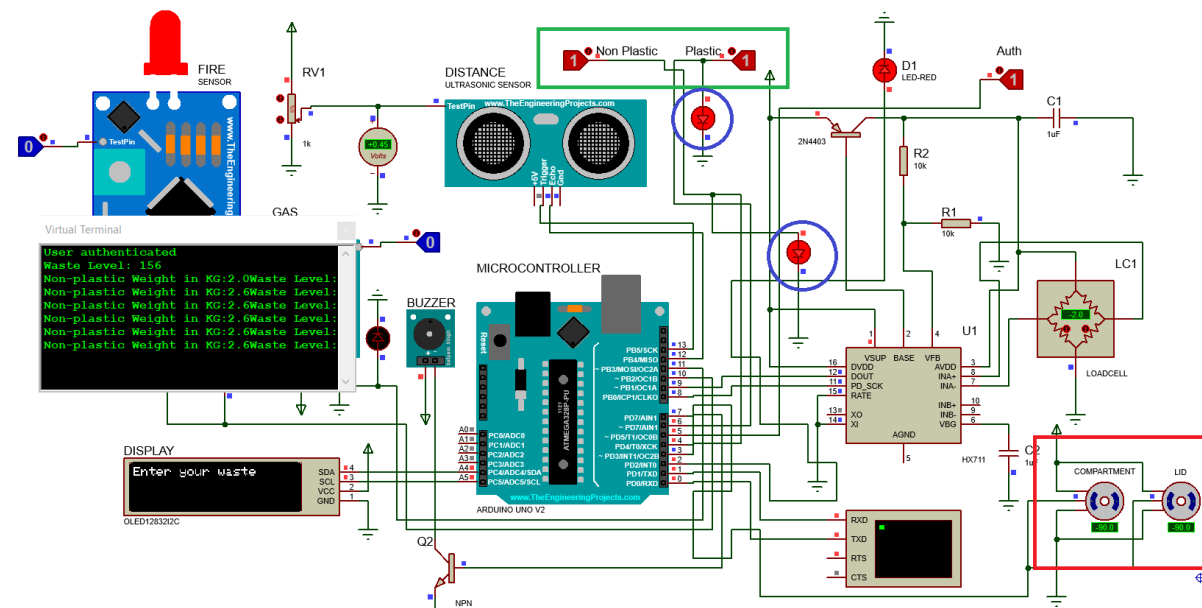


Figure 76: Full circuit representation.



Figure 77: Hardware representation.

Scenario 4 – No waste detection

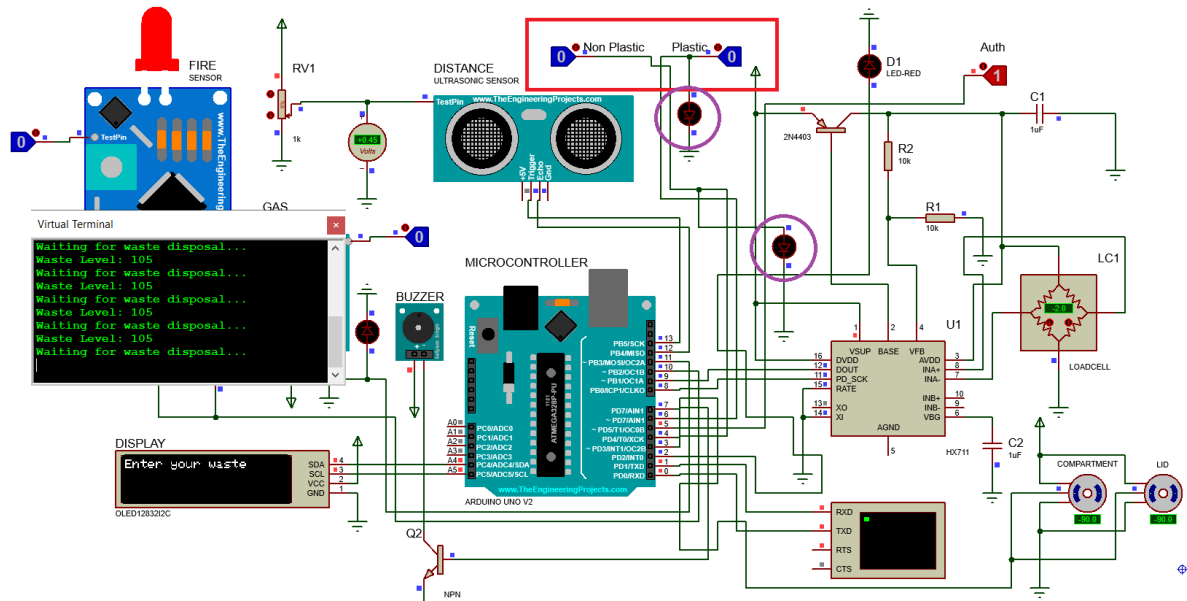


Figure 78: Full circuit representation.

5.3.3 Test case 3 – Lid operation

Scenario 1 – Plastic



Figure 79: Plastic lid operation – entry.



Figure 80: Plastic lid operation – fall.

Scenario 2 – Non-plastic



Figure 81: Non-plastic lid operation – entry.



Figure 82: Non-plastic lid operation – fall.

5.3.4 Test case 4 – Waste level detection

Scenario 1 – Empty bin

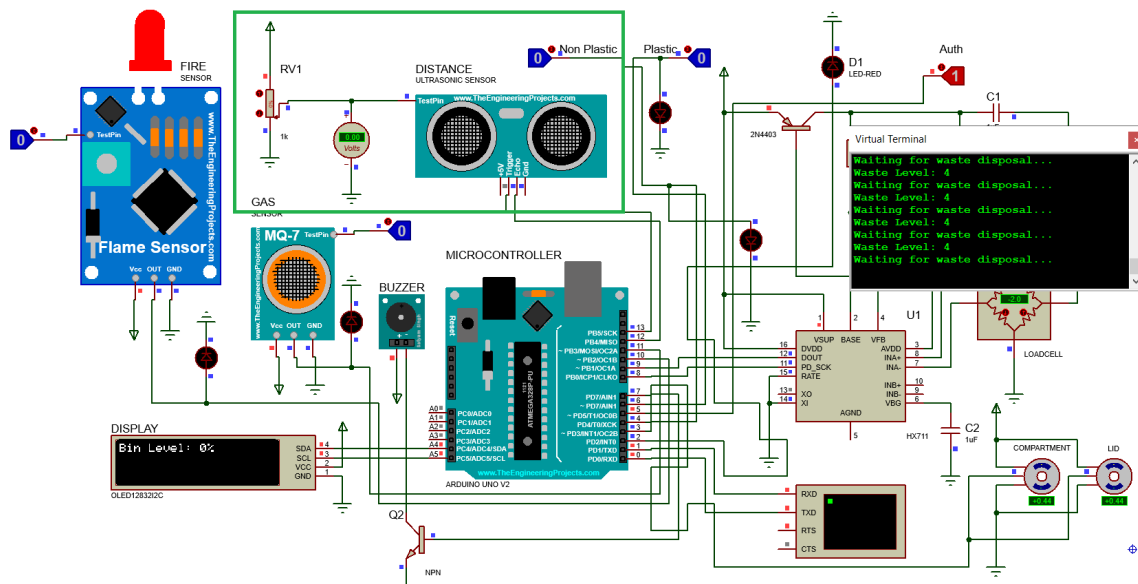


Figure 83: Waste level detection circuit – empty bin.

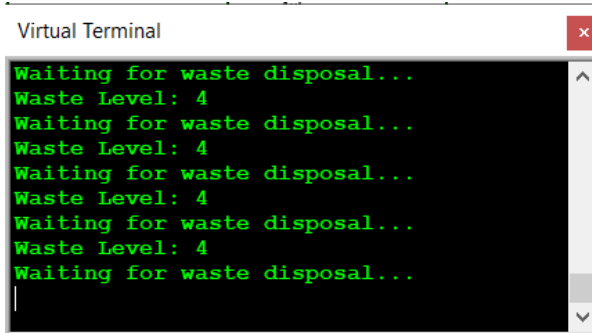


Figure 84: Waste level detection terminal view – empty bin.



Figure 85: Waste level detection display view – empty bin.

Scenario 2 – 25% equipped

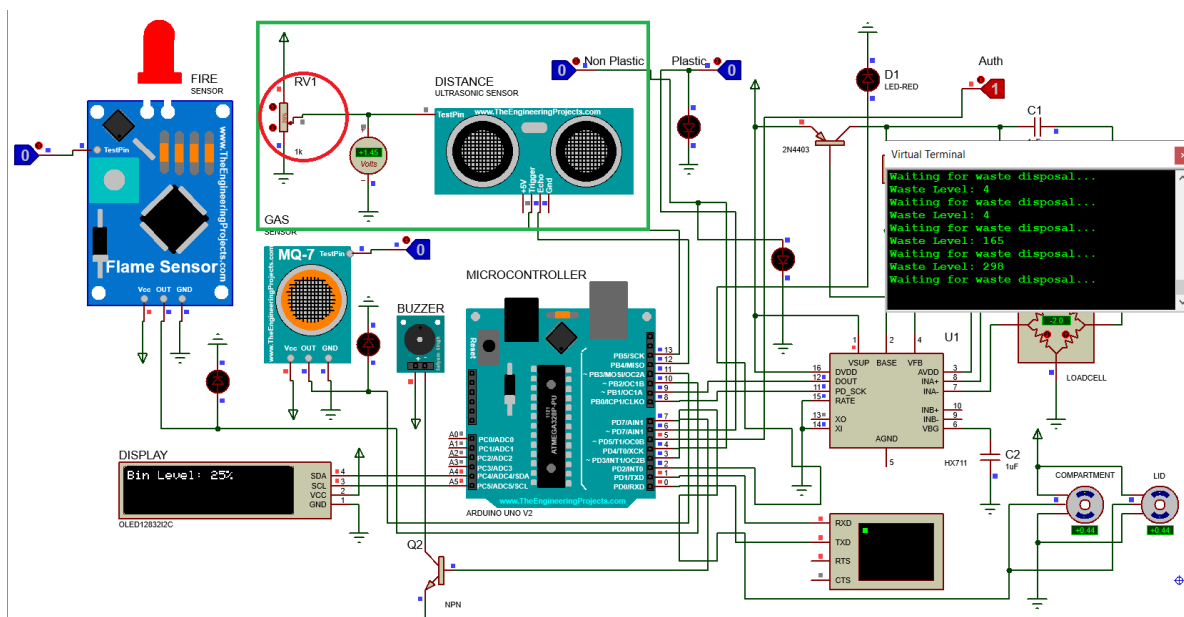


Figure 86: Waste level detection circuit – 25% equipped.

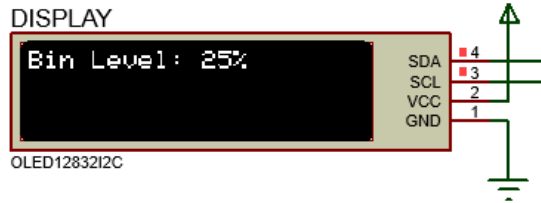


Figure 87: Waste level detection display view – 25% equipped.

Scenario 3 – 75% equipped (threshold)

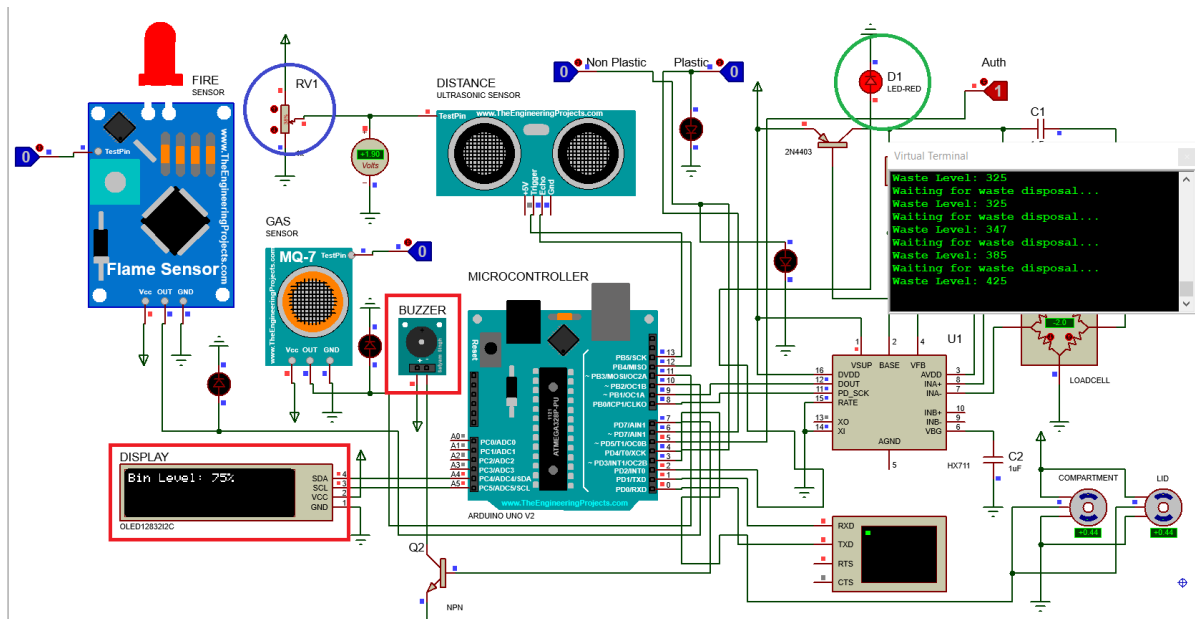


Figure 88: Waste level detection circuit – 75% equipped.



Figure 89: Waste level detection display view – 75% equipped.

Scenario 4 – 100% equipped

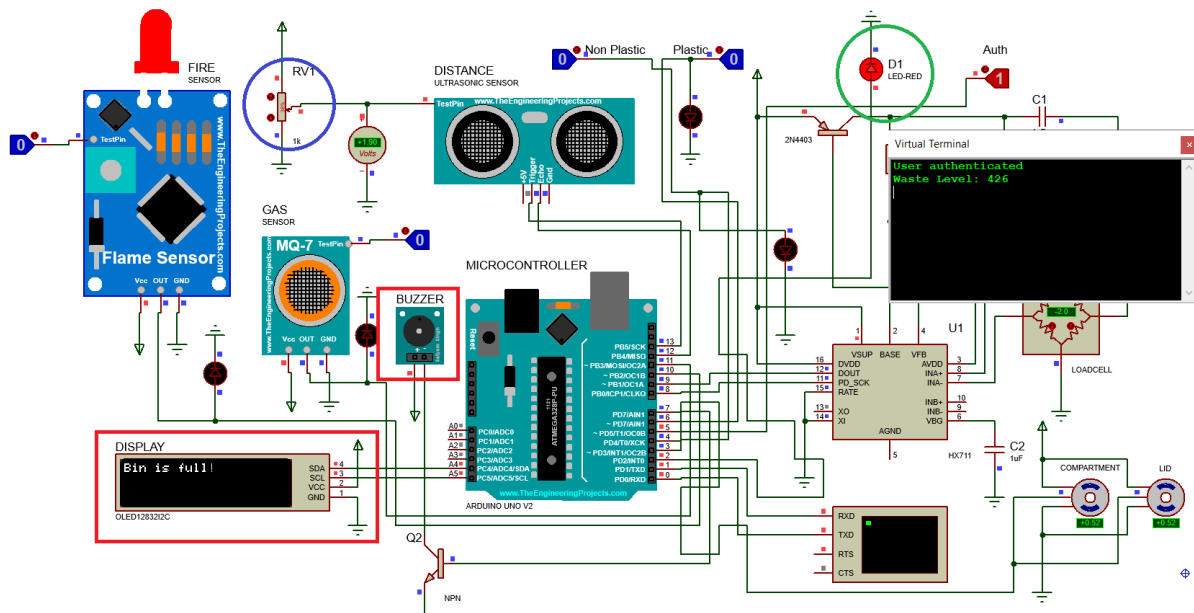


Figure 90: Waste level detection circuit – 100% equipped.

5.3.5 Test case 5 – Load cell operation

Scenario 1 – Sample weight 1

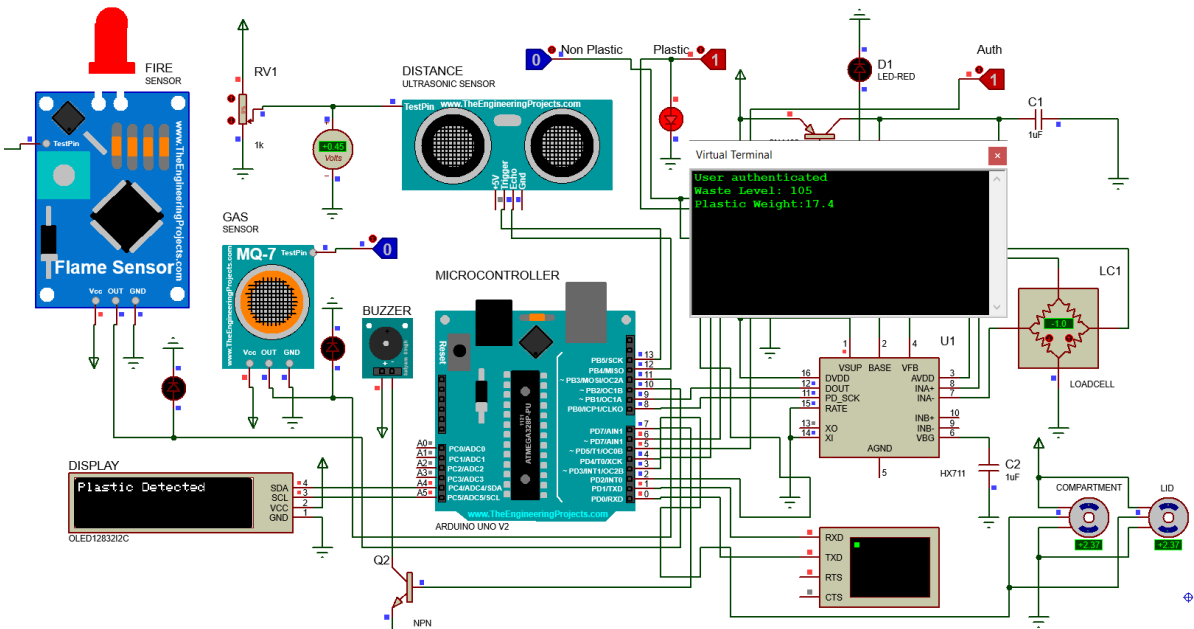


Figure 91: Weight measurement – 17.4g weight.

Scenario 1 – Sample weight 2

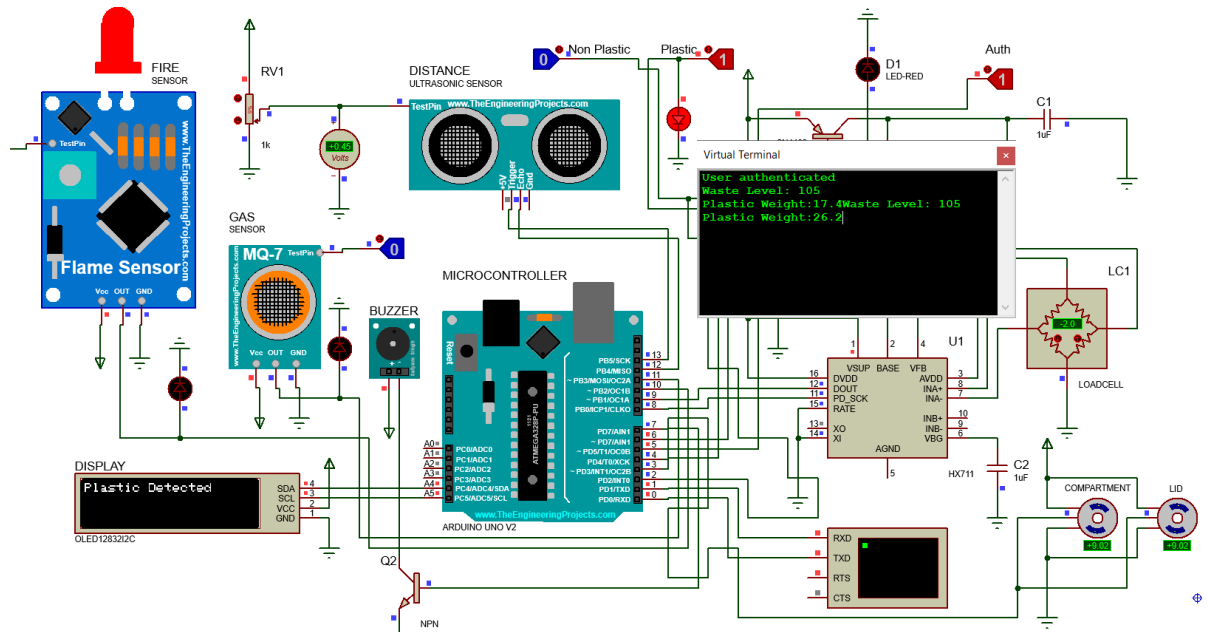


Figure 92: Weight measurement – 26.2g weight.

5.3.6 Test case 6 – Toxic gas detection

Scenario 1 – No toxic gas

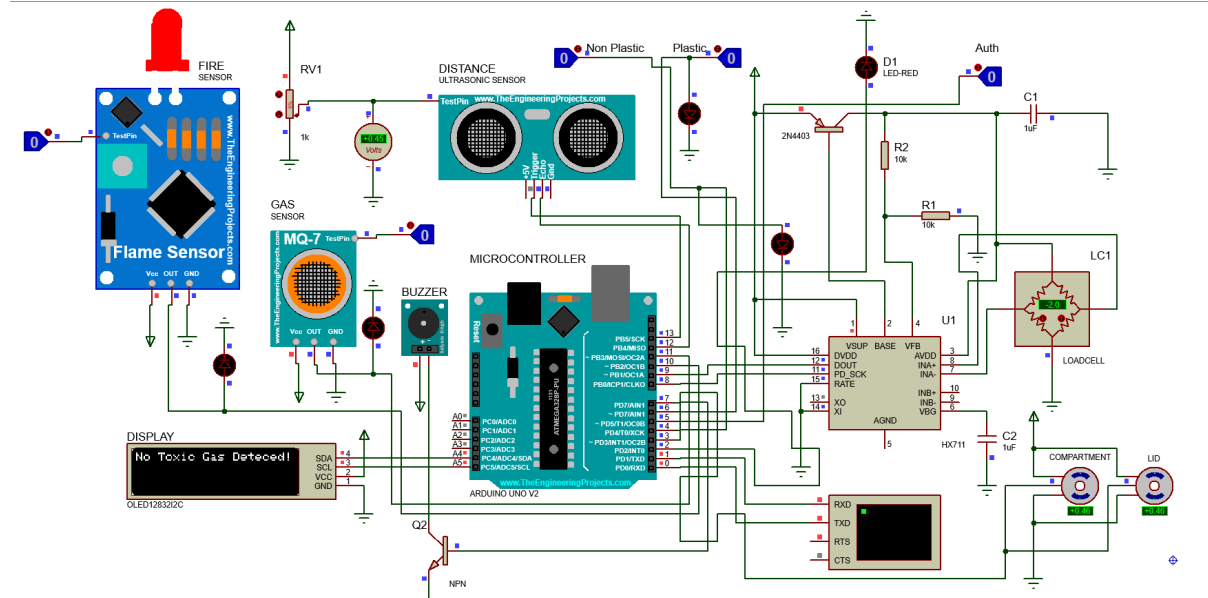


Figure 93: No toxic gas detected

Scenario 2 – Toxic gas

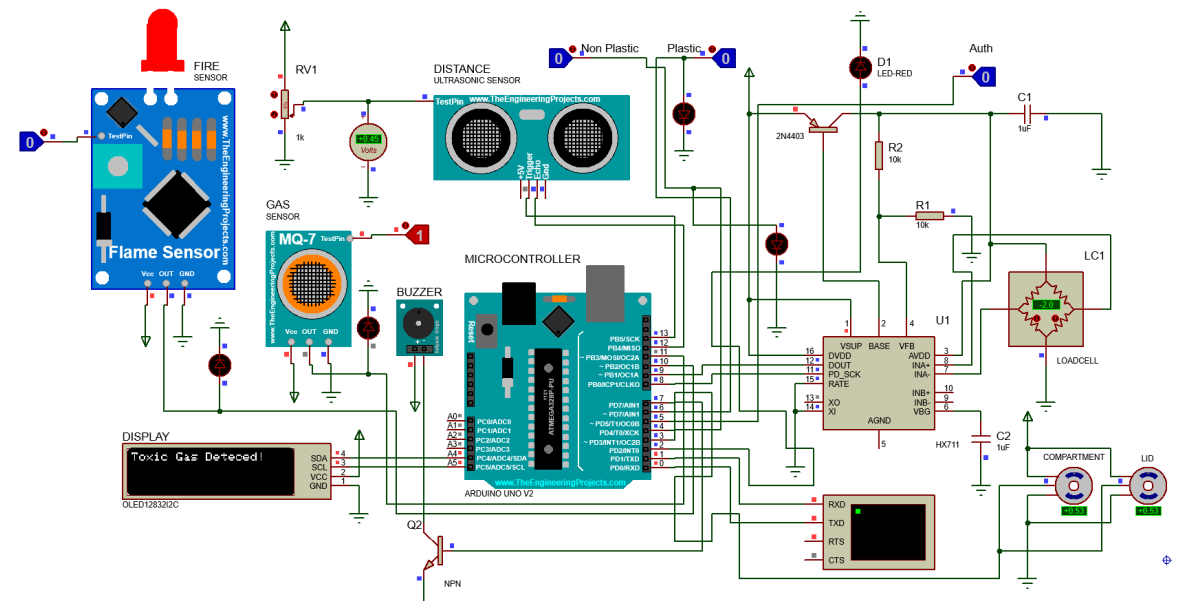


Figure 94: Toxic gas detected

5.3.7 Test case 7 – Fire hazard detection

Scenario 1 – No fire hazard

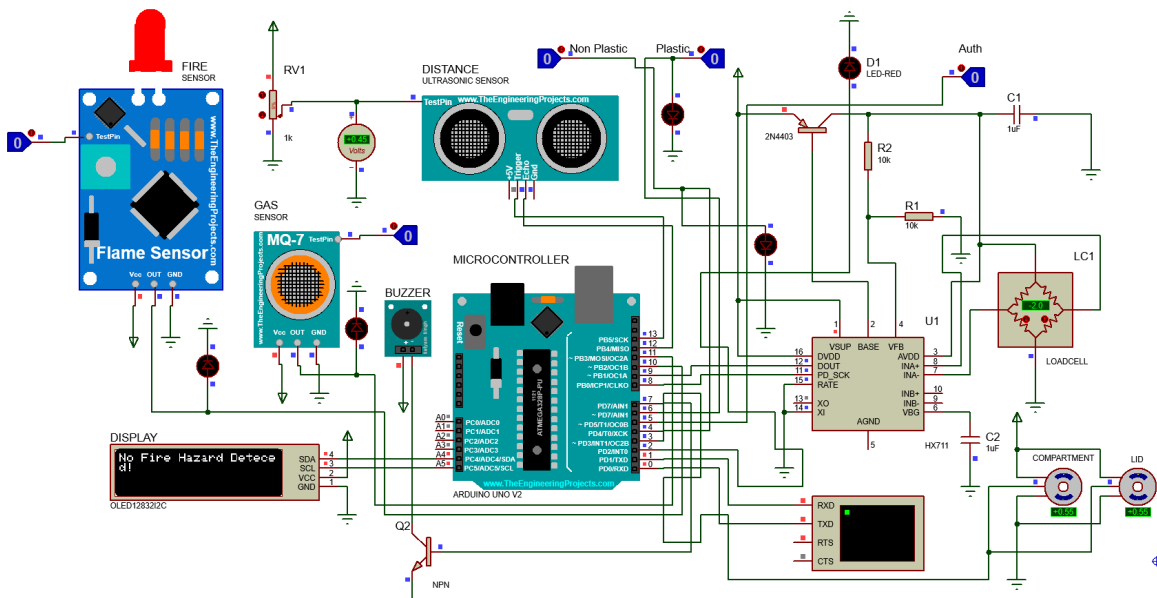


Figure 95: No fire hazard detected

Scenario 2 – Fire hazard

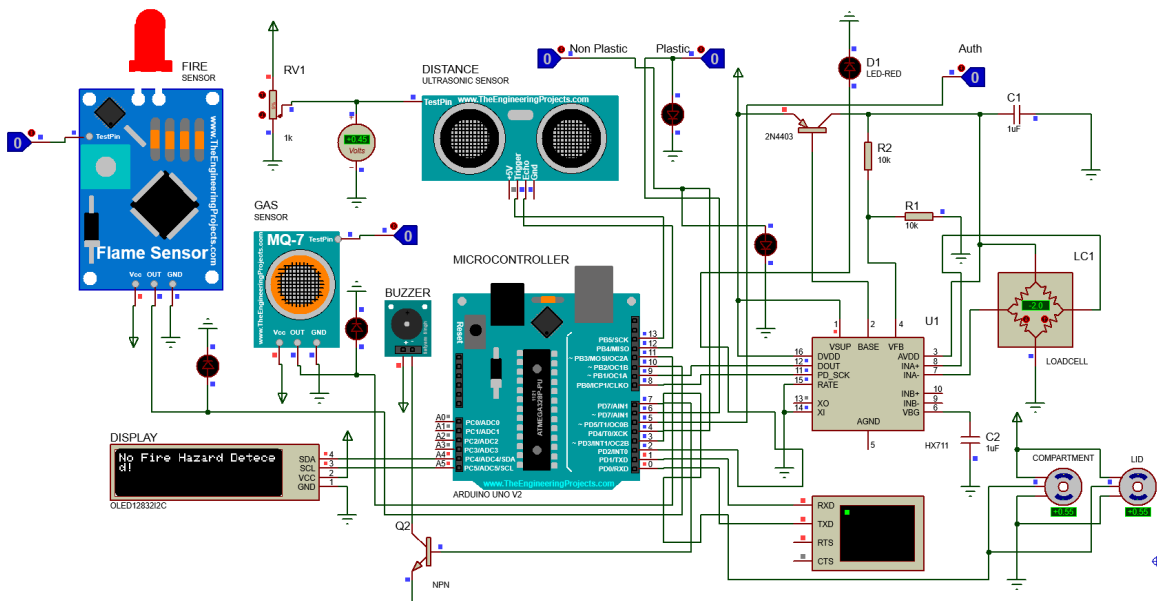
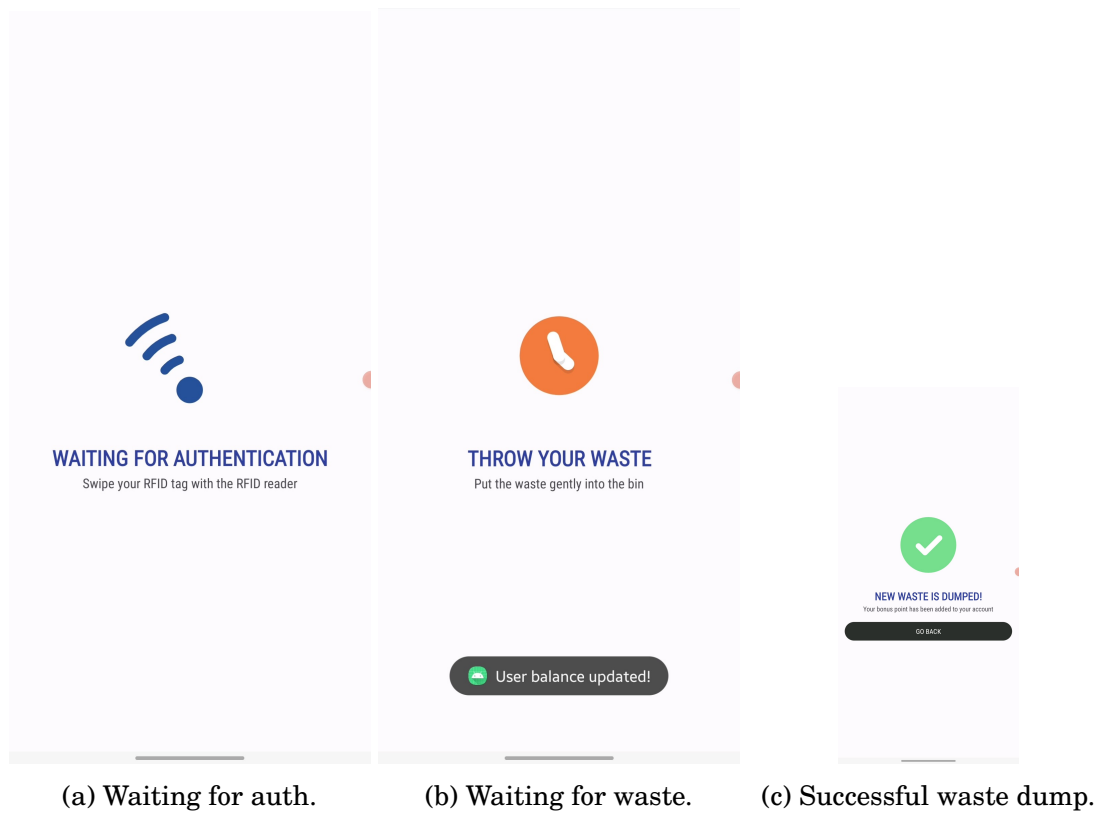


Figure 96: Fire hazard detected

5.3.8 Test case 8 – Reward Management



(a) Waiting for auth.

(b) Waiting for waste.

(c) Successful waste dump.

Figure 97: Mobile app reward management.

5.3.9 Test case 9 - User experience

Scenario 1 - Throwing waste



Figure 98: User throwing waste into the bin.

Scenario 2 – Receiving rewards



Figure 99: User checking for reward in his phone.

5.3.10 Test case 10 – Successful dumping and evaluation completion

Scenario 1 – Plastic dumping



Figure 100: Full overview of plastic dumping.

Scenario 2 – Non-plastic dumping



Figure 101: Full overview of non-plastic dumping.

Scenario 3 – Dumping completion

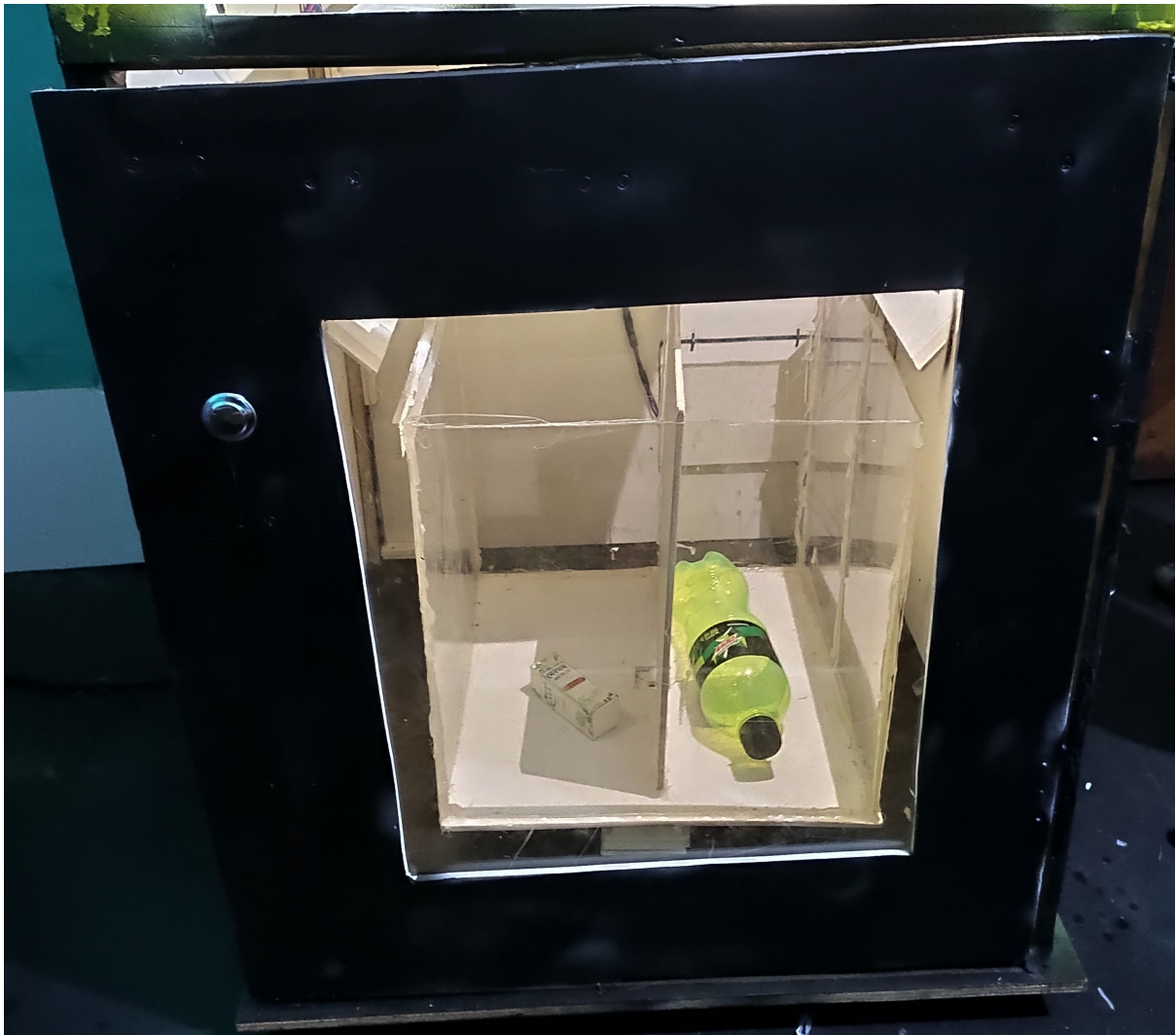


Figure 102: Wastes in their respective compartment.

Scenario 4 – User reward point view

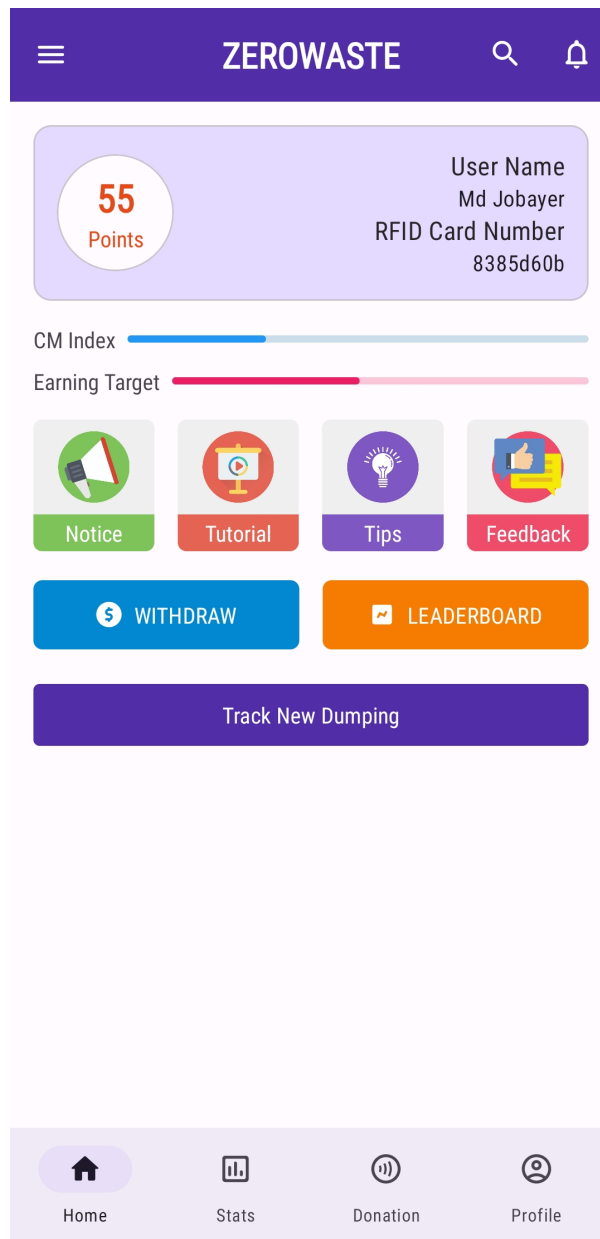


Figure 103: Mobile app to show user's current point with other statistics.

Scenario 5 – Reward notification

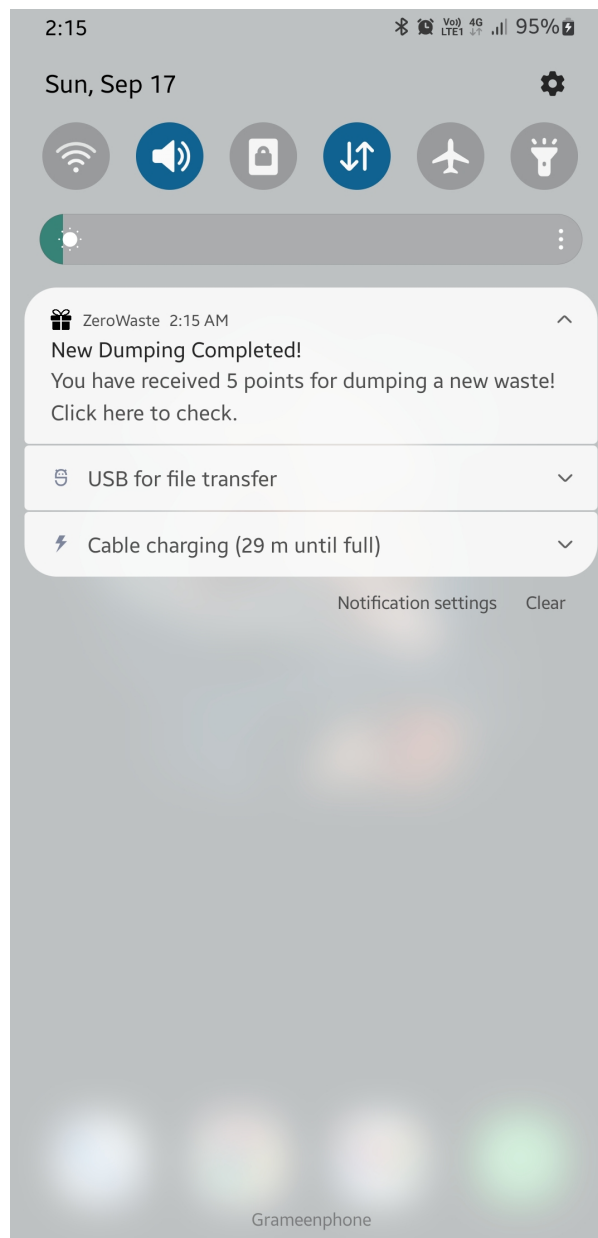


Figure 104: Mobile app notify user when a new dumping is done and a certain amount of point is added in his/her account.

5.4 Conclusion

In this chapter, we have reached a significant milestone in our project by successfully completing the final design phase, encompassing both hardware development and rigorous evaluation. This marks a crucial step towards fulfilling our objective of creating an innovative and efficient waste management solution. Through meticulous planning and execution, we have crafted a robust and user-friendly smart trash bin prototype. The culmination of these endeavours has resulted in a cohesive and effective system that addresses key waste management challenges.

During the validation process, we subjected the prototype to comprehensive testing sce-

narios to assess its performance and ability to meet desired needs. We evaluated its functionality under varying loads, tested authentication systems, assessed feedback mechanisms, and rigorously examined safety features. We have also incorporated a user rewarding system to further enhance the overall experience. By incentivizing positive behaviors and responsible waste disposal, we aim to cultivate a sustainable mindset among individuals. The introduction of rewards and recognition serves as a powerful motivation for users, fostering a sense of accomplishment and appreciation for their eco-conscious actions.

6 Impact Analysis and Project Sustainability [CO3, CO4, PO-F, PO-G]

6.1 Introduction

Our project has been implemented with the goal of long-term usage. We will ensure the system is long-lasting and capable of producing results with minimal disruption in the long run by implementing the necessary mechanisms. Accordingly, we also need to consider the various impacts that our proposed solution will have on our culture, economy and the environment in the future. The expected impacts have been detailed below. As a way to evaluate the sustainability of our project, we have created a sustainability matrix and SWOT analysis chart as well.

6.2 Assess the impact of solution

6.2.1 Cultural

Our project holds the potential for a significant cultural impact on the Bangladesh community. Firstly, it promotes responsible waste disposal practices, aligning with the cultural values of cleanliness and environmental respect. It encourages a shift towards greater environmental responsibility. Secondly, the project's community engagement initiatives, including awareness campaigns, can foster a sense of communal ownership and participation, reflecting the strong social bonds within Bangladeshi culture. Thirdly, the adoption of advanced technologies such as IoT and machine learning can ignite interest in innovation and technology, aligning with Bangladesh's aspirations for technological progress. Additionally, the project's focus on reducing plastic waste resonates with cultural values rooted in the preservation of nature. Lastly, the system's reward mechanism empowers individuals, reinforcing a sense of agency and proactivity within the community, further promoting environmental consciousness and a culture of responsible stewardship.

6.2.2 Economical

We constantly work to reduce the nation's plastic pollution as part of our eco-friendly effort. To limit the amount of plastic pollution, we must encourage people to dispose of their plastic garbage in our disposal systems rather than anywhere else. We provide our target audience with enticing redeem points/rewards that they can use for daily purchases and receive a discount on their subsequent purchases. It will help to incentivize our consumers to use our plastic disposal systems.

We have surveyed the mass audience to find out "what kind of exchanges our expected users desire to receive in exchange for redeeming points?" Their impressive response demonstrates and helps us understand what type of things they desire. The vast majority of individuals would seize the opportunity to assist us in creating a sustainable product.

6.2.3 Environmental

Since plastic garbage is already a non-biodegradable material, it will significantly negatively influence the ecosystem. Plastic bottles are intended to be used just once before being thrown away. It has long been discussed in environmental contexts. According to estimates, there are trillions of pieces of plastic in our seas, ranging from plastic wrappers to microplastic, all of which are dumped there and severely harm the ocean's biodiversity.

Finally, we tried to develop a system where users will be motivated to drop their plastic bottles in our system. Our trained algorithms will identify it as part of our project's effort to reduce the pollution of our environment. We also make sure that users' data will be stored in secure and protected cloud systems and that we adhere to all required standard regulations. Responses from our users will support us on our sustainable novel journey.

6.3 Evaluate the sustainability

6.3.1 Sustainability Matrix

Table 32: Sustainability Matrix.

Criteria	Rating (5)		Score (1)		Weight (%)
	Design 1	Design 2	Design 1	Design 2	
Eco Friendly	4	5	0.90	1.00	30
Expense	3.5	4.75	0.65	0.90	20
Longevity	3.5	4.35	0.65	0.70	15
Portability	4.5	5	0.85	1.00	15
Ease of Use	4.5	4	0.85	0.80	20
Total			3.90	4.4	100

We have compared the criteria of sustainability for both design approaches. Design 2, which is our chosen optimal design, has scored higher. The design of our proposed solution embodies a multifaceted approach to sustainability. It incorporates eco-friendly materials and components, minimizing environmental impact while maximizing resource efficiency. The system's longevity is ensured through the use of durable, high-quality materials, reducing the need for frequent replacements and contributing to long-term cost savings. Its portability and modular design allow for easy installation and relocation, adapting seamlessly to varying environments. Moreover, user-friendliness is a cornerstone of the design, ensuring intuitive operation for individuals of all backgrounds. This emphasis on accessibility enhances user engagement and encourages widespread adoption, further solidifying the project's sustainability by fostering a culture of responsible waste disposal.

6.3.2 SWOT Analysis

S	STRENGTH	W	WEAKNESS
	<ol style="list-style-type: none"> 1. Environment friendly 2. User friendly 3. Reduced power consumption 4. Remote monitoring 		<ol style="list-style-type: none"> 1. Interdependency 2. Dependent on user motivation
O	OPPORTUNITIES	T	THREATS
	<ol style="list-style-type: none"> 1. Can be applied to other wastes 2. Potential for startup 		<ol style="list-style-type: none"> 1. Data breach 2. Device malfunction 3. Reliance on imported components

Figure 105: SWOT Analysis.

This SWOT analysis highlights the project’s potential strengths, weaknesses, opportunities, and threats, providing a foundation for strategic planning and risk management. The points have been highlighted below:

- **Strengths:** The project boasts several key strengths. Firstly, it tackles a pressing environmental concern by promoting responsible plastic waste disposal, thereby mitigating environmental pollution. Additionally, it showcases a high degree of innovation through the integration of IoT, image processing, and machine learning technologies, which can capture attention and interest in the field. Furthermore, the project’s data collection capabilities hold the potential for valuable insights and revenue generation through data monetization, offering both environmental and financial benefits.
- **Weaknesses:** The project comes with inherent weaknesses. Firstly, a significant initial investment is imperative for procuring hardware, software, and establishing the necessary infrastructure. Secondly, the need for continuous maintenance and software updates is crucial, possibly incurring additional costs and resource demands over time, warranting careful financial planning and resource allocation.
- **Opportunities:** The project presents promising opportunities. Market expansion is feasible, offering the potential for growth by extending the project’s reach to other areas and regions confronted with analogous waste management challenges. Furthermore, collaboration with local governments and environmental agencies holds

the potential for financial incentives and regulatory backing, supporting sustainable initiatives. Additionally, the project has the capacity to bolster community engagement and heighten awareness concerning responsible waste disposal practices, reinforcing its social impact and significance.

- **Threats:** The project faces a few potential challenges. Competition in the waste management sector is notable, with existing and emerging competitors offering similar solutions, necessitating a strong focus on differentiation to establish a unique position in the market. Moreover, rapid technological advancements create the risk of technological obsolescence, compelling the project to keep pace with continuous upgrades to maintain competitiveness and effectiveness. Additionally, the project's financial viability may be vulnerable to economic fluctuations and budget constraints, demanding prudent financial management and adaptability to changing economic conditions.

6.4 Conclusion

In our project, we have made a concerted effort to minimize our environmental footprint. We have chosen eco-friendly materials and components to reduce harm to the environment. Additionally, we have prioritized system durability by selecting high-quality building materials, and minimized energy consumption wherever possible. Our project also serves as a platform for raising awareness about responsible waste disposal practices, aiming to enhance conventional waste collection methods for greater efficiency. Proper containment and management of plastic waste contribute to a positive environmental impact. By emphasizing sustainability throughout our project's design and implementation, while also considering its broader impacts, we strive to deliver benefits to both the environment and the communities it serves.

7 Engineering Project Management [CO11, CO14, PO-K]

7.1 Introduction

Our Final Year Design Project takes place in three stages corresponding to each semester: P (Proposal Writing), D (Design Report), and C (Project Completion). In each stage, we have maintained a Gantt chart and a logbook containing meeting summaries, task progression and assigned responsibilities to ensure that our project gets completed within the given timeframe, noting the active participation of each team member. The respective Gantt charts and detailed project plans are discussed below.

7.2 Define, plan and manage engineering project

A timeline of the tasks completed in 400P, 400D and 400C have been provided in a Gantt chart below.

7.2.1 Plan for EEE400P

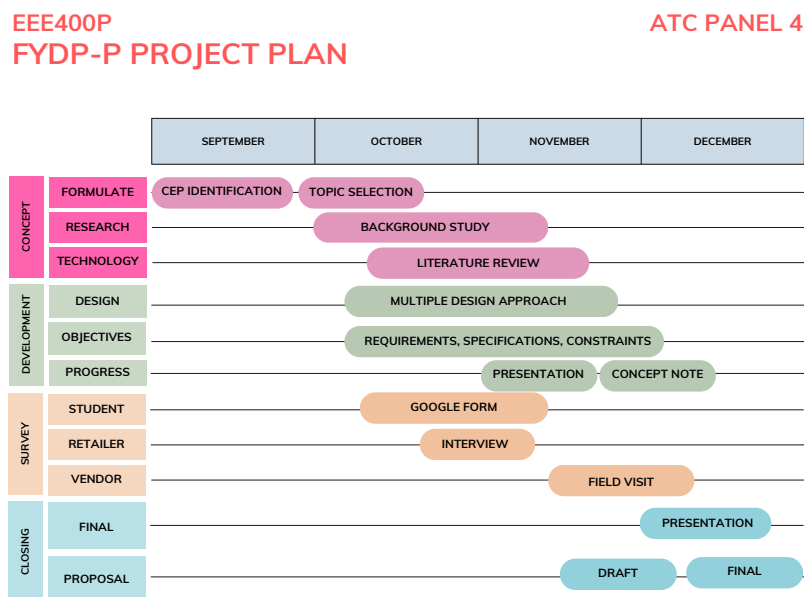


Figure 106: EEE400P Project Plan.

7.2.2 Plan for EEE400D

EEE400D FYDP-D PROJECT PLAN

ATC PANEL 4

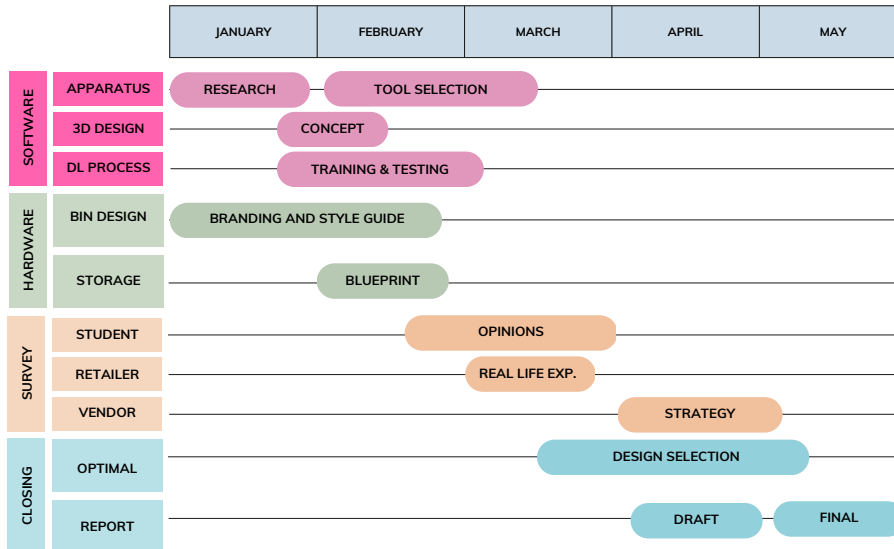


Figure 107: EEE400D Project Plan.

7.2.3 Plan for EEE400C

EEE400C FYDP-C PROJECT PLAN

ATC PANEL 4

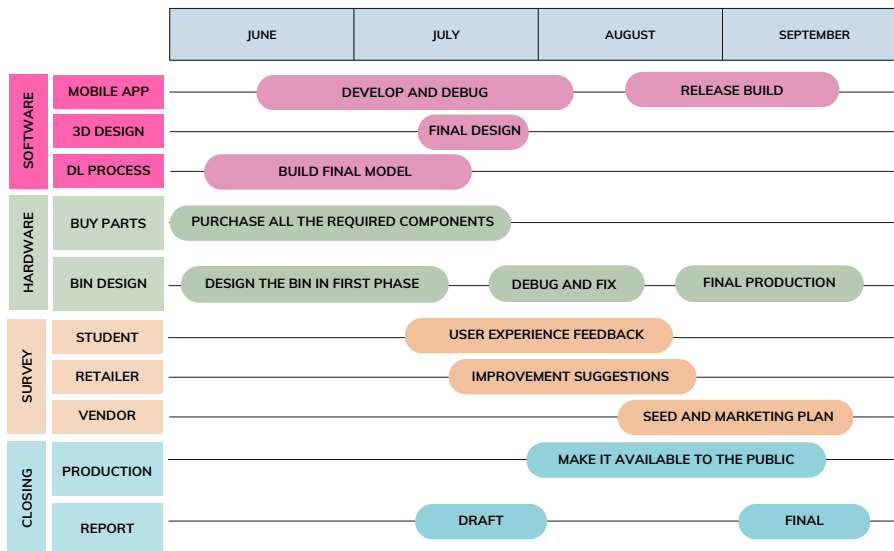


Figure 108: EEE400C Project Plan.

7.3 Evaluate project progress

7.3.1 Phase I

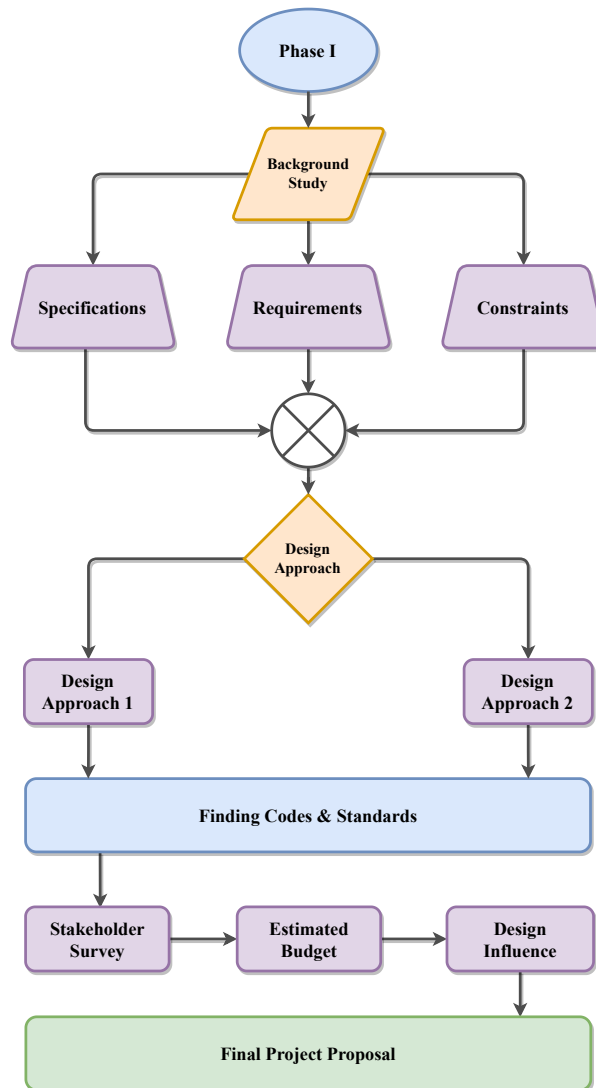


Figure 109: Methodology Phase I.

To start our project, we first had to come up with all sorts of innovative ideas. Those ideas were related to various complex engineering problems. Considering all the aspects of an engineering project, we have decided to go with a smart trash disposal system. There are several reasons to choose this project — first of all, it goes with our current environmental and health-related issues. The world is worried about the environmental impacts of various types of plastic materials.

Initially, we had a lot of background studies related to the existing trash management technologies and the potential loopholes of these technologies. This way, we have gathered enough information to fix our specifications, requirements, and constraints.

As we needed to figure out our best-fit design approach while setting our specifications and requirements, we had to consider all the possible occurrences which could happen while designing the trash disposal system. For example, trash bins of various sizes and

materials are available, so we had to select a bin with average size and common plastic material. In the same way, we have specified what should be the bin's weight and waste capacity. In terms of requirements, we categorized it into two categories — functional and non-functional. In functional requirements, we have specified such parameters which are fundamental to our system.

On the other hand, in non-functional requirements, we have specified parameters that are not vital but very useful in terms of user-friendliness, improved security, and green product. In constraints, we have only included those features that conflict with our requirements and specifications. As soon as we fixed our requirements, specifications, and constraints, we prepared two system designs to achieve our objectives. While designing the systems, we were limited to specifying the names of the technologies we are planning to use rather than the component names. Next, we gathered several application codes and standards for some of our sub-systems, including the components. However, we tried to analyze the current market to make the system more viable. So, we interviewed the stakeholders of various levels — students, waste buyers, and local shopkeepers. It helped us to visualize the amount of waste we will be receiving on a daily basis. This way, we will design our system in such a way that it can handle the existing amount of waste. Our next task was to create an estimated budget for our system. This budget includes all the sub-system level's expenses rather than the component level. Lastly, after completing all these steps, we have prepared a proposal including all the above mentioned sections. It will work as a manual, directing us toward the project completion.

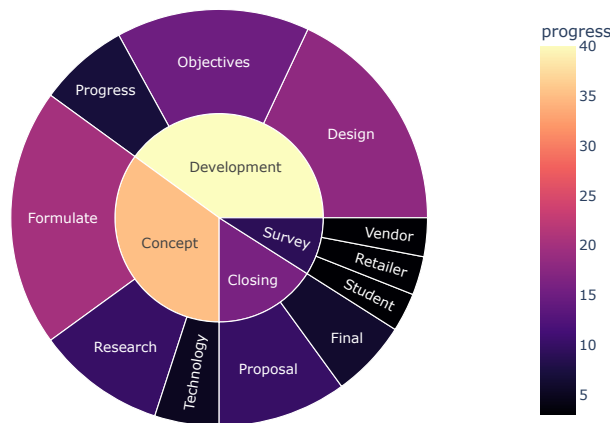


Figure 110: Phase I – progress evaluation.

7.3.2 Phase II

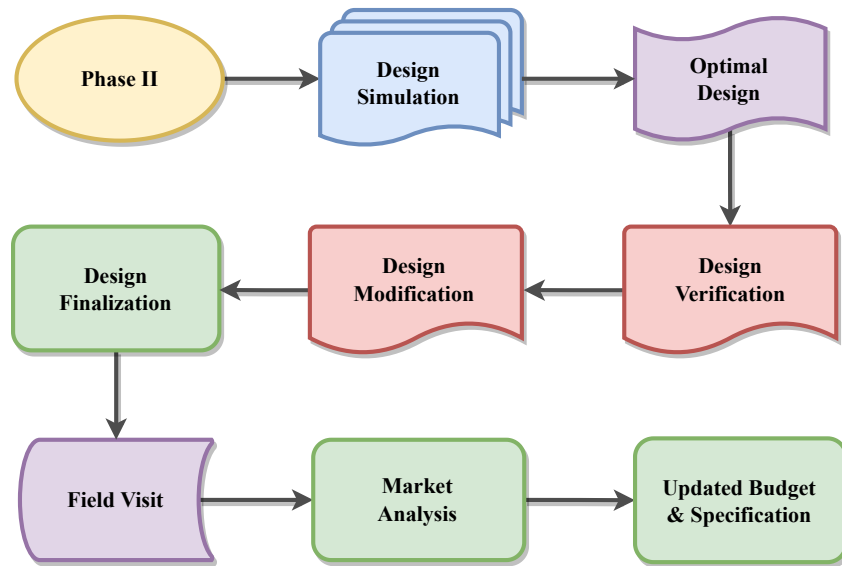


Figure 111: Methodology Phase II.

In phase II, our first task will be design verification. We will first simulate all of our proposed design approaches to do this. While doing this, we will realize the need for components, the overall loads, and the costs of the resources. We will filter out the most optimal design approach by analyzing all these factors. After that, for the last time, we will check whether our optimal design meets the requirements, specifications, and constraints. If the design collides with any of our requirements, we will make appropriate adjustments to it and finalize the design. Our next step is to visit the actual field and get an actual feel of the existing infrastructure. It will help us proceed to some sponsors, to decide where we can buy our components depending on the existing bins and their manufacturers. We will also analyze several other costs like power, server, and sub-system costs. We will also try to understand the psychology of our intended users, how much they expect from us, and any advice from them. After analyzing all these factors, if we need to modify the system design, we will make the modifications along with the budget because the budget will ultimately vary according to the system design.

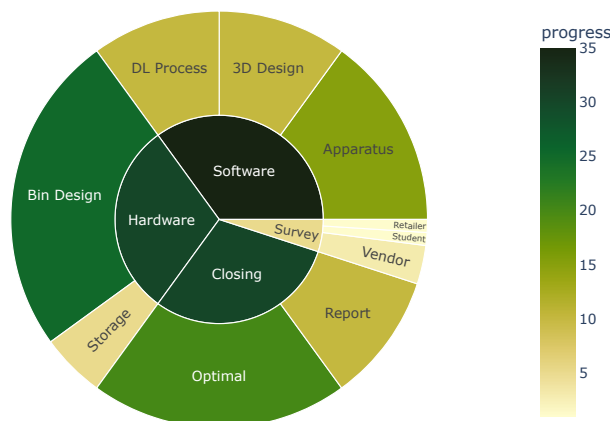


Figure 112: Phase II – progress evaluation.

7.3.3 Phase III

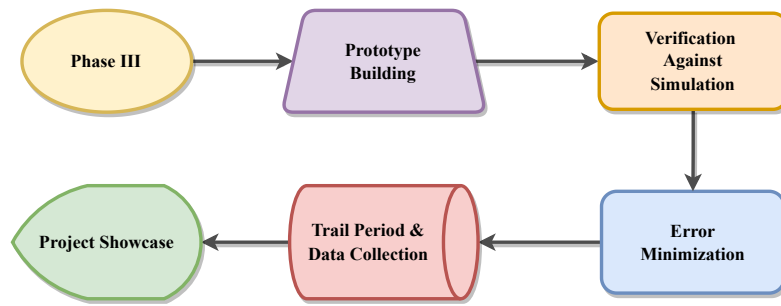


Figure 113: Methodology Phase III.

We will make the actual system or prototype in our last phase. As this will be the first time we will convert our design concept into a reality, several errors and design mismatches will occur. So, we will verify the prototype's performance against the simulation result. If the prototype's performance varies significantly compared to the simulation, we need to modify the design following the simulations. Also, we need to make sure that the design meets actual requirements and specifications. After verifying this, we launch the prototype into our private community for small-scale testing. This incident will reflect the actual scenario, which is why this stage is crucial. After several stages of rigorous testing, if there are still some errors, hopefully, those will be revealed in this stage, and we will solve those problems as fast as possible. Finally, we will demonstrate our prototype to our respected board members.

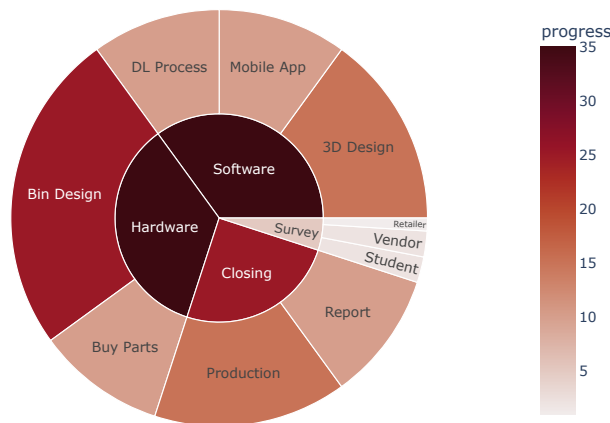


Figure 114: Phase III – progress evaluation.

7.4 Conclusion

Project management serves as the guiding force that keeps engineers on course and simplifies the intricate journey from project conceptualization to implementation, ensuring that innovative ideas evolve into functional solutions. An intricately designed project plan addresses all essential details, ultimately fostering a significantly heightened success rate of the project. Through efficient project management, we have ensured that the project meets its objectives, produces dependable and precise data, adheres to the designated budget, as well as its timely completion, to the contentment of all stakeholders involved.

8 Economical Analysis [CO12, PO-K]

8.1 Introduction

Economic analysis is the systematic process of evaluating the costs and benefits associated with a project, policy, or decision. It aims to assess the economic viability and impact of the particular project. Key components of economic analysis include identifying costs, benefits, risks, and potential returns on investment. By comparing the financial and economic implications of different alternatives, we have designed and implemented our project, aiming for outcomes that maximize benefits while minimizing costs and risks.

8.2 Economic analysis

Comparing the estimated budget of both design approaches, we found that our optimal design solution i.e. Design 1 is more cost-efficient.

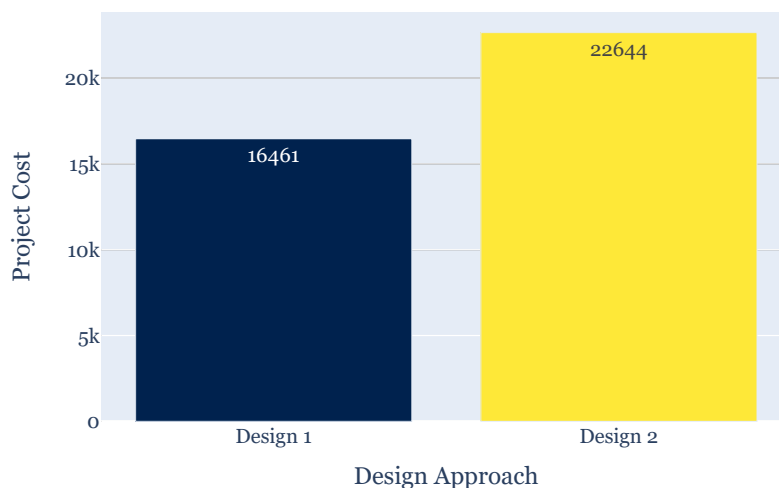


Figure 115: Budget comparative analysis.

The following is a breakdown of the actual costs throughout our project based on our optimal design approach.

Cost analysis

The following list offers a comprehensive breakdown of the costs associated with developing and maintaining a state-of-the-art technological product. It presents a detailed overview of expenses across different areas, including research and development, hardware components, software development, labor costs, ongoing maintenance, updates, customer support, marketing, sales expenses, and Value Added Tax (VAT). Each category further explores specific subcategories, providing transparent insights into the financial considerations involved in bringing the product to life and ensuring its successful operation.

P.B.: All the prices shown below are in BDT.

1. Research and Development: 80,000 (Cost period: 5 years)

- Market research: 24,000
- Concept development: 16,000
- Prototyping: 32,000
- Testing and refinements: 8,000

$$\therefore \text{Research and Development cost per year} = \frac{80000}{5} = 16000 \text{ BDT}$$

$$\therefore \text{Research and Development cost per year per bin} = \frac{16000}{500} = 32 \text{ BDT (Assuming R\&D will facilitate 500 bins)}$$

2. Hardware Components: 10561 (Cost period: 5 years)

- Acrylic Sheet: 600
- Battery: 1180
- Battery Charger: 200
- Buck Converter: 222
- Buzzer: 15
- Camera: 1000
- Connector: 50
- ESP32: 650
- Flame Sensor: 50
- Freewheel: 240
- Gas Sensor: 178
- Glue Gun: 335
- Heat Sink: 25
- LED: 50
- Load Cell: 400
- OLED Display: 350
- PCB: 500
- Plyer: 150
- Plywood: 250
- PVC: 1800
- RFID Card: 70
- RFID Scanner: 190
- MG996 Servo: 830

- Soldering Iron: 676
- Switch: 100
- Ultrasonic Sensor: 200
- Wire: 250

$$\therefore \text{Hardware Components cost per year per bin} = \frac{10561}{5} = 2112 \text{ BDT}$$

3. Software Components: 395 (Cost period: 1 month)

- Cloud Storage: 195
- MAP API: 200

$$\therefore \text{Software Components cost per year per 100 bins} = 395 \times 12 = 4740 \text{ BDT}$$

$$\therefore \text{Software Components cost per year per bin} = \frac{4740}{100} \approx 48 \text{ BDT}$$

4. Software Development: 2900 (Cost period: 10 years)

- Play Console: 2900

$$\therefore \text{Software Development cost per year per 100 bins} = \frac{2900}{10} = 290 \text{ BDT}$$

$$\therefore \text{Software Development cost per year per bin} = \frac{290}{100} \approx 3 \text{ BDT}$$

5. Labor Costs: 10000 (Cost period: 1 month)

- Waste collector: 10000

$$\therefore \text{Labor Costs per month per bin} = \frac{10000}{30} \approx 334 \text{ BDT (Assuming it will facilitate 30 bins)}$$

$$\therefore \text{Labor Costs per year per bin} = 334 \times 12 = 4008 \text{ BDT}$$

6. Maintenance: 5000 (Cost period: 1 month)

- Routine inspections: 5000

$$\therefore \text{Maintenance cost per month per bin} = \frac{5000}{30} \approx 167 \text{ BDT (Assuming it will facilitate 30 bins)}$$

$$\therefore \text{Maintenance cost per year per bin} = 167 \times 12 = 2004 \text{ BDT}$$

7. Marketing and Sales Cost: 100000 (Cost period: 1 year)

- Advertising campaigns: 30000
- Salesman salaries and commissions: 70000

$$\therefore \text{Marketing and Sales cost per year per bin} = \frac{100000}{100} \approx 1000 \text{ BDT (Assuming it will facilitate 100 bins)}$$

8. Electricity Bill: 162 (Cost period: 1 month)

According to the *General rate form*, we know that the general equation for electric tariff calculation is as follows:

$$y = dx + ez + c$$

Here,

y = Total amount of bill for period during which energy was consumed, BDT

d = Unit charge for metered or allowed maximum demand during billing period, BDT per kW

x = Maximum demand during billing period, kW

e = Unit charge for energy, BDT per kWh

z = Total energy consumed during period, kWh

c = A constant charge made each billing period

In our case, we have the following data for a month,

Consumed energy, $z = 0.1236$ Units (kWh) [$\therefore 0.00412 \times 30 = 0.1236$ (Table 30)]

Maximum connected load, $d = 10$ kW

Demand rate, $x = 15$ BDT/kW/Month

Service charge, $c = 10$ BDT/Month

VAT = 5%

If we consider electric tariff from Bangladesh Energy Regulatory Commission [22],

For first 0 to 75 unit, the Energy Rate/Charge (BDT/kWh) is 4.85 BDT.

Now, based on the consumed electricity unit of the system,

$$\begin{aligned} \text{The energy charge, } ez &= e_1 z_1 \\ &= 0.1236 \times 4.85 \text{ BDT} \\ &= 0.59946 \text{ BDT} \end{aligned}$$

$$\begin{aligned} \text{The demand charge, } dx &= 10 \times 15 \\ &= 150 \text{ BDT} \end{aligned}$$

$$\begin{aligned} \text{Electricity bill without VAT, } y' &= ez + dx + c \\ &= 0.59946 + 150 + 10 \\ &= 160.59946 \text{ BDT} \end{aligned}$$

$$\begin{aligned} \text{5\% VAT of electricity bill, } y'' &= 5\% \text{ of } y' \\ &= 160.59946 \times 0.05 \\ &= 0.80299 \text{ BDT} \end{aligned}$$

$$\begin{aligned} \text{Net electricity bill, } y &= y' + y'' \\ &= 160.59946 + 0.80299 \\ &= 161.40245 \text{ BDT} \end{aligned} \tag{30}$$

- Electric tariff: 162

\therefore Electricity Bill per year per bin = $162 \times 12 = 1944$ BDT

9. User Reward: 10 (Cost period: per kg per user)

- Reward Points: 10

∴ User reward per year per bin = $10 \times 365 \times 10 = 36500$ BDT

Total costs so far: $32 + 2112 + 48 + 3 + 4008 + 2004 + 1000 + 1944 + 36500 = 47650$ BDT per bin per year

Table 33: System expenses breakdown.

Criteria	Cost, BDT (per bin per year)
Research & Development	32
Hardware Components	2112
Software Components	48
Software Development	3
Labor Cost	4008
Maintenance	2004
Marketing & Sales Cost	1000
Electricity Bill	1944
User Reward	36500
Total	47650

Revenue

Based on the information we have, here's a revenue model considering waste collection and recycling, as well as displaying advertisements on the smart trash bin:

1. Waste Collection and Recycling

- Determine the waste collection amount: Estimate a reasonable amount of waste we will collect from customers.
- Calculate the potential number of customers: Identify the cities or locations where we will operate the bin and will estimate the potential number of customers based on population size, waste generation rates, and market research.
- Estimate the waste collection frequency: We need to determine how often we will collect waste from each bin.
- Calculate the revenue: We can calculate the revenue easily with the information of waste amount and number of customers for a particular bin.

2. Advertisement Revenue

- Identify potential advertisers: Research local businesses or organizations that might be interested in advertising on our smart trash bins.
- Set advertising fees: We will have to determine the amount we will charge businesses for advertising on our smart bins.
- Estimate the number of advertisements: Calculate the maximum number of advertisements that can be displayed on each smart trash bin based on its design and available advertising space.

- Calculate the revenue: We can calculate the total revenue from advertisement by multiply the advertising fee by the potential number of advertisers and the estimated number of smart bins deployed

Revenue by waste recycling

Let's say, we have installed a bin into a renowned university or any shopping complex where we will have a significant number of customers.

As we have discussed earlier, our bin can store around 5kg waste and the run time of our bin is 12h. Over the period of 24h, we can expect to have 10kg waste for 2 round bin replacement.

Also, from several sources [23], we came to know that,

Cost price, (Cp) \approx 20 BDT per kg

Selling price, (Sp) \approx 50 BDT per kg

So, the profit from per kg per day, $X = 50 - 20 = 30$ BDT

\therefore Total profit from per bin per year = $30 \times 10 \times 365 = 109500$ BDT

Table 34: Projected Profitability Statement [3]

Particulars	1st Year	2nd Year	3rd Year	4th Year	5th Year
Input (per annum)	41176	55294	69412	83529	97647
Output (per annum)	20000	32000	44000	56000	68000
Net Sale	15200	31520	43520	55520	67520
Sale Price Per Kg	70	72	74	76	78
Sale (in Thousands)	80.64	94.69	106.20	118.20	130.67
Production Cost (in Thousands)	61.30	67.00	73.26	80.16	87.75
Gross Profit (in Thousands)	19.34	27.69	32.94	38.04	42.92
Net Profit (in Thousands)	18.373	26.305	31.293	36.138	40.774

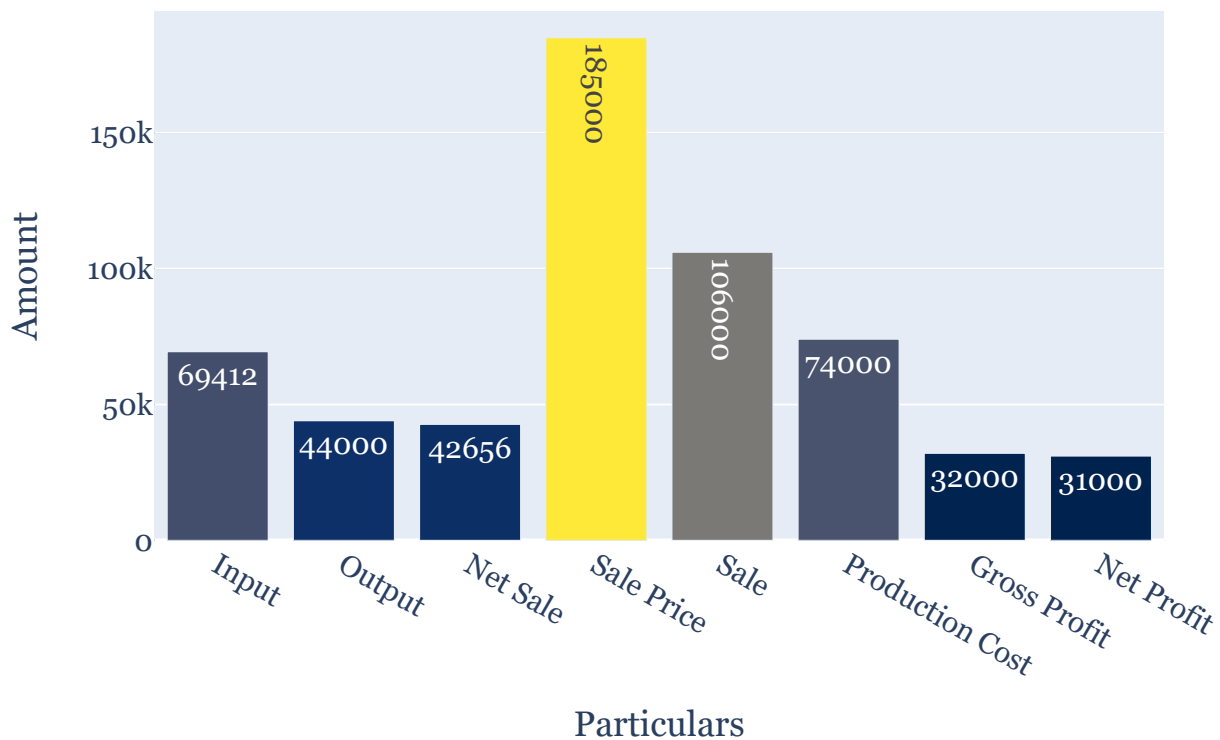


Figure 116: Average profitability statement.

Impact Analysis

A smart trash bin with a reward system can have several economic impacts on society and a country. Here are some potential ways:

1. **Encouraging recycling and waste reduction:** The reward system can incentivize individuals to properly dispose of their waste and encourage recycling. This can lead to a reduction in waste disposal costs and the need for landfill space, ultimately saving money for local governments or waste management companies.
2. **Promoting a cleaner environment:** By encouraging people to use the smart trash bin and rewarding them for their proper waste disposal behavior, the overall cleanliness of the environment can improve. This can have positive effects such as attracting tourists, boosting local businesses, and increasing property values.
3. **Stimulating local economy:** The implementation of smart trash bins with rewards may require investment in technology, infrastructure, and maintenance. This can create job opportunities in manufacturing, installation, maintenance, and waste management services, contributing to local economic growth and employment.
4. **Enhanced public perception and sustainability image:** Implementing innovative solutions like smart trash bins with a reward system demonstrates a commitment to sustainability and environmental responsibility. This can improve the reputation of a city, region, or country, attracting businesses, investment, and tourism.
5. **Environmental savings:** Fewer collection trips also mean reduced greenhouse gas emissions from collection vehicles. This can help in achieving environmental

targets and can lead to carbon credit savings.

6. **Job creation:** The development, installation, and maintenance of smart trash bins, as well as the management of reward programs, can create jobs in technology, manufacturing, and waste management sectors.
7. **Attracting Investments:** Cities and regions that adopt innovative waste management systems like smart trash bins may attract more investment due to their commitment to sustainability and efficiency.

8.3 Cost benefit analysis

Cost benefit analysis provides a basic overview of the potential costs and benefits associated with the project. We have calculated the costs and revenue in the previous section. Now, we need to consider the intangible benefits of our project, which include cost savings in waste management as well as environmental and social benefits. These cost savings are a result of reduced overflow and cleanup costs, and reduced environmental impact costs. The environmental and social benefits associated with this project stem from reduced plastic waste impact alongside increased awareness and engagement. As it is difficult to assign a monetary value to these quantities, we will ignore these for the sake of simplifying the calculation process.

- **Net Benefit:**

Net Benefit = (Total Annual Savings + Total Potential Revenue + Total Non-Monetary Benefits) - Total Annual Operational Costs
Net Benefit = [(109,500 - 47,650) + 109,500] - (2,004 + 1,944)
Net Benefit = 171,350 - 3,948
Net Benefit = 167,402 BDT per bin per year

- **Return on Investment (ROI):**

ROI = [(Total Annual Savings + Total Potential Revenue + Total Non-Monetary Benefits) / Total Initial Investment] x 100
ROI = [171,350 / (32 + 2,112 + 48 + 3)] x 100
ROI = (171,350 / 2,195) x 100
ROI = 7,806%

- **Break-Even Point (BEP):**

BEP = [Total Initial Investment / (Total Annual Savings + Total Potential Revenue + Total Non-Monetary Benefits)] x 100
BEP = (2,195 / 171,350) x 100
BEP = 1.28%

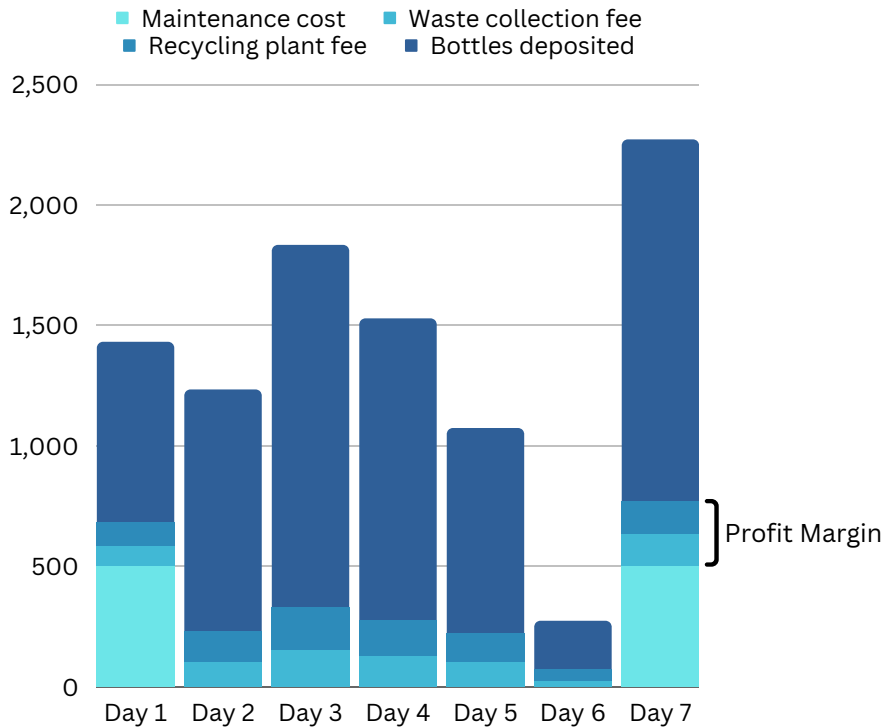


Figure 117: Cost-revenue bar chart.

The cost-benefit analysis of the project has yielded highly favorable results. The benefits far outweigh the costs, with a significant positive Return on Investment (ROI). The project demonstrates the potential to generate substantial economic, environmental, and societal benefits. It not only offers a sustainable solution to plastic waste management but also provides avenues for revenue generation through data monetization. Therefore, the cost-benefit analysis underscores the project's strong financial and societal viability, making it a sound investment for both the present and the future.

Comparative analysis

Table 35: Comparative analysis: existing smart bin vs. proposed smart bin.

Feature	Existing Smart Bin	Proposed Smart Bin
Capacity	10 kg	5 kg
	Stainless steel	PVC
Power Source	Plug-in electricity	Battery powered
	Motion sensor	–
Composting Functionality	Not available	Yes
	Not available	Carbon filters
Smart Connectivity	Bluetooth and mobile app	WiFi and mobile app
	Weight sensors	Ultrasonic sensors
Bin Status Notification	Push notifications	LED & push notification
	Single compartment	Single compartment
Waste Segregation	N/A	LCD display
	Basic reporting	Advanced analytics
Price Range	25000-30000 BDT	15000-18000 BDT

Based on the comprehensive tabular analysis conducted, our proposed system demonstrates a notably superior cost-benefit profile. This assessment is grounded in a rigorous examination of various parameters and factors.

The data presented in the tabular analysis clearly illustrates that our proposed system not only minimizes costs but also maximizes benefits when compared to alternative solutions or the status quo. This outcome underscores the robust economic viability and efficiency of our proposed system, which is critical for informed decision-making and resource allocation.

Furthermore, it is important to emphasize that the analysis has been conducted following established standards and methodologies to ensure the accuracy and reliability of the results. This formal approach to evaluating the cost-benefit aspect of our proposed system reinforces its credibility and positions it as a compelling choice for consideration and implementation.

8.4 Evaluate economic and financial aspects

- **Economic aspects:** Economic aspects provide a holistic view of a project's impact on society and the environment. Some of the key aspects have been detailed below:
 - **Cost Savings:** Bangladesh, like many countries, faces waste management challenges, including plastic waste. Implementing the system could reduce the costs associated with waste overflow and environmental damage. This could result in cost savings for municipalities and waste management authorities.
 - **Environmental Impact:** Bangladesh places great importance on environmental conservation. The reduction in plastic waste can lead to environmental benefits, potentially attracting support from environmental organizations and government incentives for sustainable initiatives.
 - **Job Creation:** The project could create jobs in areas such as system installation, maintenance, and data management. This can contribute to local employment and economic growth.
- **Financial aspects:** On the other hand, financial aspects are more focused on the project's monetary considerations, profitability, and fiscal sustainability. The relevant points have been discussed below:
 - **Initial Investment and Operational Costs:** Bangladesh's relatively lower labor and production costs have made the initial hardware setup somewhat more affordable. Software development costs are minimal as we have developed the app on our own. Operational costs, including maintenance and electricity, have been evaluated using local rates.
 - **Revenue Streams, ROI and Break-Even Point:** The potential for data monetization and increased business through user engagement is substantial in a densely populated country like Bangladesh. ROI calculations have been done considering local costs, potential savings in waste management, and revenue projections specific to the Bangladeshi market. The break-even point has been calculated based on the initial investment and the rate of cost savings and revenue generation in the local context.
 - **Government Support:** The government of Bangladesh has shown interest in sustainable projects. Exploring favorable partnerships or monetary incen-

tives from the government could appreciably effect the assignment's economic viability.

- **Market Viability:** The undertaking's fulfillment relies upon on its attraction to neighborhood groups and residents. We have conducted marketplace research and surveys to better recognize consumer behavior and options.
- **Sustainability:** We have made sure that the product stays economically sustainable ultimately via contemplating elements like prices, system enhancements, and changing market dynamics.

8.5 Conclusion

In conclusion, the financial analysis of the challenge well-known shows its ability to create a effective impact on both the economy and society. By assessing a large variety of factors, which includes value-advantage issues, environmental and social influences, and long-time period sustainability, we've gained valuable insights into the project's economic viability and its capacity to make a contribution to a more wealthy and sustainable future. This analysis underscores the significance of a complete economic evaluation in guiding knowledgeable choices and maximizing the advantages of the assignment.

9 Ethics and Professional Responsibilities [CO13, CO2, PO-H, PO-C]

9.1 Introduction

In the pursuit of science and innovation, researchers must endure the moral duty to express their work with the utmost integrity, transparency, and recognize to take a look at product, the surroundings, and society at large. Ethical guidelines have to be maintained to assure the lawful and morally sound behavior of research. As such, we've taken into consideration the following moral troubles and expert duties in regards to our challenge.

9.2 Identify ethical issues and professional responsibility

The ethical issues and professional responsibilities have been outlined below:

- Equity Towards Users
- Data Privacy and Security
- Transparency
- Technological Reliability and Safety
- Sustainability
- Community Consequence

9.3 Apply ethical issues and professional responsibility

These ethical issues and professional responsibilities have been applied to our project in the following manner:

- **Equity Towards Users:** It is the responsibility of the project team to guarantee that the system can be used by all users, irrespective of their socioeconomic standing or geographic location. For instance, the team working on the project needs to make certain that the expense of the system will not hinder populations with lower incomes from reaping the benefits of the system. We have ensured this by keeping our project cost-efficient and making our mobile application available for free on Google Play Store. In addition, we need to take into consideration the potential implications the system might have on the various trash collection systems already in place and make sure that the system does not provide any waste collecting systems an edge or disadvantage over the others. As such, we will collaborate with local garbage collectors, local scrap stores and plastic recycling factories to make the existing trash collection methods more efficient and effective. We have also ensured fair reward distribution by assigning rewards based on disposed bottle weight to avoid favoritism or discrimination towards any user.
- **Data Privacy and Security:** As the system makes use of sensors and cameras, there is a possibility of the collection and storage of personally identifiable information, which, if not managed correctly, could lead to inappropriate use of the data. Due to the fact that the system is dependent on the transfer of data and the connection between various devices, it is also necessary to protect it from potential

cybersecurity risks such as hacking and data breaches. It is critical to ensure that the privacy of users is respected and that their personal information is shielded from unauthorised access, hackers, and theft at all times by integrating stringent security procedures such as encryption and access control systems. For our project, we have established a user authentication system such that users can obtain and redeem rewards solely for the plastic bottles they have personally discarded. To access the system in the first place, users have to scan their personal ID card using the RFID scanner and only upon successful authorization will they be able to use the system. An account also needs to be created beforehand on the mobile app which will be password-protected. By logging into their account, users will be able to view their account details, reward points, redeem options as well as access other features. Consequently, users have the ability to view, alter, or delete the data that has been stored.

- **Transparency:** The team working on the project should be transparent and honest about the operation of the system, including the sorts of data that are collected, the goals for which it is utilised, who has access to that data, and who collects the data in the first place. Accordingly, we have incorporated a system message detailing all aspects regarding data collection and usage in our 'Privacy Policy' and 'Terms of Condition', which must be agreed to before creating an account on our app so as to gain official user consent. We have also created short user guides and tutorial videos to inform users about our system operation, as well as guide them on how to use our system and mobile app.
- **Technological Reliability and Safety:** Guaranteeing the reliability and accuracy of the technology used in the system is both an ethical and professional responsibility to avoid any potential harm or inconvenience to users. We have performed exhaustive testing and reviewing in order to locate any potential flaws and have placed safeguards appropriately within the system. In the design procedure, we have also taken into account fail-safe procedures and built-in redundancies so that catastrophic failures may be avoided and continuous service can be maintained. High quality components and materials have been used to design the system so as to prevent component failure or system breakdown. To ensure technological reliability during regular operation, security audits will be carried out on a routine basis in order to detect and resolve any possible system vulnerabilities. Periodic maintenance and up-to-date software updates will be performed to ensure that all components are functioning as intended. There will be on-call technicians, support teams and security teams to handle emergencies as well.
- **Sustainability:** For our project, we have utilized eco-friendly materials and components as much as we could to reduce damage to the environment. We have designed the system to be energy-efficient and long-lasting by using decent quality building materials and reducing energy consumption wherever possible. The project has been designed with end-of-life considerations in mind, so that the system can be readily disassembled and recycled or repurposed once its useful life has ended.
- **Community Consequence:** The goal of this project is to design a system that benefits the communities it serves. For this, we will assess how this project might influence waste management practices, the lives of stakeholders, and its environ-

mental and economic impacts. Firstly, our system will encourage proper waste disposal practices within the community, raising awareness about waste management amongst regular citizens. By sorting out plastic from the environment, the system will reduce plastic waste in the environment, thus ensuring a clean and hygienic environment. We also plan to partner with local waste collection teams, nearby scrap shops, and plastic recycling facilities to enhance the efficiency and effectiveness of current trash collection methods while keeping their livelihoods intact.

9.4 Conclusion

In upholding ethical standards and professional responsibilities, we have laid a solid foundation for the integrity of our research. By addressing ethical concerns, respecting professional obligations, and considering the broader implications of our research, it would be possible to earn the trust of the consumers and guarantee that the our system is seen as a dependable and safe solution by the masses. Above all, fulfillment of these responsibilities would contribute positively to the well-being of individuals, communities, and the environment.

10 Conclusion and Future Work

10.1 Project summary/Conclusion

This project represents a significant stride towards addressing the ever-pressing issue of plastic waste. By combining image processing, IoT integration, and user-centric design, this innovative system promotes responsible plastic disposal, engages users through incentives, and elevates the efficiency of waste management. We have thoroughly analyzed the pros and cons of different design approaches to illustrate why our design is the best fit for this project. To ensure the service is accessible to users, we put in significant effort to keep the technology affordable while utilizing top-quality components. Extensive research and analysis have been employed to make this project feasible, sustainable and successful.

10.2 Future work

While the system stands as a robust solution in its current form, we recognize the potential for further enhancements and innovations. Expanding the user database for public usage, integration of renewable energy sources, instant internet connectivity, geolocation enhancements, and advanced notification systems demonstrate a commitment to constant improvement and adaptation. Some of the potential avenues for further development have been outlined below:

- **Database Expansion:** Although we have considered our Brac University campus as the setting for our project, there is potential for scalability. As of now, student identity cards with RFID are being used to authenticate the users of our system. However, with the ongoing digitalization of National Identity Cards, it would soon be possible to extend the database of users to any citizen in need of disposing rubbish who would then be able to use the disposal system and receive rewards respectively. This expansion democratizes the waste disposal process, allowing a broader community to participate actively in responsible plastic bottle disposal. It not only benefits the environment but also engages a wider audience in sustainable practices.
- **Integration of Renewable Energy:** Incorporating renewable energy sources such as solar panels, can harness clean energy from the sun to power the system, reducing its reliance on conventional energy sources and minimizing its carbon footprint. This move toward renewable energy aligns with sustainability goals and reduces operational costs over time.
- **Instant Internet Connectivity:** This addition would enable instant internet connectivity, ensuring seamless data transmission and real-time updates. Users could access the system's features and monitor their rewards through the respective mobile applications even in areas with limited Wi-Fi coverage. This expansion would broaden the system's accessibility and usability, reaching users regardless of their location.
- **Geolocation and Mapping:** By applying technologies like Google Maps to pinpoint bin locations and monitor waste levels in real time, the system gains enhanced operational efficiency. This feature facilitates optimized waste collection

routes, minimizing fuel consumption and environmental impact. It also ensures timely bin emptying, reducing the chances of overflow and littering.

- **Notification System for Garbage Collectors:** Timely notifications can alert collectors to bins that are nearing full capacity, enabling them to schedule pickups more effectively. This proactive approach not only streamlines waste collection processes but also reduces the risk of overflowing bins.

11 Identification of Complex Engineering Problems and Activities

11.1 Identify the attribute of complex engineering problem (EP)

Table 36: Attributes of complex engineering problems.

	Attribute	Put tick (✓) as appropriate
P1	Depth of knowledge required	✓
P2	Range of conflicting requirements	✓
P3	Depth of analysis required	✓
P4	Familiarity of issues	
P5	Extent of applicable codes	
P6	Extent of stakeholder involvement and needs	✓
P7	Interdependence	✓

11.2 Provide reasoning how the project address selected attribute (EP)

P1: We explored different papers, journals and articles on plastic mismanagement and its potential solutions. To implement our project, knowledge of different component usage is required, such as microcontrollers, sensors and motors. A certain level of mechanical expertise is also necessary to design the system's main body properly in order to facilitate the movement or rotation of different parts of the system. Machine learning algorithms need to be applied for plastic detection via image processing as well.

P2: To overcome the constraints of our project, we may need to add extra components or sub-systems, which would increase the budget. As we have to work with a limited budget to not only build the system successfully but also make it economically viable, this creates conflicting requirements.

P3: Defining the parameters of our system such as determining the requirements, specifications, and constraints of our project, required extensive analysis for real-life implementation and operation. Further optimization has also been done to ensure the smooth operation of the system. Risk management and safety protocols have been considered while designing the system. Assessing the impacts of our project, its sustainability in the long run alongside economic feasibility called for substantial analysis as well.

P6: Stakeholders for our project include the mass people who will use the disposal system, garbage collectors, companies offering virtual rewards, and plastic recycling factories. We have conducted surveys and interviews to determine their requirements and inputs for this project.

P7: Our project has a sub-system each for authentication, plastic detection, weight measurement, and rewards allocation. Each sub-system is linked to another and would impede normal operation if either one malfunctions.

11.3 Identify the attribute of complex engineering activities (EA)

Table 37: Attributes of complex engineering activities.

	Attribute	Pick tick (✓) as appropriate
A1	Range of resources	✓
A2	Level of interaction	✓
A3	Innovation	
A4	Consequences for society and the environment	✓
A5	Familiarity	

11.4 Provide reasoning how the project address selected attribute (EA)

A1: In order to gather information regarding our project, we studied relevant papers, journals, and articles. These provided a guideline for the technology implemented in our project. We also researched the costs of different equipment to create an estimate of the budget, as well as their corresponding specification sheets to make necessary calculations for our system.

A2: We visited the local scrap store near our university to collect information regarding plastic waste. We also conducted a survey via Google Forms, which was circulated amongst the student body, to gain input from potential users of our system.

A4: As the general population is not familiar with the usage of smart disposal systems, it may take some time to integrate into our daily lives. However, there is an immense positive impact on the environment. The environment would become cleaner and safer by properly managing plastic waste and promoting plastic recycling. There would also be a rising consciousness about the environment amongst the mass people.

Acronyms

IDE Integrated Development Environment.

IoT Internet of Things.

IR Infrared Radiation.

LED Light Emitting Diode.

ML Machine Learning.

PCB Printed Circuit Board.

PPE Personal Protective Equipment.

PV Photovoltaic.

QR Quick Response.

RFID Radio Frequency Identification.

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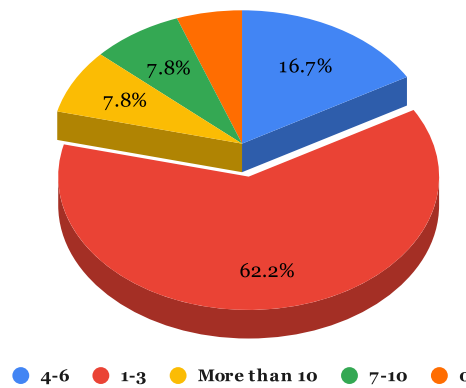
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Appendices

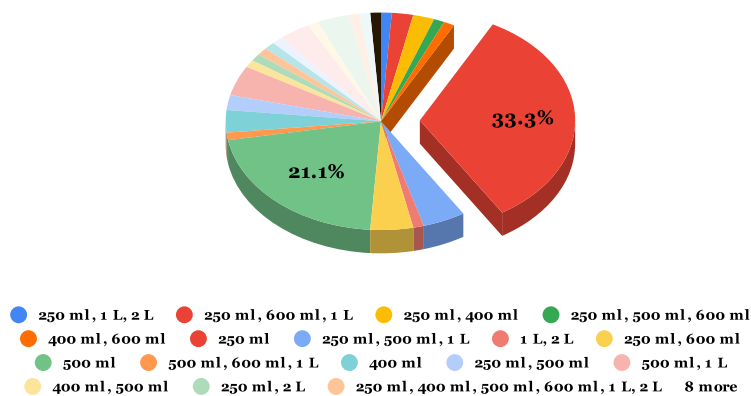
Appendix A Survey Response

In order to conduct an in-depth analysis of the present market, we have spoken with stakeholders of varying levels. We inquired ninety users who wished to remain anonymous their thoughts on the manner in which plastic waste is disposed of, the frequency with which they consume beverages, and the methods by which they deal with empty bottles. The majority of those who took part in this study were currently enrolled at Brac University. This is a sample of the responses that were given in the survey.

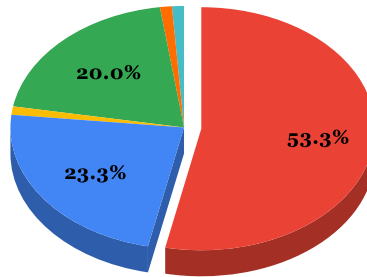
How many plastic bottles do you use per week?



What size plastic bottles do you typically purchase?

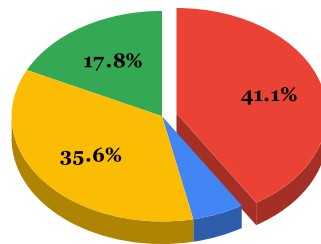


When you purchase a drink in a plastic bottle, where do you usually consume it?



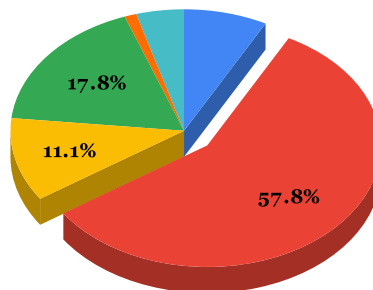
● On the go ● At home ● Anywhere ● At work ● Restaurants ● সব

After consuming the drink, how do you dispose of the empty bottle?



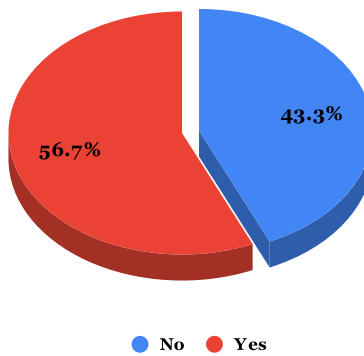
● Carry on until I find a trash can to throw it in
 ● Throw it anywhere I can ● In a trash bin if it is nearby; otherwise, throw it on the road
 ● Keep it to myself for other purposes

How many plastic bottles do you typically save up at home before throwing them out?

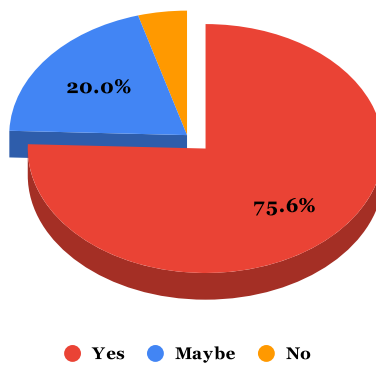


● 11-20 ● 2-5 ● 6-10 ● None ● 1 or 2 ● More than 20

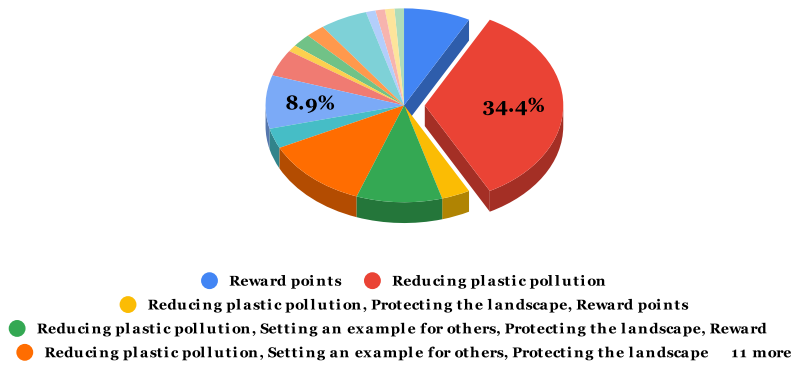
Do you make an active effort to reduce plastic pollution?



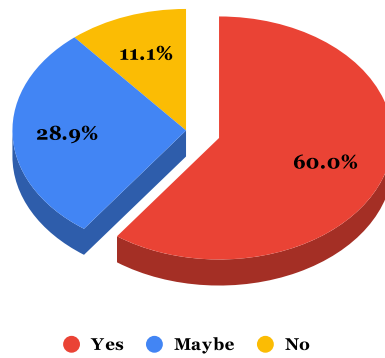
Would you be willing to throw the empty plastic bottle in a "Smart Waste Disposal System" rather than a normal bin?



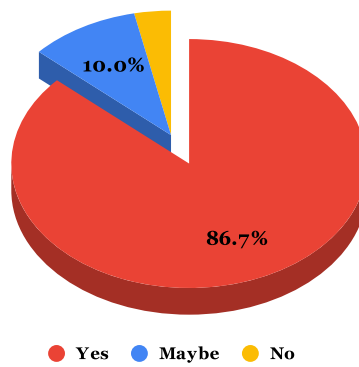
What would motivate you to throw the bottle in a "Smart Waste Disposal System"?



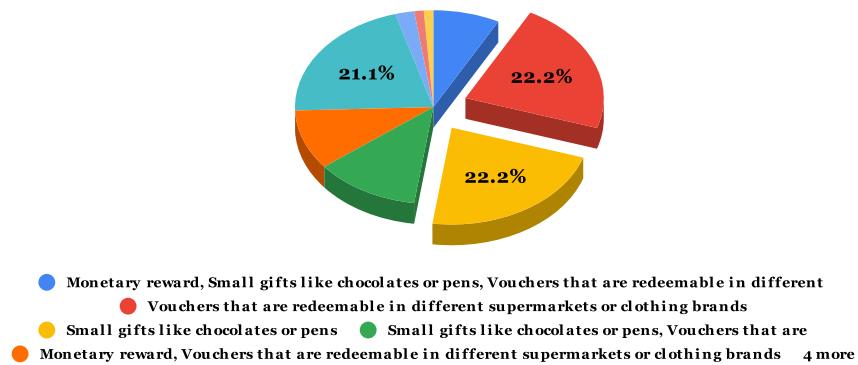
Would you be willing to download an app to track the reward points you have earned?



Count of Do you think encouraging users to throw bottles in return for rewards would encourage more users overall?



What would you prefer to get in exchange for redeeming your points?



Appendix B Password-based Simulation Code

```
1  #include <Arduino.h>
2
3  #include <Keypad.h>
4
5  #include <LiquidCrystal.h>
6
7  // Arduino pin number for LCD
8  const int rs = 13,
9      e = 12,
10     d4 = 11,
11     d5 = 10,
12     d6 = 9,
13     d7 = 8;
14
15  const int locked = A0,
16     unlocked = A1;
17
18  LiquidCrystal lcd(rs, e, d4, d5, d6, d7);
19
20  const byte row_num = 4;
21  const byte col_num = 3;
22
23  char key[row_num][col_num] = {
24      {
25          '1',
26          '2',
27          '3'
28      },
29      {
30          '4',
31          '5',
32          '6'
33      },
34      {
35          '7',
36          '8',
37          '9'
38      },
39      {
40          '*',
41          '0',
42          '#'
43      }
44  };
45
46  byte row_pins[row_num] = {
47      3,
```

```

48     2,
49     1,
50     0
51 };
52
53 byte col_pins[col_num] = {
54     4,
55     5,
56     6
57 };
58
59 Keypad keypad = Keypad(makeKeymap(key), row_pins, col_pins, row_num, col_
    _num);
60
61 int pos = 0;
62
63 char * passphrase = "1234";
64
65 String codeMsg = "";
66
67 void showInstruction() {
68     lcd.setCursor(0, 0);
69     lcd.println("Enter password");
70     lcd.setCursor(0, 1);
71     lcd.println("To open valve");
72 }
73 void lock() {
74     digitalWrite(unlocked, LOW);
75     digitalWrite(locked, HIGH);
76     lcd.clear();
77     lcd.setCursor(0, 0);
78     lcd.println("Wrong password!");
79     lcd.setCursor(0, 1);
80     lcd.println("Try again.");
81     delay(1000);
82     pos = 0;
83     lcd.clear();
84     showInstruction();
85 }
86 void unlock() {
87     digitalWrite(unlocked, HIGH);
88     digitalWrite(locked, LOW);
89     lcd.clear();
90     lcd.setCursor(0, 0);
91     lcd.println("Access granted!");
92     lcd.setCursor(0, 1);
93     lcd.println("Welcome back!");
94     delay(5000);

```

```

95     pos = 0;
96     lcd.clear();
97     showInstruction();
98 }
99 void setup() {
100     pinMode(locked, OUTPUT);
101     pinMode(unlocked, OUTPUT);
102     lcd.begin(16, 2);
103     digitalWrite(unlocked, LOW);
104     digitalWrite(locked, HIGH);
105 }
106 void loop() {
107     if (pos == 0) {
108         showInstruction();
109     }
110     int input;
111     char code = keypad.getKey();
112     if (code != NO_KEY) {
113         codeMsg = codeMsg + code;
114         lcd.clear();
115         lcd.setCursor(0, 0);
116         lcd.print("Password:");
117         // lcd.print(" ");
118         // lcd.setCursor(7, 1);
119
120         for (input = 0; input <= pos; ++input) {
121             lcd.setCursor(0, 1);
122             lcd.print(codeMsg);
123         }
124
125         if (code == passphrase[pos]) {
126             ++pos;
127             if (pos == 4) {
128                 codeMsg = "";
129                 unlock();
130                 pos = 0;
131             }
132         } else {
133             codeMsg = "";
134             lock();
135             pos = 0;
136         }
137     }
138 }

```

Code snippet 1: C program of password-based authentication subsystem.

Appendix C RFID-based Simulation Code

```
1  #include <Arduino.h>
2
3  char c;
4  String rfid;
5  int rfid_len = 8;
6  int count = 0;
7  String allowed_id = "19321007";
8
9  void setup() {
10     Serial.begin(9600);
11     Serial.println("Scan your RFID TAG");
12 }
13
14 void loop() {
15     while (Serial.available() > 0) {
16         c = Serial.read();
17         count = count + 1;
18         rfid += c;
19
20         if (count == rfid_len) {
21             Serial.println(rfid);
22             if (rfid == allowed_id) {
23                 Serial.println("Valid RFID tag found!");
24             } else {
25                 Serial.println("Invalid RFID tag!");
26             }
27         }
28     }
29     count = 0;
30     rfid = "";
31     delay(500);
32 }
```

Code snippet 2: C program of RFID-based authentication subsystem.

Appendix D Waste Level Detection Code

```
1  #include <LiquidCrystal.h>
2
3  #include <AccelStepper.h>
4
5  #define motorPin1 2
6  #define motorPin2 1
7  #define motorPin3 3
8  #define motorPin4 4
9
10 #define triggerPin 7
```

```

11  #define echoPin 8
12
13  #define ledIndicator 0
14
15  LiquidCrystal lcd(6, 5, 9, 10, 11, 12);
16  AccelStepper stepper(AccelStepper::FULL4WIRE, motorPin1, motorPin2,
17  _motorPin3, motorPin4);
18
19  void setup() {
20
21      Serial.begin(9600);
22
23      pinMode(ledIndicator, OUTPUT);
24
25      stepper.setMaxSpeed(1000);
26      stepper.setAcceleration(500);
27
28      stepper.setCurrentPosition(0);
29
30      lcd.begin(16, 2);
31
32      lcd.setCursor(0, 0);
33      lcd.print("Smart Bin");
34
35      lcd.setCursor(0, 1);
36      lcd.print("Initializing...");
37  }
38
39  void loop() {
40
41      lcd.setCursor(0, 0);
42      lcd.print("Smart Bin");
43
44      lcd.setCursor(0, 1);
45      lcd.print("          ");
46
47      long duration, inches, cm;
48
49      pinMode(triggerPin, OUTPUT);
50
51      digitalWrite(triggerPin, LOW);
52
53      delayMicroseconds(2);
54
55      digitalWrite(triggerPin, HIGH);
56
57      delayMicroseconds(10);

```

```

58
59 digitalWrite(triggerPin, LOW);
60
61 pinMode(echoPin, INPUT);
62
63 duration = pulseIn(echoPin, HIGH);
64
65 cm = microsecondsToCentimeters(duration);
66
67 lcd.setCursor(0, 1);
68
69 if (cm >= 835) {
70     lcd.print("Full Empty");
71     digitalWrite(ledIndicator, LOW);
72     rotateMotor();
73
74 } else if ((cm < 835) && (cm >= 630)) {
75     lcd.print("75% Full");
76     digitalWrite(ledIndicator, LOW);
77     rotateMotor();
78
79 } else if ((cm < 630) && (cm >= 420)) {
80     lcd.print("50% Full");
81     digitalWrite(ledIndicator, LOW);
82     rotateMotor();
83
84 } else if ((cm < 420) && (cm >= 210)) {
85     lcd.print("25% Full");
86     digitalWrite(ledIndicator, HIGH);
87     rotateMotor();
88
89 } else {
90     lcd.print("Almost Full");
91     digitalWrite(ledIndicator, HIGH);
92 }
93
94 Serial.print(cm);
95 Serial.print("cm");
96 Serial.println();
97
98 delay(100);
99
100 }
101
102 void rotateMotor(void) {
103     int targetAngle1 = 90;
104
105     stepper.moveTo(targetAngle1);

```



```

106  while (stepper.distanceToGo() != 0) {
107      stepper.run();
108  }
109
110  stepper.moveTo(0);
111  while (stepper.distanceToGo() != 0) {
112      stepper.run();
113  }
114
115  }
116
117  long microsecondsToCentimeters(long microseconds) {
118      return microseconds / 29 / 2;
119  }

```

Code snippet 3: C program of the compartment and storage subsystem simulation written for Arduino Nano microcontroller.

Appendix E Bin Lid Performance Assessment Matlab Code

```

1  clear all
2  close all
3  clc
4
5  % angular displacement in radians
6  theta = pi/2;
7
8  % maximum load in kilogram
9  m = 5;
10
11 % height of the lid in meter
12 h = 0.25;
13
14 % width of the lid in meter
15 w = 0.15;
16
17 % distance in meter
18 d = w / 2;
19
20 % time interval in second
21 t = 1:0.001:500;
22
23 % momentum of inertia in kilogram per meter squared
24 MOI = (1/12) * m * ((h^2) + (w^2));
25
26 % angular velocity in radians per second
27 w_value = zeros(1, length(t));

```

```

28
29 % angular acceleration in radians per second squared
30 a_value = zeros(1, length(t));
31
32 % torque values in Newton meter
33 torque_value = zeros(1, length(t));
34
35 % force values in Newton
36 force_value = zeros(1, length(t));
37
38 % power values in Watt
39 power_value = zeros(1, length(t));
40
41 % rpm values in RPM
42 rpm_value = zeros(1, length(t));
43
44 for i = 1:length(t)
45     w_value_i = (theta / t(i));
46     w_value(i) = w_value_i;
47
48     a_value_i = (w_value_i / t(i));
49     a_value(i) = a_value_i;
50
51     torque_value_i = (MOI * a_value_i);
52     torque_value(i) = torque_value_i;
53
54     force_value_i = torque_value_i / d;
55     force_value(i) = force_value_i;
56
57     power_value_i = torque_value_i * w_value_i;
58     power_value(i) = power_value_i;
59
60     rpm_value_i = (power_value_i / (2 * pi * torque_value_i));
61     rpm_value(i) = rpm_value_i;
62 end
63
64 disp(torque_value(1:20))
65 disp(power_value(1:20))
66
67 subplot(2,1,1)
68 plot(t, torque_value)
69 xlabel('Time (s)'), ylabel('Torque (Nm)'), title('Torque vs Time (Lid)')
70
71 subplot(2,1,2)
72 plot(torque_value, power_value)
73 xlabel('Torque (Nm)'), ylabel('Power (W)'), title('Power vs Torque (Lid)
    _')

```

Code snippet 4: Matlab program to check the performance of bin lid over the time.

Appendix F Bin Storage Performance Assessment Matlab Code

```
1 clear all
2 close all
3 clc
4
5 % angular displacement in radians
6 theta = pi;
7
8 % maximum load in kilogram
9 m = 5;
10
11 % radius in meter
12 r = 0.225;
13
14 % time interval in second
15 t = 1:0.001:500;
16
17 % momentum of inertia in kilogram per meter squared
18 MOI = 0.5 * m * r^2;
19
20 % angular velocity in radians per second
21 w_value = zeros(1, length(t));
22
23 % angular acceleration in radians per second squared
24 a_value = zeros(1, length(t));
25
26 % torque values in Newton meter
27 torque_value = zeros(1, length(t));
28
29 % force values in Newton
30 force_value = zeros(1, length(t));
31
32 % power values in Watt
33 power_value = zeros(1, length(t));
34
35 % rpm values in RPM
36 rpm_value = zeros(1, length(t));
37
38 for i = 1:length(t)
39     w_value_i = (theta / t(i));
40     w_value(i) = w_value_i;
41
42     a_value_i = (w_value_i / t(i));
```

```

43     a_value(i) = a_value_i;
44
45     torque_value_i = (MOI * a_value_i);
46     torque_value(i) = torque_value_i;
47
48     force_value_i = torque_value_i / r;
49     force_value(i) = force_value_i;
50
51     power_value_i = torque_value_i * w_value_i;
52     power_value(i) = power_value_i;
53
54     rpm_value_i = (power_value_i / (2 * pi * torque_value_i));
55     rpm_value(i) = rpm_value_i;
56 end
57
58 disp(torque_value(1:20))
59 disp(power_value(1:20))
60
61 subplot(2,1,1)
62 plot(t, torque_value)
63 xlabel('Time (s)'), ylabel('Torque (Nm)'), title('Torque vs Time (Bin_
    _Compartment)')
64
65 subplot(2,1,2)
66 plot(torque_value, power_value)
67 xlabel('Torque (Nm)'), ylabel('Power (W)'), title('Power vs Torque (Bin_
    _Compartment)')

```

Code snippet 5: Matlab program to check the performance of bin storage compartment over the time.

Appendix G Code For System Simulation

```

1  #include <Arduino.h>
2  #include "HX711.h"
3  #include <Servo.h>
4  #include <Wire.h>
5  #include <Adafruit_GFX.h>
6  #include <Adafruit_SSD1306.h>
7
8  #define AUTHED 5
9  #define PLASTIC 6
10 #define NON_PLASTIC 4
11 #define FIRE_SENSOR 10
12 #define GAS_SENSOR 11
13 #define BUZZER 7
14 #define SERVO 3
15 #define LED 2

```

```

16 #define DISTANCE_TRIG 13
17 #define DISTANCE_ECHO 12
18
19 #define SCREEN_WIDTH 128
20 #define SCREEN_HEIGHT 32
21
22 Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, 4);
23
24 long binLevelMaxThreshold = 620;
25 long binLevelThreshold = 420;
26
27 int levelBin = 0;
28
29 Servo motor;
30 int motPos = 0;
31
32 const int DOUT_PIN = 9;
33 const int SCK_PIN = 8;
34
35 HX711 scale;
36
37 int alreadyAuthed = 0;
38
39 void definePins() {
40     pinMode(AUTHED, INPUT);
41     pinMode(PLASTIC, INPUT);
42     pinMode(NON_PLASTIC, INPUT);
43     pinMode(FIRE_SENSOR, OUTPUT);
44     pinMode(GAS_SENSOR, OUTPUT);
45     pinMode(BUZZER, OUTPUT);
46     pinMode(DISTANCE_ECHO, INPUT);
47     pinMode(DISTANCE_TRIG, OUTPUT);
48     pinMode(LED, OUTPUT);
49
50     scale.begin(DOUT_PIN, SCK_PIN);
51
52     scale.set_scale(36.059);
53     scale.tare();
54
55     motor.attach(SERVO);
56 }
57
58 void setupDisplay() {
59     if (!display.begin(SSD1306_SWITCHCAPVCC, 0x3C)) {
60         Serial.println(F("SSD1306 allocation failed"));
61         for (;;)
62             ;
63     }

```

```

64     delay(10);
65     display.clearDisplay();
66 }
67
68 void displayText(String text) {
69     display.clearDisplay();
70     display.setTextSize(1);
71     display.setTextColor(WHITE);
72     display.setCursor(0, 0);
73     display.println(text);
74     display.display();
75 }
76
77 void mkSound() {
78     digitalWrite(BUZZER, HIGH);
79     delay(500);
80     digitalWrite(BUZZER, LOW);
81 }
82
83 void checkWeight(int mat) {
84     if (mat == 1) {
85         Serial.print("Plastic Weight:\t");
86     } else if (mat == 2) {
87         Serial.print("Non-plastic Weight:\t");
88     }
89     Serial.print(-(scale.get_units() / 1000) * 10, 1);
90 }
91
92 void rotateMotorForPlastic() {
93     for (motPos = 90; motPos <= 180; motPos += 1) {
94         motor.write(motPos);
95         delay(15);
96     }
97     for (motPos = 180; motPos >= 90; motPos -= 1) {
98         motor.write(motPos);
99         delay(15);
100    }
101 }
102
103 void rotateMotorForNonPlastic() {
104     for (motPos = 90; motPos >= 0; motPos -= 1) {
105         motor.write(motPos);
106         delay(15);
107     }
108     for (motPos = 0; motPos >= 90; motPos += 1) {
109         motor.write(motPos);
110         delay(15);
111     }

```

```

112 }
113
114 void checkForPlasticNonPlastic() {
115     if ((digitalRead(PLASTIC) == HIGH) && (digitalRead(NON_PLASTIC) ==
116         LOW)) {
117         checkWeight(1);
118         displayText("Plastic Detected");
119         rotateMotorForPlastic();
120         digitalWrite(LED, LOW);
121     } else if ((digitalRead(PLASTIC) == LOW) && (digitalRead(NON_PLASTIC)
122         == HIGH)) {
123         checkWeight(2);
124         displayText("Non-plastic Detected");
125         rotateMotorForNonPlastic();
126         digitalWrite(LED, LOW);
127     } else if ((digitalRead(PLASTIC) == LOW) && (digitalRead(NON_PLASTIC)
128         == LOW)) {
129         Serial.println("Waiting for waste disposal...");
130         digitalWrite(LED, LOW);
131     } else if ((digitalRead(PLASTIC) == HIGH) && (digitalRead(NON_PLASTIC)
132         == HIGH)) {
133         digitalWrite(LED, HIGH);
134     }
135 }
136
137 long msToCm(long microseconds) {
138     return microseconds / 29 / 2;
139 }
140
141 void checkBinLevel() {
142     long duration, inches, cm;
143
144     digitalWrite(DISTANCE_TRIG, LOW);
145     delayMicroseconds(2);
146
147     digitalWrite(DISTANCE_TRIG, HIGH);
148     delayMicroseconds(10);
149
150     digitalWrite(DISTANCE_TRIG, LOW);
151
152     duration = pulseIn(DISTANCE_ECHO, HIGH);
153     cm = msToCm(duration);
154
155     int perct = 0;
156
157     if (cm < 250) {
158         perct = 0;
159         levelBin = 0;

```

```

156 } else if (cm >= 250 && cm < 300) {
157     perct = 25;
158     levelBin = 25;
159 } else if (cm >= 300 && cm < 420) {
160     perct = 50;
161     levelBin = 50;
162 } else if (cm >= 420 && cm < 570) {
163     perct = 75;
164     levelBin = 75;
165 } else if (cm >= 620) {
166     perct = 100;
167     levelBin = 100;
168 }
169
170 if (perct < 75) {
171     String msg = "Bin Level: " + String(perct) + "%";
172
173     displayText(msg);
174 }
175
176 Serial.print("Waste Level: ");
177 Serial.println(cm);
178
179 if (cm > binLevelThreshold) {
180     digitalWrite(BUZZER, HIGH);
181     digitalWrite(LED, HIGH);
182     displayText("Bin is full!");
183 } else {
184     digitalWrite(BUZZER, LOW);
185     digitalWrite(LED, LOW);
186     displayText("Enter your waste");
187     checkForPlasticNonPlastic();
188 }
189 }
190
191 void initialize() {
192     Serial.begin(9600);
193     definePins();
194     setupDisplay();
195 }
196
197 void setup() {
198     initialize();
199 }
200
201 void loop() {
202     if (digitalRead(AUTHED) == HIGH) {
203         if (alreadyAuthed == 0) {

```



```

204     Serial.println("User authenticated");
205     displayText("User authenticated");
206     alreadyAuthed = 1;
207 }
208 delay(500);
209 checkBinLevel();
210 } else {
211     Serial.println("User not authenticated");
212     displayText("User not authenticated");
213 }
214
215 if (digitalRead(GAS_SENSOR) == HIGH) {
216     mkSound();
217     Serial.println("Toxic Gas Deteced!");
218     displayText("Toxic Gas Deteced!");
219 } else {
220     Serial.println("No Toxic Gas Deteced!");
221     displayText("No Toxic Gas Deteced!");
222 }
223
224 if (digitalRead(FIRE_SENSOR) == HIGH) {
225     mkSound();
226     Serial.println("Fire Hazard Deteced!");
227     displayText("Fire Hazard Deteced!");
228 } else {
229     Serial.println("No Fire Hazard Deteced!");
230     displayText("No Fire Hazard Deteced!");
231 }
232 delay(250);
233 }

```

Code snippet 6: C++ code to evaluate the bin's component-wise performance.

FYDP (P) Fall 2022 Summary of Team Log Book/ Journal

Final Year Design Project (P) Fall 2022			
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Date/Time/Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
26.09.2022 (Group Meeting 1)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. How to find complex engineering problem 2. Search for potential project ideas	Noshin, Jobayer, Shaikat, Borhan	N/A
11.10.2022 (ATC Meeting 1)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Introduction with ATC Panel 2. Shared potential problem statements	Noshin, Jobayer, Shaikat, Borhan	1. Need to research papers and literature review 2. Need to finalize topic
13.10.2022 (Group Meeting 2)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Discuss finalized topic 2. Research multiple design approaches	Noshin, Jobayer, Shaikat, Borhan	N/A
16.10.2022 (ATC Meeting 2)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Presented revised problem statement 2. Presented 3 design approaches	Noshin, Jobayer, Shaikat, Borhan	1. Need to find specifications, requirements and constraints 2. Need to conduct field visit and survey
20.10.2022 (Group Meeting 3)	1. Jobayer 2. Borhan	1. Discussion on design approaches, requirements and specifications	Noshin, Jobayer, Shaikat, Borhan	N/A
21.10.2022 (Group Meeting 4)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Discussion on constraints 2. Revised requirements	Noshin, Jobayer, Shaikat, Borhan	N/A
25.10.2022 (Group Meeting 5)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Project title finalization	Noshin, Jobayer, Shaikat, Borhan	N/A
26.10.2022 (ATC Meeting 3)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Shared progress on concept note	Noshin, Jobayer, Shaikat, Borhan	1. Need to revise requirements and specifications
27.10.2022 (Group Meeting 6)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Revised requirements and specifications	Noshin, Jobayer, Shaikat, Borhan	N/A
30.10.2022 (ATC Meeting 4)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Shared concept note draft	Noshin, Jobayer, Shaikat, Borhan	1. Need more literature review for problem statement

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01.11.2022 (Group Meeting 7)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Preparation of progress presentation slides	Noshin, Jobayer, Shaikat, Borhan	N/A
12.11.2022 (Group Meeting 8)	1. Jobayer 2. Shaikat	1. Spoke to stakeholders 2. Gathered information	Jobayer, Shaikat	N/A
15.11.2022 (ATC Meeting 5)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Discussed feedback from progress presentation	Noshin, Jobayer, Shaikat, Borhan	1. Need to prepare survey for potential users
17.11.2022 (Group Meeting 9)	1. Noshin 2. Jobayer	1. Add block diagram for subsystems	Jobayer	N/A
22.11.2022 (ATC Meeting 6)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Presented survey questions	Noshin, Jobayer, Shaikat, Borhan	1. Need to ensure system is user-friendly
29.10.2022 (ATC Meeting 7)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Presented survey response 2. Discussion on overall system design	Noshin, Jobayer, Shaikat, Borhan	1. Need to work on overall system design
07.12.2022 (Group Meeting 10)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Worked on methodology, project plan, budget, expected outcome	Noshin, Jobayer, Shaikat, Borhan	N/A
10.12.2022 (Group Meeting 11)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Preparation of final presentation slides	Noshin, Jobayer, Shaikat, Borhan	N/A
13.12.2022 (ATC Meeting 8)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Mock presentation 2. Shared progress on project proposal	Noshin, Jobayer, Shaikat, Borhan	1. Need to revise complex engineering attributes 2. Advice for presentation
14.12.2022 (Group Meeting 12)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Discussion on final presentation	Noshin, Jobayer, Shaikat, Borhan	N/A
17.12.2022 (Group Meeting 13)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Worked on impact, sustainability, risk management and analysis	Noshin, Jobayer, Shaikat, Borhan	N/A
19.10.2022 (Group Meeting 14)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Worked on safety consideration, ethical consideration, attributes of CEP and CEA	Noshin, Jobayer, Shaikat, Borhan	N/A

FYDP (D) Spring 2023 Summary of Team Log Book/ Journal

Final Year Design Project (D) Spring 2023			
Student Details	NAME & ID	EMAIL ADDRESS	PHONE
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Member 2	Md Al Hasan Shaikat; ID:19321001	md.al.hasan.shaikat@g.bracu.ac.bd	01620248484
Member 3	Md Jobayer; ID:19321007	md.jobayer@g.bracu.ac.bd	01322688680
Member 4	Md. Borhan Uddin Antor; ID:19321025	md.borhan.uddin.antor@g.bracu.ac.bd	01841311297
ATC Details:			
ATC 1			
Chair	Mohammed Belal Hossain Bhuian	belal.bhuian@bracu.ac.bd	
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Date/Time/Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
25.01.2023 (ATC Meeting 1)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Overview of EEE400D	Noshin, Jobayer, Shaikat, Borhan	1. Need to simulate overall system and subsystems 2. Need to ensure fulfillment of CO's
04.02.2023 (Group Meeting 1)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Discussed different simulations that can be done 2. Discussed selection of simulation tools	Noshin, Jobayer, Shaikat, Borhan	N/A
13.02.2023 (ATC Meeting 2)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Presented simulation of authentication system 2. Shared progress on image processing and 3D design	Noshin, Jobayer, Shaikat, Borhan	1. Need to integrate subsystems 2. Small scale model of system required for visualization
16.02.2023 (Group Meeting 2)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Worked on building a small scale model	Jobayer, Shaikat, Borhan	N/A
20.02.2023 (ATC Meeting 3)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Presented the built model 2. Discussed modifications made to design approaches	Noshin, Jobayer, Shaikat, Borhan	1. Need to complete 3D design
24.02.2023 (Group Meeting 3)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Preparation of progress presentation slides	Noshin, Jobayer, Shaikat, Borhan	N/A
27.02.2023 (ATC Meeting 4)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Presented progress presentation slides	Noshin, Jobayer, Shaikat, Borhan	1. Proper scaling, labeling and placement of components required in 3D design
01.03.2023 (Group Meeting 4)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Discussion on progress presentation	Noshin, Jobayer, Shaikat, Borhan	N/A
02.03.2023	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Progress Presentation	Noshin, Jobayer, Shaikat, Borhan	1. Need to determine optimal design 2. Use more data in image processing 3. More simulations required

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18.03.2023 (Group Meeting 5)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Worked on selection of modern engineering/IT tools (report)	Noshin, Jobayer, Shaikat, Borhan	N/A
27.03.2023 (ATC Meeting 5)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Discussed feedback on progress presentation	Noshin, Jobayer, Shaikat, Borhan	1. Need to perform calculations for motor selection
03.04.2023 (Group Meeting 6)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Discussed calculations required for selection of motor, microcontroller and battery requirements	Noshin, Borhan	N/A
10.04.2023 (ATC Meeting 6)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Presented calculations required for component selection 2. Discussed possible motor choices	Noshin, Jobayer, Shaikat, Borhan	1. Perform backward calculation to determine parameters 2. Plot graphs
15.04.2023 (Group Meeting 7)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Worked on functional verification of multiple design solutions (report)	Noshin, Jobayer, Shaikat, Borhan	N/A
20.04.2023 (Group Meeting 8)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Worked on analyzing the multiple design solutions to find the optimal solution (report)	Noshin, Jobayer, Shaikat, Borhan	N/A
26.04.2023 (Group Meeting 9)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Preparation of final presentation slides	Noshin, Jobayer, Shaikat, Borhan	N/A
27.04.2023	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Final Project Presentation	Noshin, Jobayer, Shaikat, Borhan	1. Need block diagram integrating subsystems 2. Need to present calculations 3. Need to mention scalability of project
29.04.2023 (Group Meeting 10)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Worked on design report summary	Noshin, Jobayer, Shaikat, Borhan	N/A

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06.06.2023 (ATC Meeting 1)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Discussed various choices of components 2. Discussed material selection of system structure	Noshin, Jobayer, Shaikat, Borhan	1. Need to prioritize working on prototype 2. Need to ensure fulfillment of CO's
10.06.2023 (Group Meeting 1)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Finalized component selection 2. Discussed revised design of system structure	Noshin, Jobayer, Shaikat, Borhan	N/A
13.06.2023 (ATC Meeting 2)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Provided updates on ordering of components, app development and image processing	Noshin, Jobayer, Shaikat, Borhan	N/A
16.06.2023 (ATC Meeting 3)	1. Jobayer 2. Shaikat 3. Borhan	1. Discussed material selection of system structure	Noshin, Jobayer, Shaikat, Borhan	1. Need to use decent quality plastic for system structure
20.06.2023 (Group Meeting 2)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Worked on building system structure	Noshin, Jobayer, Shaikat, Borhan	N/A
05.07.2023 (Group Meeting 3)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Modified Introduction, Project Design Approach, and Use of Modern Engineering and IT Tools (Report)	Noshin, Jobayer, Shaikat, Borhan	N/A
12.07.2023 (ATC Meeting 4)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Provided update on system structure and PCB design	Noshin, Jobayer, Shaikat, Borhan	1. Need to show prototype related progress during presentation
12.07.2023 (Group Meeting 4)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Preparation on progress presentation	Noshin, Jobayer, Shaikat, Borhan	N/A
13.07.2023	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Progress Presentation	Noshin, Jobayer, Shaikat, Borhan	1. Need to exclude some of the content from FYDP-D
25.07.2023 (Group Meeting 5)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Modified Impact Analysis and Project Sustainability, Engineering Project Management, and Conclusion and Future Work (Report)	Noshin, Jobayer, Shaikat, Borhan	N/A
01.08.2023 (ATC Meeting 5)	1. Jobayer 2. Shaikat 3. Borhan	1. Provided update on app development, image processing and PCB design	Noshin, Jobayer, Shaikat, Borhan	1. Need to finish system structure and image processing

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08.08.2023 (ATC Meeting 6)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Presented complete authentication system and complete PCB design 2. Provided update on system structure	Noshin, Jobayer, Shaikat, Borhan	1. Need to bring prototype in person 2. Need to train dynamic images
13.08.2023 (Group Meeting 6)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Discussed details of poster 2. Shared updates on task progress thus far	Noshin, Jobayer, Shaikat, Borhan	N/A
17.08.2023 (ATC Meeting 7)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Mock Presentation 2. Discussed issues with system in detail	Noshin, Jobayer, Shaikat, Borhan	1. Need to modify system structure 2. Need to add protective circuit measures
20.08.2023 (ATC Meeting 8)	1. Jobayer 2. Shaikat 3. Borhan	1. Presented updated system structure 2. Demonstrated successful identification and deposition of plastic bottles	Noshin, Jobayer, Shaikat, Borhan	1. Need to work on identifying and separating non-plastics
22.08.2023 (ATC Meeting 9)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Discussed deposition of unwanted trash 2. Presented initial draft of poster	Noshin, Jobayer, Shaikat, Borhan	1. Need to incorporate lid locking system and penalty for users depositing unwanted trash 2. Need to work on economic analysis 3. Include more graphics and reduce text in poster
22.08.2023 (Group Meeting 7)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Modified Ethics and Professional Responsibilities (Report) 2. Worked on Economic Analysis (Report)	Noshin, Jobayer, Shaikat, Borhan	N/A
25.08.2023 (Group Meeting 8)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Preparation for project demonstration	Noshin, Jobayer, Shaikat, Borhan	N/A
26.08.2023	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. FYDP Project Showcase/ Demonstration	Noshin, Jobayer, Shaikat, Borhan	1. Need to train more images for non-plastics 2. Need to work on the business aspect of project
28.08.2023 (Group Meeting 9)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Worked on Optimization of Multiple Design and Finding the Optimal Solution (Report)	Noshin, Jobayer, Shaikat, Borhan	N/A
31.08.2023 (Group Meeting 10)	1. Noshin 2. Jobayer 3. Shaikat 4. Borhan	1. Worked on Completion of Final Design and Validation (Report)	Noshin, Jobayer, Shaikat, Borhan	N/A