DESIGN AND IMPLEMENTATION OF SMART WASTE BIN FOR OFFICE PLACE

By

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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

Department of Electrical and Electronic Engineering
Brac University
April 2023

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Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is my/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. I/We have acknowledged all main sources of help.

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Ethics Statement

[Students who submit their project must check the plagiarism and maintain the similarity index below 35%.]

Abstract/ Executive Summary

The goal of this project is to create a smart bin that will enhance office space waste management systems by maintaining a clean office environment. A dual compartment design has been adopted - one for disposable and one for non-disposable waste. The design consists of ultrasonic sensors for waste level detection, load sensors for weight limits and the lids which require servo motors. At the heart of the system lies an Arduino Uno. Smart hands free waste bins have the potential to revolutionize waste management by improving efficiency, reducing costs, and promoting a healthier environment. However, there are some challenges to consider such as the high cost of implementing such technology, potential technical issues, and the need for proper maintenance and upkeep to ensure optimal performance. Overall, the benefits of smart hands free waste bins outweigh the drawbacks, and further research and development are needed to improve the technology and make it more accessible to a wider range of communities.

Keywords: Smart Dustbin; Ultrasonic sensor; Wi-Fi connectivity; Internet of Things; Arduino; Waste Categorizing; Waste Monitoring.

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List of Acronyms

Chapter 1: Introduction

1.1 Introduction

In recent years, there has been a great push in the industry towards environment friendliness, environment sustainability and waste management. Due to the ever growing population of humans inhabiting the planet, the need to effectively tackle these problems has become a very important thing for the current generation of researchers and engineers across the globe. Several organizations have pushed innovation to the limits to present the world with different ways to enhance our lifestyle. One such innovation is a smart waste bin. With the use of sensors, actuators and automated scripts, this project focuses on presenting a design and implementation of one such bin. The smart bin is designed for office spaces where it needs to be functional, convenient, environmentally friendly, cost effective and aesthetically pleasing.

1.1.1 Problem Statement

A total of 2 billion tons of municipal solid waste are produced annually throughout the world which is expected to rise up to 3.4 billion tons by 2050. About 33 percent of this waste is not properly managed to protect the environment [1]. 75% of global pollution is caused mainly by activities predominantly in cities [2]. Especially for a low income country like Bangladesh, the total quantity of waste is expected to rise 3 times. For a sustainable, livable and healthy city (SHL) a proper waste management system is a must specially for a densely populated city [3]. However, solid wastes is one of the biggest issues of Dhaka city. Around 234,000 deaths, including 80,000 in urban areas, due to environmental contamination and related health risks occurred in 2015 [3]. Oftentimes, the bins are overflowed with waste as they are cleared once in the morning. As such, it gives rise to an unhygienic environment which poses serious risk to our health, mental state and environment [4]. The waste management workers of Bangladesh work with little to none safety measures which makes them exposed to health hazards. As such, a solution is needed which will deal with the issue of efficient waste disposal, reduce the transmission of diseases as much as possible and reduce wastes all at the same time.

Specially, in office spaces a proper waste disposal system is a top priority. The major challenges in this regard is to control, manage and process waste generation on a daily basis [5]. Otherwise, a pleasant work environment will be hard to come by which will lower down productivity and may pose the threat of transmitting diseases among the families of the employees [3]. However, monitoring and controlling a waste manually can be very time consuming and tedious. As such, the office employees and staff require a modern solution for the waste disposal issue. On the other hand, the manufacturers will also have to provide a solution which is relevant to the current industry and fulfill the requirements of the users.

1.1.2 Background Study

Different studies have been done on waste management systems in literature. A GSM Based Monitoring Scheme for smart garbage management systems has been implemented [6]. The system consists of smart bins or containers, each of which has a 16-bit microcontroller, a laser sensor and a global system for mobile communication (GSM) module attached to it. It provides a simple and easy way to control household appliances with a single SMS or by calling a cell phone. However, the project focuses on residential areas and cannot provide options for disposable and non-disposable wastes.

Moreover, "Smart Dustbin for Waste Management" introduces the idea of a reward point by means of eco point through which households, small and large businesses can buy the desired category of waste which can be of use to them. Recycle centers can also use this web application to see how much of each type of waste is there and then place a purchase order. This research project's main goal is to offer a useful and practical system for classifying waste prior to waste collection and also encourage people to properly dispose of trash in smart waste bins as well which can be later recycled for proper use [4].

QR code is introduced in "An IoT-based Architecture for Waste Management" for the usage of only authorized personnel of a certain organization. The users can access the bin by scanning the QR code from the application. However, this approach is time consuming for a simple task as to dispose of waste [7].

Moreover, oftentimes toxic gases produced from wastes pose serious health risks. These gases may cause respiratory disorders, cough, shortness of breath, diarrhea etc. Among the gases, Methane (CH_4) is odorless and colourless which makes it very difficult to trace. Among the gases, Methane (CH_4) is odorless and colourless which makes it very difficult to trace. A Sensor-based Garbage Gas Detection System is developed to determine poisonous gases such as Hydrogen Sulfide (H_2S) by MQ-136, Methane (CH_4) by MQ-137 and Ammonia (NH_3) by TGS-2611 [8].

"IoT based Smart Garbage System Powered with Solar Cell" proposes a smart garbage bin with a real time monitoring system, incorporating sensors. It mainly focuses on a cost effective and efficient waste disposal system by the use of solar cells. However, this has a disadvantage as it cannot be used in closed spaces such as for indoor usage [9].

1.1.3 Survey

In order to assess the view of the stakeholders and the targeted users of our project, we conducted a survey which may provide us better insight to choose our optimal design solution.

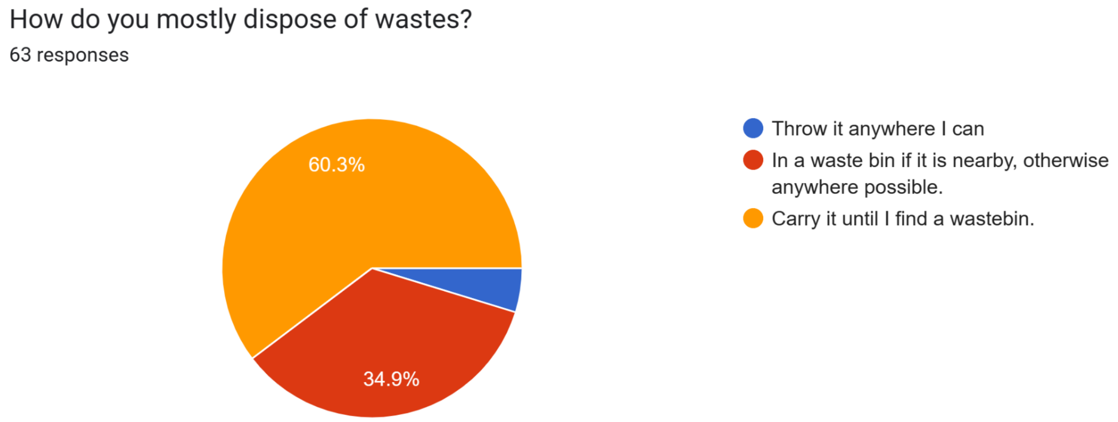

Fig. 1. Pie chart of disposed wastes

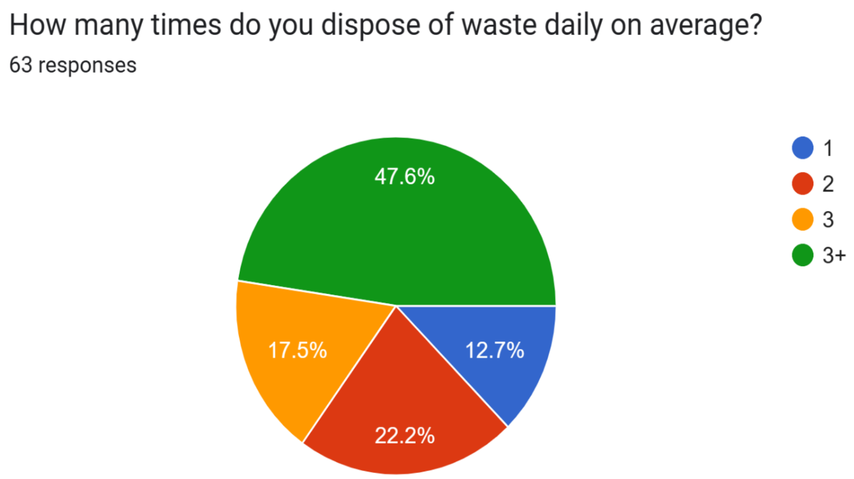

Fig. 2. Pie chart of average disposed waste.

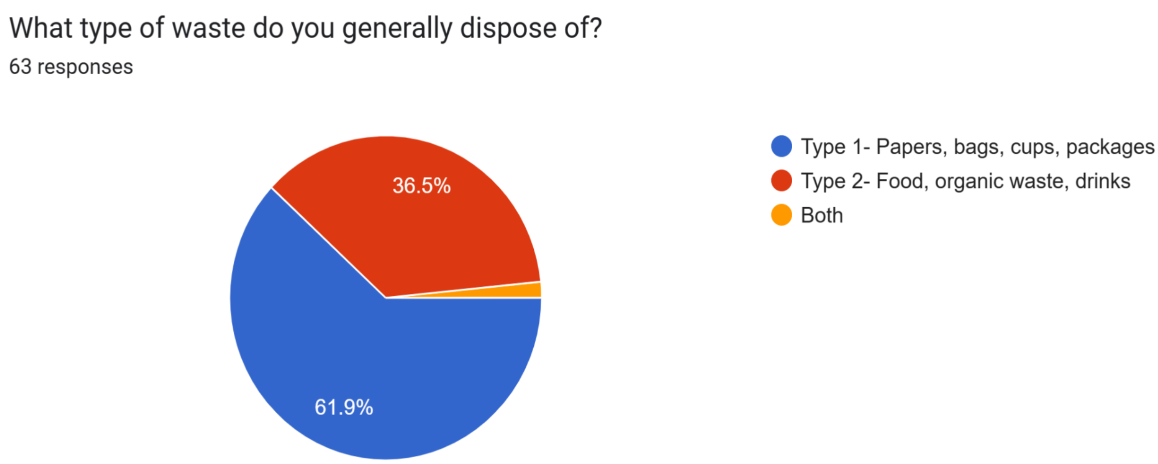

Fig. 3. Pie chart of types of disposed wastes

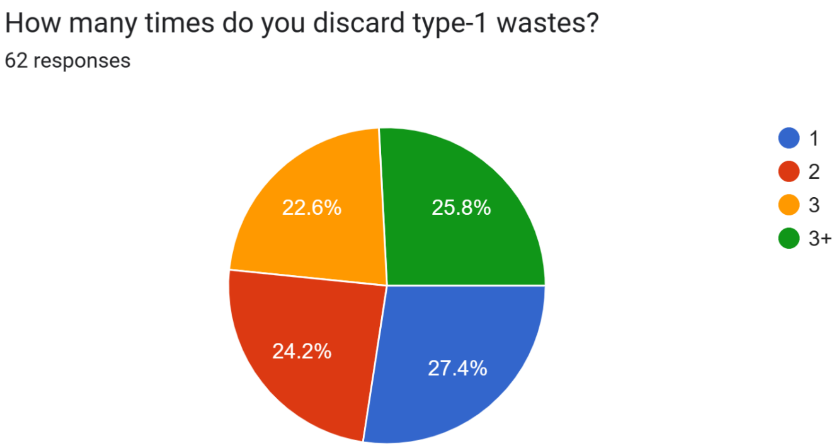

Fig. 4. Pie chart of number of times type-1 waste disposed

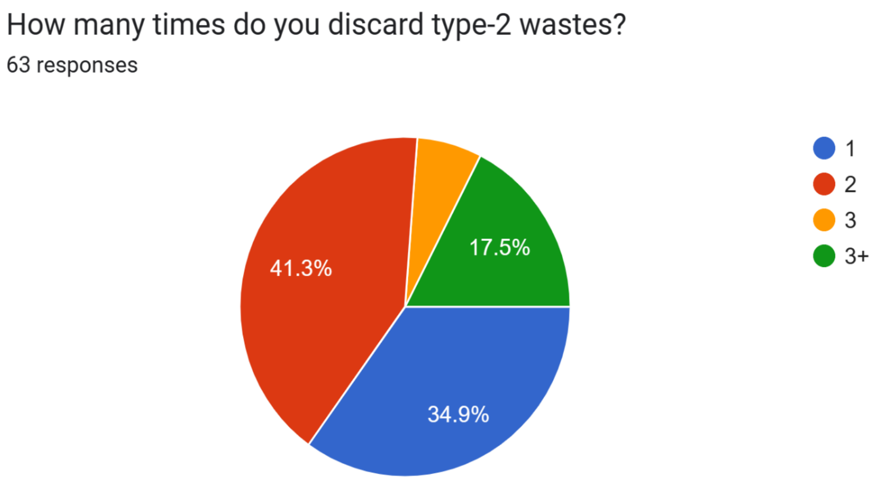

Fig. 5. Pie chart of of number of times type-2 waste disposed

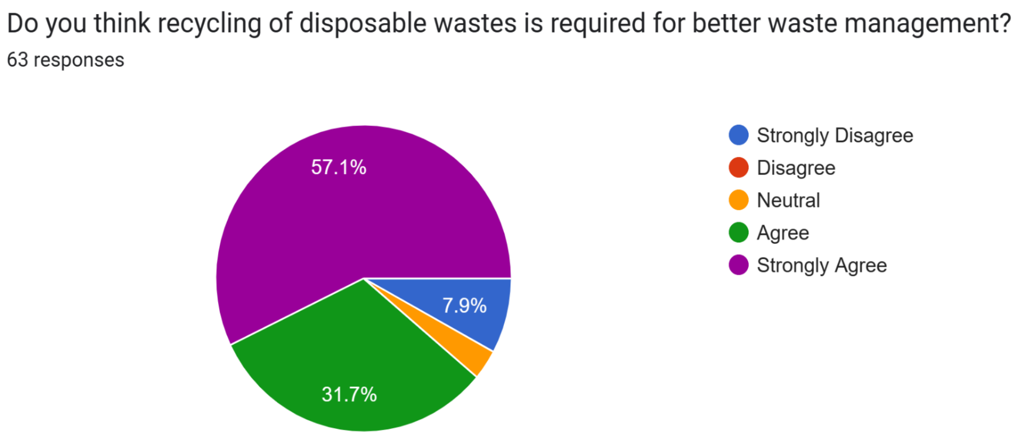

Fig. 6. Pie chart of opinion on recycling of wastes

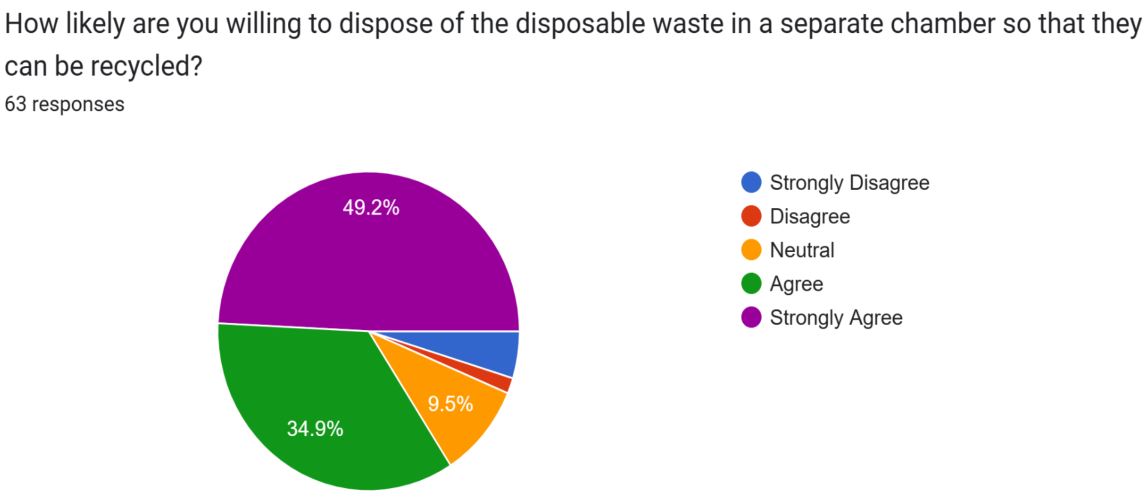

Fig. 7. Pie chart of willingness of users in using a separate chamber of the waste bin

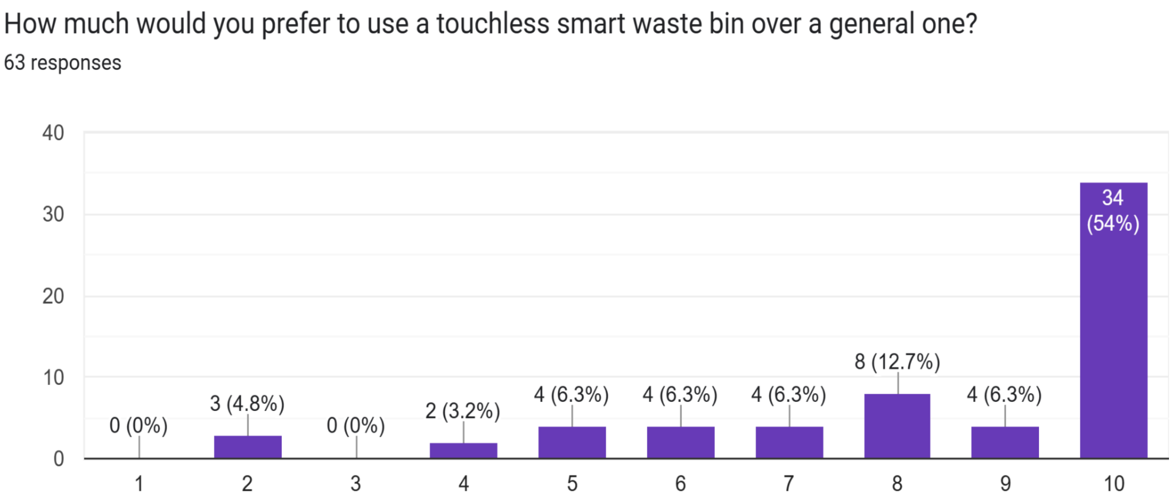

Fig. 8. Level of preference of users of using a smart waste bin.

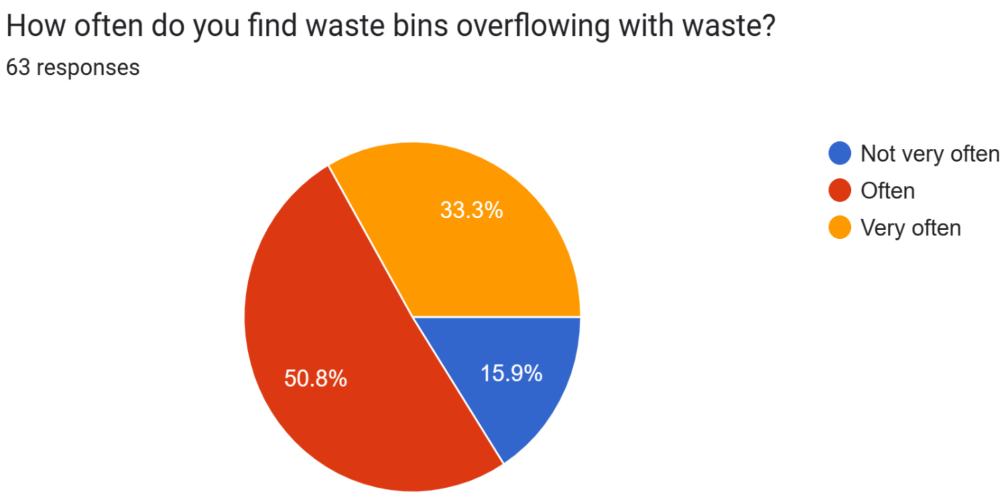

Fig. 9. Pie chart of how often waste bins are found to be overflowing

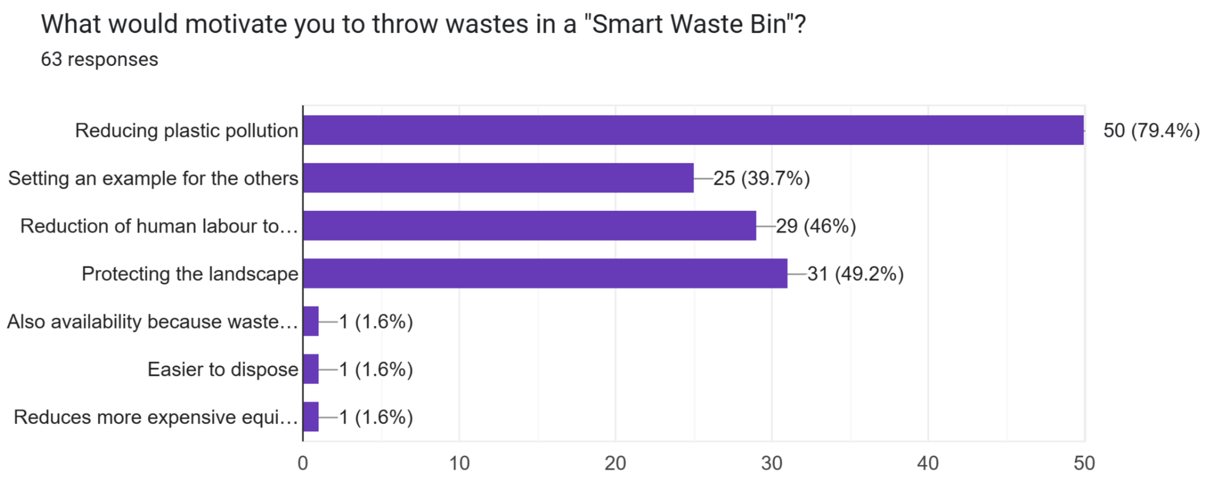

Fig. 10. Motivation of users to use a 'Smart Waste Bin'

From the survey results, it is evident that often the dustbins are found to be overflowing with waste. Hence people tend to lean towards an automated alternative. In this regard, a separate chamber for disposable wastes will further help to recycle wastes and keep the environment clean.

1.1.4 Literature Gap

Smart bins have become increasingly popular in recent years as they provide an efficient and effective waste management solution. These bins typically use sensors or other technology to detect when waste has been added to the bin and can even sort the waste into different categories for recycling purposes.

However, one area that has received less attention in the literature is the design and mechanical operation of touchless smart waste bin. This can be an important aspect of the bin's functionality as it determines how easily the user can dispose of waste and how reliably the bin can detect when waste is added. there is.

To fill this gap in the literature, researchers may need to develop their own designs for touchless smart waste bin, considering factors such as ease of use, durability and cost effectiveness. You may also need to consider using newer technologies such as linear actuators that provide precise and reliable movements for opening and closing containers.

Additionally, communication modules like the ESP32 enable seamless integration with other smart devices such as smartphones and home automation systems. This makes the recycle bin even more functional and more convenient and user-friendly for consumers.

Overall, existing research on the mechanical design and operation of no-touch smart bins may be lacking, but this provides opportunities for researchers to develop innovative and effective solutions in the field.

1.1.5 Relevance to current and future Industry

According to a report published in the Daily Star, our capital, Dhaka, is facing serious waste management problems. The report highlights that the city generates about 4,000 tons of waste every day, but the current waste management system can only handle about 2,200 tons of waste[14]. As a result, a significant portion of waste remains uncollected and ends up in vacant land and bodies of water[14].

The report also notes that the current waste management system relies heavily on manual labor, which is not only inefficient but also poses health risks to workers. The traditional bins in use today are often overfilled and the collection process is irregular, exacerbating the problem of waste management. In the face of this dire situation, it is clear that new and innovative approaches are needed to tackle our country's waste management problems. The smart waste bin that our project aims to develop could play an important role in this regard.

With touch-free operation and the ability to separate waste into different categories, this smart bin can make your waste collection process more efficient, hygienic and environmentally sustainable.

In summary, the current state of waste management in our country is far from satisfactory and there is an urgent need for innovative solutions to address this problem. The smart trash bin that our project aims to develop is a step in the right direction, providing an efficient and effective solution to waste management problems and contributing to a more sustainable and livable environment for all. It can be an important step.

1.2 Objectives, Requirements, Specification and Constraints

1.2.1. Objectives

The main objectives of our project are as follows:

1. Designing a smart bin for office purposes.
2. Implementation of the smart bin.
3. Notifying about relevant information for disposal purpose.
4. Feasibility analysis of the designed smart bin.

1.2.2 Functional and Nonfunctional Requirements

The Functional Requirements

1. Compartments: The waste bin has to consist of two separate compartments built in one body. One for disposable & the other for non-disposable waste.

2. Capacity of the bin: The waste bin should have a capacity to store up to 50kg of waste.

3. Toxic gas detection: The disposable unit must be able to detect toxic Methane gas, Hydrogen Sulfide, Ammonia that produces bad smell [10].

4. Maximum weight detection: The whole bin should have a weight detection sensor system in case it reaches 50 kg.

5. Height detection: The waste bin should be able to detect different waste levels up to a height of 26 inches.

6. Fire protection: The waste bin should be able to detect fire hazards.

7. Providing Output: The real time information of the waste bin is displayed in an LCD display and also on a webpage.

The Non-Functional Requirements:

1. Compartments: The bin should be non-touchable for health issues (especially because of covid)

2. Capacity of the bin: The disposable unit should have a secondary lid to cover bad smell.

1.2.3 Specifications

System level specifications are as follows:

TABLE I. System Specifications

System level	Components
Structure	17x15x26 inch structure
Interfacing system	A 20 by 4 line LCD
User interaction system	Motion sensor detecting up to 7 meters
Measuring and Monitoring system	An ultrasonic sensor with range 2-400 cm
	Gas sensor with detecting concentration scope of 200-10000 ppm
	Weight detection by load sensor up to 50 kg
Control system	Arduino with operating voltage 5V, input voltage 7-12V, Digital I/O Pins: 14, flash memory: 32 KB
Communication system	GPRS module for communication with 2 PWMs and built-in ADC
Safety System	Smoke sensor with a working range of 300-10000 ppm

1.2.4 Technical and Non-technical consideration and constraint in design process

Non-technical Constraints:

The project has to be designed considering several non-technical constraints such that it can benefit the users in their day to day life. Otherwise, it can create problems for an office space. It has to be budget friendly, occupy less space etc.

Some of the non-technical constraints that we have faced are:

1. Budget: As we are making a waste bin for the office place, we will need multiple devices to cover the office. In that case, failing to complete a project within a budget will make it impossible for the office to afford it.
2. Space: As rent for commercial offices in Bangladesh are high, allocating huge space for a waste bin will be difficult for companies.

3. Availability and Rate of Jute polybags: Jute poly bags are comparatively newer products. So ensuring the availability of the products throughout the country at a cheap price will be difficult.

Technical Constraints:
Since the project is based on IoT, the safety of the components as well as the users in the vicinity is of utmost importance.
The technical constraints of our project was:

1. Damage from wet environment: As most of the disposable waste is wet in nature, it creates relatively high humidity inside the bin which will accumulate in our sensors and development boards which can give incorrect data and make them difficult to use.

2. Malfunction of components: In case of software bugs, the servo motors may malfunction which may lead to opening of the two lids unexpectedly. This may emit a bad odor in the workspace.

1.2.5 Applicable compliance, standards, and codes

The following table represents the Codes and Standards relevant to this project.

TABLE II. Applicable Codes

Codes	Description	Impact on the project
IEC 62430	This paper outlines guidelines, lays out standards, and discusses concepts for firms looking to include environmental considerations into the creation of their goods. Any organization, regardless of its size, nature, or industry, is covered by this document. It also pertains to the methods used to incorporate environmentally conscious design (ECD) into the design and manufacture of products.	This code expressed interest in the substance utilized to construct the bin. We must ensure that the materials used to build the bin do not, under any circumstances, harm the environment. This code's primary concern is the design of a material and how it connects to the environment.
IEC 62309	This paper introduces the idea of testing the dependability and performance of recycled components before using them in new projects. Additionally, it gives details and requirements for the testing and analysis necessary for goods using such recycled components that are deemed to be "qualified-as-good-as-new" in relation to the intended lifespan of the product. This standard's goal is to assure via testing and analysis that the functionality and dependability of a new product utilizing recycled parts is equal to a product made entirely of new components.	This code's primary goal is to separate recycled goods from other goods so that we may discard non-recycled goods. Recycling now aids in energy conservation, and everyone's health is our first priority. The non disposable waste will be used further after being recycled as our bin will be able to differentiate between the disposable and the non disposable waste.
IEC 62402	This article offers guidelines and standards for managing obsolescence that are relevant to any organization that depends on another organization to benefit from the usefulness of the products it offers. All stages of an item's life cycle can benefit from a cost-effective obsolescence management approach and the activities utilized to implement the process.	This code focuses mostly on how dependent our product is on other organizations. We may provide an example to make it more understandable. To safeguard the environment, for instance, we will use jute plastic bags rather than paper or plastic ones. Utilizing jute polybags will benefit the environment, as well as our nation's rural economy. In this sense, the jute sector in our country is essential to our project.

Practiced codes:

- To make sorting out the garbage easier, different colors are utilized for different types of rubbish to be dumped [12].
- Countries like Seoul have introduced the QR code management system so that everyone in the city can request maintenance work for each bin [13].

Extent of professional practices:

- The shape of the bin should be a square shaped polygon so that it can hold the maximum amount of trash.
- The ground of the bin should be placard at the bottom so that the excess current can pass through it.
- All the active wires should have been insulated twice for better protection.
- Use of anti burnol material for the body of the bin to protect it from fire.
- The compartments should be clearly separated into chambers and each chamber should possess a different opening lid and each compartment should have been labeled clearly so that waste can be sorted out according to that.

1.3 Systematic Overview/summary of the proposed project

This touchless smart bin uses modern sensors and techniques to transform waste management. The smart bin eliminates the need for physical contact due to its ability to detect the presence of the user, reducing the risk of contamination and infections. Due to the wireless connectivity of the bin, real-time monitoring and reporting are possible. This data is crucial for enhancing sustainability and waste management procedures. This creative approach could advance environmental sustainability, public health, and a better waste management system.

1.4 Conclusion

The problem of waste management has become a global issue due to its high impact on the environment. As the world continues to produce more waste, there is an urgent need for innovative solutions to mitigate its negative impacts. The development of truly smart waste bins that can sort waste into disposable and reusable items is a promising solution to help build a greener environment.

This smart waste bin facilitates the recycling process by sorting waste into different categories, minimizing the amount of waste that ends up in landfills. This not only reduces environmental pollution, but also helps conserve natural resources. In addition, the introduction of a new waste management system that can be monitored via mobile app and web will significantly improve the way waste is managed.

The proposed system has the potential to provide a comprehensive waste management solution that can be tailored to the specific needs of different regions. With the help of mobile applications and web-based monitoring systems, the waste collection process can be made more efficient, reliable and cost-effective. This reduces reliance on manual work and enables immediate response when problems arise.

In summary, the development of truly smart waste bins and the introduction of new waste management systems that can be monitored via mobile apps and the web can greatly improve the way waste is managed. By facilitating the recycling process and minimizing the amount of waste that ends up in landfills, this solution helps create a greener environment and pave the way for a sustainable future.

Chapter 2: Project Design Approach

2.1 Introduction

The smart, hands-free waste bin design is a new and innovative approach to waste management. With the increase in waste and the need for sustainable waste management practices, the development of smart, hands-free trash bins has become a necessary solution. These bins are designed to make waste disposal more convenient, hygienic and efficient.

The main goal of smart hands-free waste bins is to provide a touch-free waste disposal system. This is achieved by integrating a sensor that detects the presence of the user and automatically opens the bin lid. This technology reduces the need for physical contact and minimizes the spread of germs and bacteria.

The smart hands-free bin design also includes features such as odor control and easy access to waste disposal. The use of high-quality materials and sophisticated design makes the bin an attractive addition to any office space.

In addition to their practical properties, smart waste bins can also contribute to a sustainable future. Waste bins can be equipped with smart technology that tracks waste level and provides data that can be used to improve waste management. This information helps us identify areas where we can improve our waste reduction and recycling efforts.

Overall, the intelligent, hands-free bin design approach is an innovative solution to the growing waste management problem. It offers a no-touch, hygienic waste disposal system and its sustainability features bring a valuable added value to any environment. As the world continues to grapple with waste management challenges, the development of smart, hands-free waste bin is a step towards a cleaner, greener future.

2.2 Identify multiple design approach

We have studied several designs and proceeded to perform research on their features to match our requirements. Our primary motive is to make a smart bin with advanced features so that it enhances the way we handle waste in an efficient manner with minimal interaction from the users.

Existing design approach 1: A Smart Waste Management Solution Geared towards Citizens [2]

A paper by Pardini, K (2020) proposes a solution that can improve waste management. The approach employs IoT and sensors to monitor the trash inside the bin. IoT middleware stores and processes the data for waste collection. Finally, with the internet and mobile phone these information can be accessed for accurate monitoring and waste collection. Here is the block diagram:

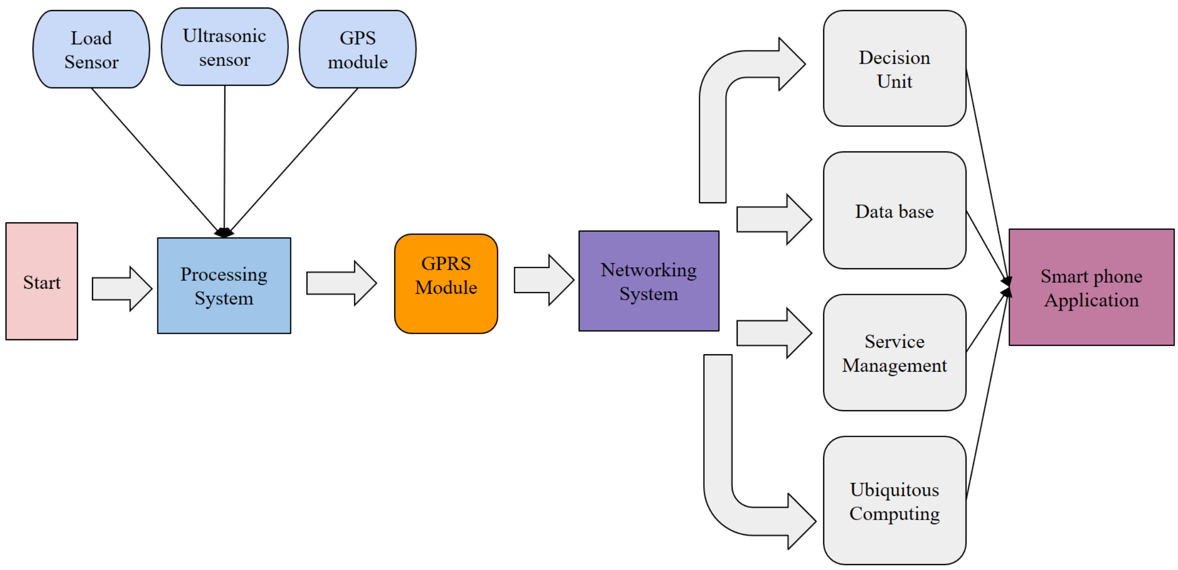

Fig. 11. Block diagram of a Smart Waste Management Solution geared towards citizens [2]

The block diagram shows the procedure of the design approach. At first, the data from the load sensor, ultrasonic and the GPS modules are collected by the processing system which is a type of micro controller and sent to the GPRS module. Then, the GPRS module further transmits the data to the networking system that goes to the database for continuous monitoring, and goes to the ubiquitous computing and decision unit for route optimization and service management. Finally, all these are sent to the smartphone application and viewed by concerned personnel.

Existing design approach 2: IoT based solid waste management system for smart city [11]
K. Nirde (2017) provides an ultrasonic sensor for detecting waste levels. Furthermore, it is controlled by a microcontroller, a GSM module and an LCD display for output. This method focuses solely on remote monitoring of two sensor systems that provide real-time container status data as outputs.

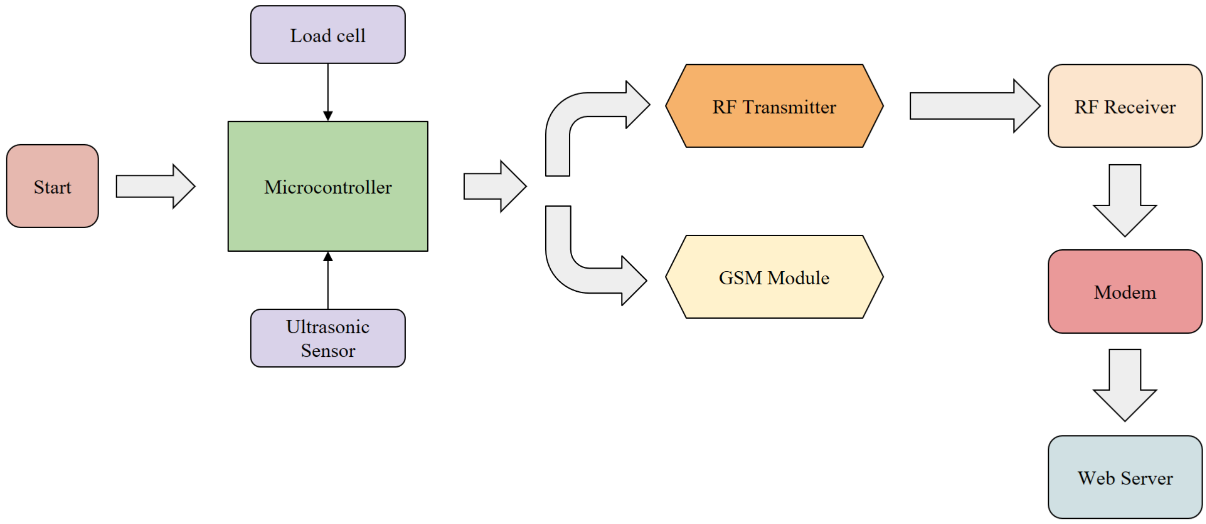

Fig. 12. Block Diagram for IoT based solid waste management system for smart city [11]

In this approach, at first, the load sensor and the ultrasonic sensor data are sent to the microcontroller for processing. Then these data are sent to the RF transmitter and the GSM module. The GSM module takes the data and directly sends messages to the operator. At the same time the RF transmitter sends these data to the modem via RF receiver which is updated directly to the web server for further processing.

Proposed design approach: Design and Implementation of Smart Waste Bin for Office Place.

In our design, we introduced a motion sensor that can automatically control the container without touching it. We created separate compartments for storing disposable and reusable waste. Single-use units use both a waste level detection system and a weight detection system. In our reusable unit we added smoke detection, waste level detection and weight detection systems. Data collected by sensors from both units, then processed by the micro controller and using the GSM module, is sent to the user.

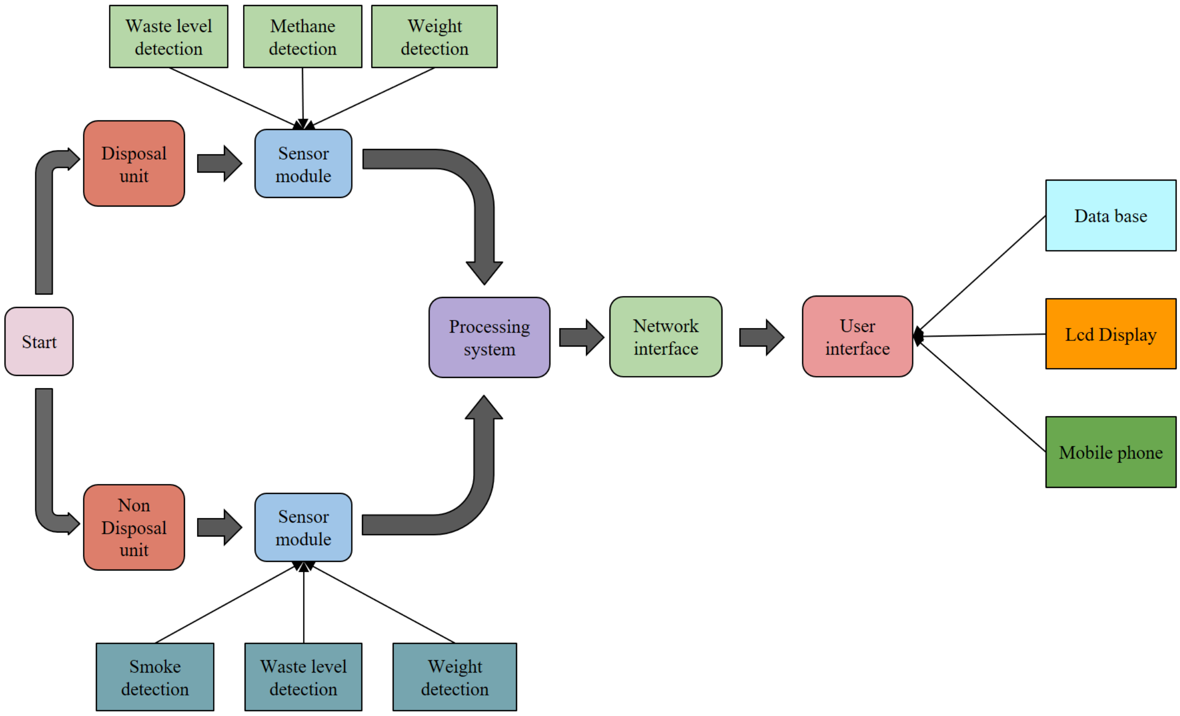

Fig. 13. Block Diagram Design and Implementation of Smart Waste Bin for Office Place.

The proposed system has two compartments. In the disposal unit, the sensor module consists of waste level detection, weight detection and methane gas detection. For the non disposal unit, the sensor module consists of smoke detection, waste level detection and weight detection. The controlling of the sensor module is done by the processing system which would be a type of microcontroller. The collected data from sensors goes to the networking system via the processing system. Lastly, the user interface consists of a database, LCD display and the mobile phone.

2.3 Describe multiple design approach

Existing design approach 1: A Smart Waste Management Solution Geared towards Citizens [2]

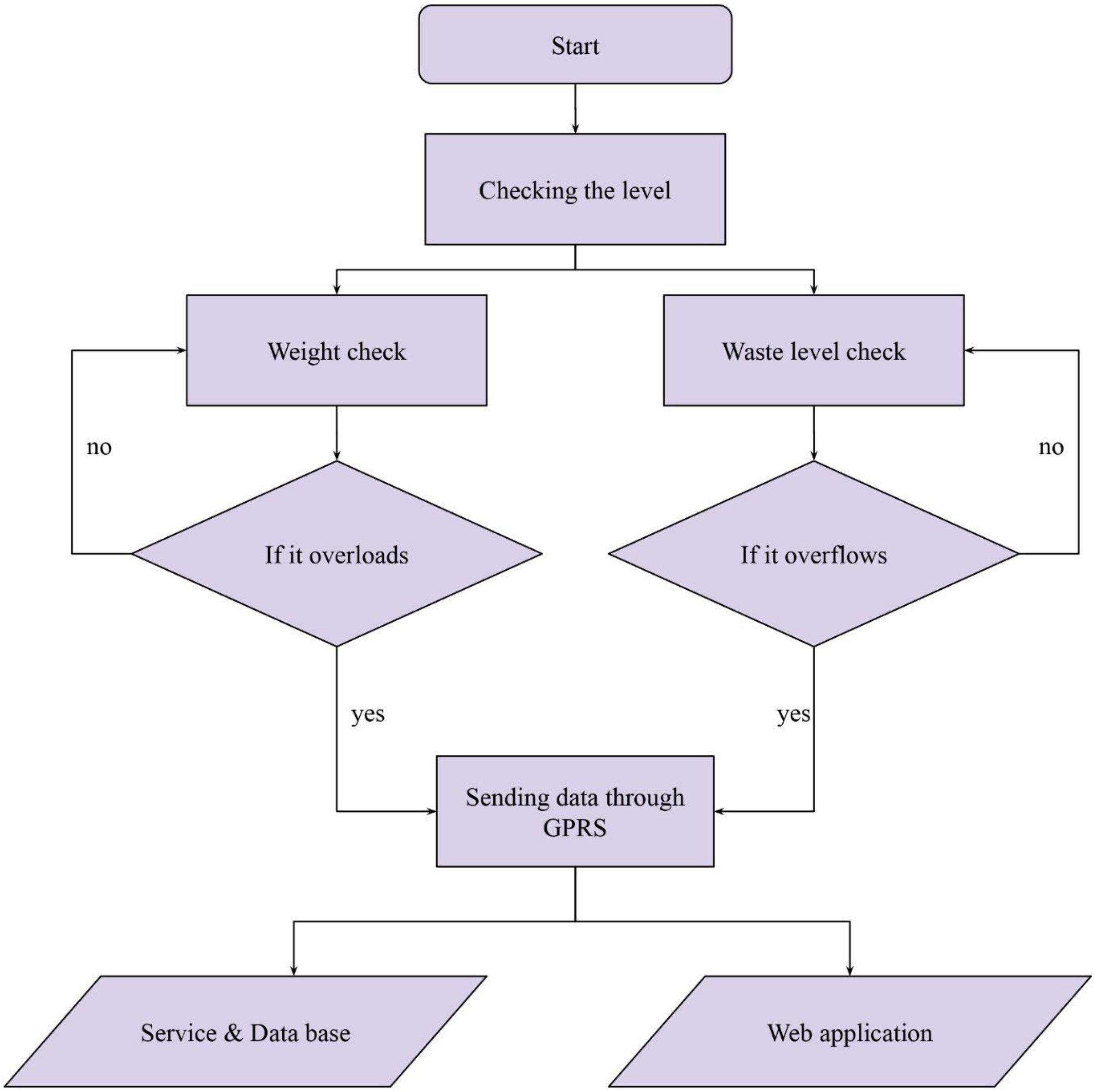

Fig. 14. Flow Chart of a Smart Waste Management Solution geared towards citizens [2]

First, the condition of the waste is checked. It is divided into two segments: weight check and waste level check. It is checked by the microcontroller with the help of a load sensor. If the weight is overloaded the data is sent through the GPRS. On the other hand, the waste level is checked by the ultrasonic sensor which is then processed by the microcontroller. Incase of overflow, the data is sent through the GPRS module. Otherwise, the status of the bin is continuously monitored. The GPRS module sends the data for efficient path navigation by the dump trucks and uploaded to the web database for monitoring.

Existing design approach 2: IoT based solid waste management system for smart city [11]

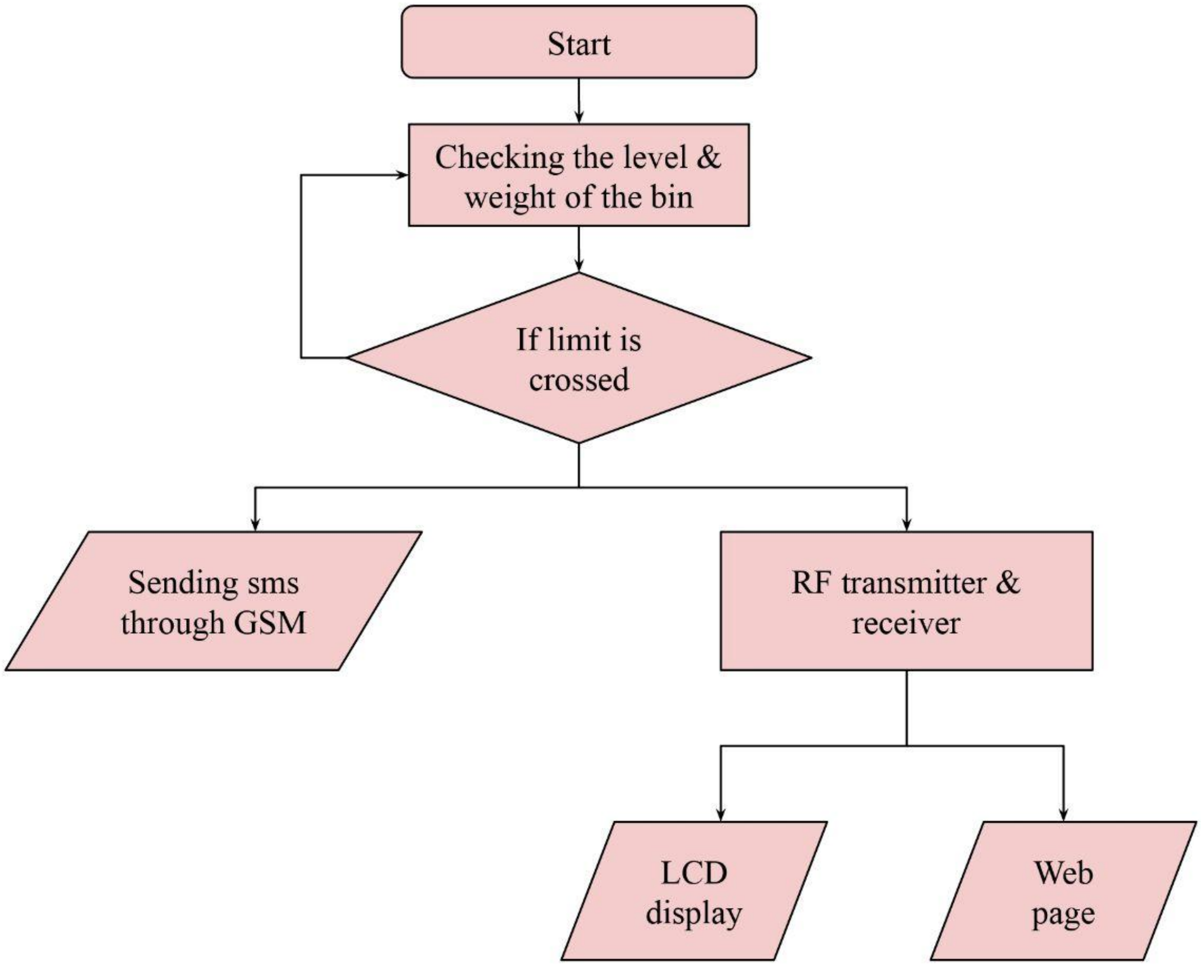

Fig. 15. Flow chart for IoT based solid waste management system for smart city [11]

To begin with the waste level and weight of the bin is checked by load cell and ultrasonic sensor. If the limit is crossed an SMS is sent to the concerned personnel with the help of a GSM module. Furthermore the data is shown at an output LCD display and webpage.

Proposed design approach: Design and Implementation of Smart Waste Bin for Office Place.

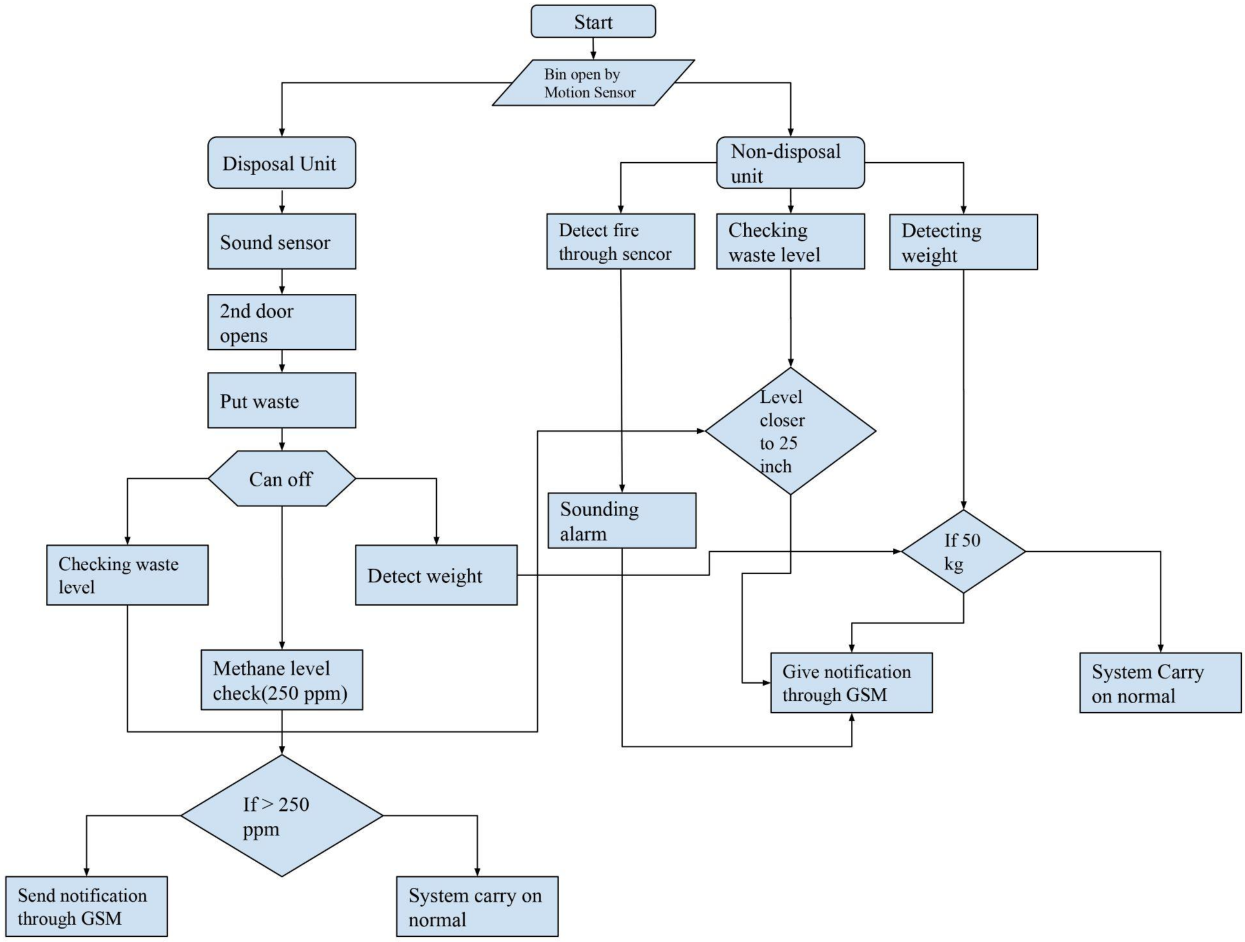

Fig. 16. Flow Chart Design and Implementation of Smart Waste Bin for Office Place.

To begin, when the motion sensor is triggered, the main lid of the bin opens. There are two compartments, a disposal and a non-disposal unit. The non disposal unit can be used right away. The smoke, gas and ultrasonic sensor take readings and display the status of the bin on LCD. The ultrasonic sensor is triggered if the level of 26 inches is crossed. The gas sensor is triggered if the methane level crosses 250 ppm. The smoke sensor is triggered at any instance of fire that produces smoke. If any anomalies are detected, an SMS is sent by the GSM module to the concerned personnel. For the disposal unit, one has to trigger the sound sensor to open the second lid. After disposing of the waste it is then detected by the smoke, gas and ultrasonic sensors to check the status. Firstly, the weight and waste level is detected. The smoke and gas sensors detect fire and toxic gas. If a methane level of 250 ppm is detected by the gas sensor it is triggered. If any anomaly is detected a similar SMS is sent by the GSM module to the concerned personnel.

2.4 Analysis of multiple design approach

2.4.1 Qualitative assessment

TABLE III. Qualitative assessment the three design approaches

Topics	Existing approach 1	Existing approach 2	Proposed approach 3
Volume Detection	(√)	(√)	(√)
Weight Detection	(√)	(√)	(√)
Gas Detection	(X)	(X)	(√)
Display	(X)	(√)	(√)
Contactless operation	(X)	(X)	(√)
Fire Detection	(X)	(X)	(√)
Humidity Detection	(√)	(X)	(√)
Disposable Chamber	(X)	(X)	(√)

In the proposed design approach:

1. Built-in fire detection system to prevent fire accidents that cannot be detected by the other two approaches.
2. It is also equipped with a system that detects toxic gas (methane) generated inside the container.
3. The system is equipped with an automatic motion sensor. This may be useful in relation to the COVID-19 situation, as there is no need to touch anything.
4. The system can be notified so assigned workers know when bins will be filled and cleaned accordingly.

2.4.2 Quantitative assessment

TABLE IV. Quantitative analysis the three design approaches*

Selection Criteria	Percentage out of 100	Existing Approach 1	Existing Approach 2	Proposed Approach
Ease of Use	12	9	9.5	11
Durability	12	7	8	10.5
Ease of Manufacture	15	9	10	10
Portability	12	7	7.5	8.5
Availability of Components	15	8	9.5	11.5
Complexity level of working	12	7	9	11
Budget	12	9	8	10.5
Environmental Friendliness	6	3	4	4.5
Risk and Safety	4	2	2.5	3.3
Total (out of 100)	**100**	**61**	**68**	**80.8**

*Scoring is done by the four members

2.5 Conclusion

In summary, a smart touchless waste bin design approach is a promising solution to the challenges of waste management. By providing a no-touch, hygienic waste disposal system, these bins can improve the overall cleanliness of any environment while reducing the spread of germs and bacteria. Incorporation of IoT can provide value for improving waste management practices and moving towards a more sustainable future.

As more individuals and organizations become aware of the importance of smart waste management, the demand for smart, hands-free waste bins is likely to grow. With their elegant design and practical functionality, these bins blend seamlessly into any office space, making them a valuable addition to any professional workspace. Overall, the smart, hands-free bin design approach represents a major advance in waste management technology, improving overall community cleanliness and sustainability while making waste disposal more convenient and hygienic for all. As we continue to look for ways to reduce waste and improve our environmental impact, the development and implementation of smart, hands-free waste bin will undoubtedly play a key role in achieving these goals.

Chapter 3: Use of Modern Engineering and IT Tools.

3.1 Introduction

The development of our smart hands-free waste bin has been made possible by the use of the latest engineering and IT tools. These tools enable the integration of sensors and other technologies, allows the bin to work seamlessly, and provides a contactless, hygienic waste disposal system.

3.2 Select appropriate engineering and IT tools

In order to design our project numerous engineering tools are required. They can primarily be divided into three sections.

1. Design tools.
2. Simulation tools.
3. Coding tools.

3.3 Use of modern engineering and IT tools

3.3.1 Design tools

TABLE V. Selection of Design Tools

Criteria	SketchUp Pro 2021	Autocad	Blender
Prerequisite of Usage	☑	(x)	(x)
Architectural Model Design	☑	(x)	(x)
Ease of Learning	☑	(x)	☑
Quality of Design	☑	☑	☑
3D Rendering	(x)	☑	☑

The Sketchup is a 3D modeling software that can be used to create 3D objects in a 2D environment. Whether you plan to model for 3D printing or for other purposes, Sketchup offers all the tools needed to produce professional and quality results even for a beginner. It is designed for high quality 3D modeling programs in architectural design. The software is very friendly to design anything with the knowledge of 1 or 2 tutorial sessions from youtube.

Blender is the free and open source 3D creation suite. It supports the entirety of the 3D pipeline i.e. modeling, rigging, animation, simulation, rendering, compositing and motion tracking, even video editing and game creation. Though this tool provides some unique features, it requires prior knowledge and is tough to learn the designing methods. Moreover it is not that good in architectural design which is a key requirement for us.

AutoCAD is the CAD software used by millions around the world. It can be used to create precise 2D and 3D drawings and models, as well as electrical diagrams, construction drawings, and more. Despite having a large community and good quality design, AutoCAD is not good for architectural model design compared to sketchup and it is not friendly to learn.

3.3.2 Simulation tools

TABLE VI. Selection of Simulation Tools

Criteria	Proteus	Tinkercad	AutoDesk Eagle
Component Library	☑	(x)	(x)
Schematics Design	☑	(x)	(x)
User Interface	☑	☑	☑
Pricing	☑	☑	(x)

The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. As our project is based on Arduino Uno so most of the components can be easily found in the latest updated software. We have used several sensors which can also be found in the Proteus software library such as HX711, SIM900 etc. If any component is not found in the library then we can easily collect and upload in the library which is very easy. For real life simulation experience we need to run circuit design with code and verify the result. It is easy to upload code in circuit from CodevisionAVR or arduino which was mandatory for this project. Moreover, we are already familiar with this software from various course lab experiments. Thus we have selected Proteus software.

Tinkercad Circuits is a popular digital and analog electronics simulator for hobbyists, students, and makers. But it is more like an online 3D modeling program that runs in a web browser. So it is good for 3D design. The components library is not that rich and the schematic diagram from proteus is better than this. We are not familiar with this.

EAGLE is electronic design automation (EDA) software that lets printed circuit board (PCB) designers seamlessly connect schematic diagrams, component placement, PCB routing, and comprehensive library content. Mainly it is good for PCB designing and it is new for us.

So based on this analysis we have selected Proteus for our circuit design.

3.3.3 Coding Platforms

TABLE VII. Selection of Coding Platforms

Criteria	Geany	Arduino IDE	PlatformIO
Variation of development board	(x)	(x)	(x)
Component Library	(x)	☑	(x)
Ease of learning	(x)	☑	(x)
Available community	(x)	☑	(x)

Geany is the coding platform for Raspberry Pi. It provides several features. Variation of development board supported by geany is lower compared to Arduino IDE and PlatformIO. In terms of the availability of the components library, other good options are available. The supporter community is lower and it's a bit tough to learn this platform.

The Arduino IDE is the most used platform nowadays. It has a huge collection of component libraries and there is a huge community available for helping if any kind of problem is detected. As there are lots of users, a huge amount of tutorial sessions are available. So, it will be easier to learn. Overall this one is perfect for this project,

PlatformIO is used for coding platform purpose.But most of the users are not familiar with this platform. As the user base is lower compared to Arduino IDE, the available community is smaller and the setup of this platform is quite hard. Limited tutorial sessions make it difficult to learn the techniques. Variation of development board is lower compared to Arduino IDE.

Based on this analysis we have selected ArduinoIDE as the coding platform.

3.4 Conclusion

We have chosen the design, simulation and coding tools depending upon the criterias as depicted above in order to design our project efficiently and effectively. While doing so, we have also considered the possibility of ease of use, time constraint and availability of resources such that we may design the project as per requirement. User-friendliness was a top priority when choosing a design tool. Selected tools offer intuitive interfaces and user-friendly features to help designers create models and simulations quickly and accurately. Prioritizing ease of use allows designers to spend more time building and testing projects without struggling with complex tools and features, so projects run more efficiently. Time constraints were another important criterion considered when choosing a suitable design tool. The tools of choice lend themselves to rapid prototyping, allowing the team to quickly build and test multiple iterations of the project. This is critical to meeting demanding project deadlines while maintaining high standards of quality and accuracy.

In summary, choosing the right design, simulation, and coding tools is critical to the successful implementation of a Smart Waste Bin project. By prioritizing ease of use, time constraints, and resource availability, projects can be completed efficiently and effectively while maintaining high standards of quality and accuracy.

Chapter 4: Optimization of Multiple Design and Finding the Optimal Solution.

4.1 Introduction

Designing multiple solutions according to our requirements is of utmost importance. First two designs were developed and optimized based on existing solutions. The final proposed design is developed and enhanced incorporating the multiple beneficial features of the existing solutions. The design, simulation and evaluation of feedback are to be conducted thoroughly in order to develop a feasible design.

4.2 Optimization of multiple design approach

4.2.1 Optimization of Existing Approach 1

This is the first design approach that we have simulated in Proteus.

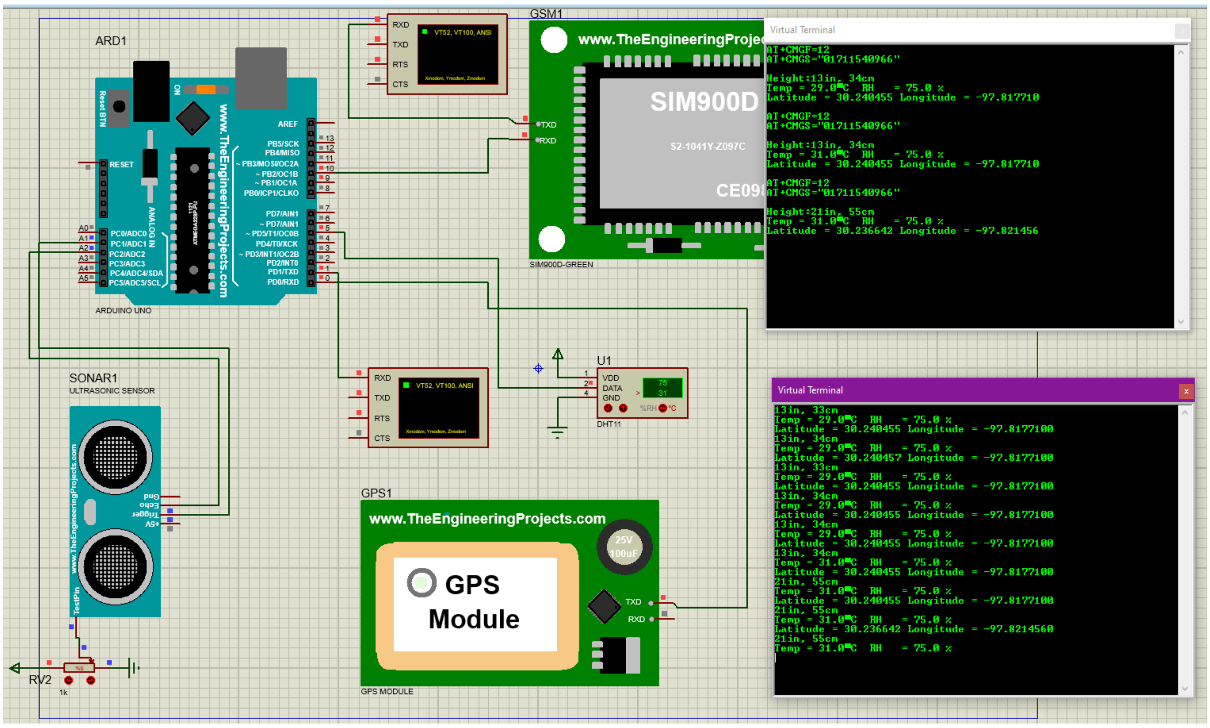

Fig. 17.Schematic diagram of a Smart Waste Management Solution geared towards citizens [2]

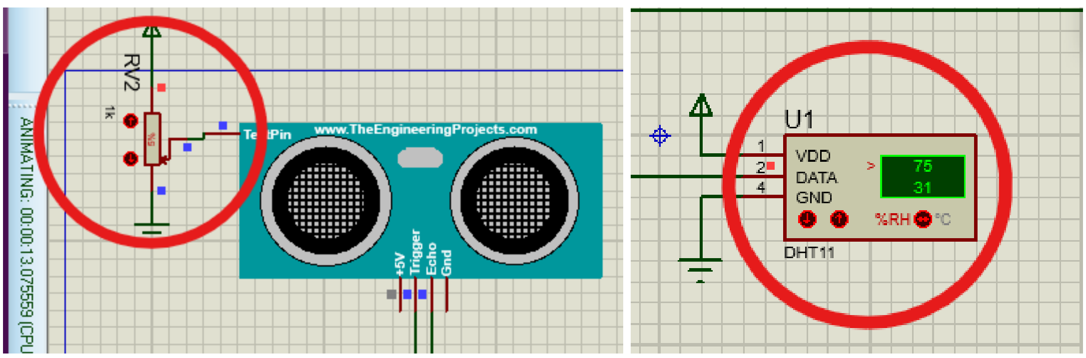

Fig. 18. Ultrasonic sensor and Temperature and humidity sensor.

Here we have used a potentiometer to simulate the level of waste inside the bin. Furthermore we have used the DHT11 sensor as the temperature and humidity sensor to collect temperature and humidity data .

Case 1:Update in webpage

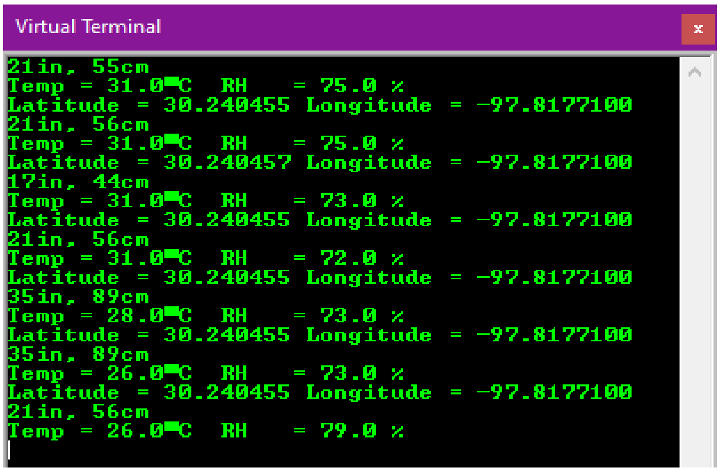

Fig. 19. Sending Data to webpage

The above shows the data that has been sent to the webpage. We get continuous updates about temperature, humidity, bin location and the space that is full. For example, the first data reflects that the Ultrasonic data is 21 inch (55cm), and the temperature inside the bin box is 31 celsius along with the humidity being 75%. The latitude and longitude information are sent by the GPS module which helps to detect the location. As the bin is fixed in a place so the GPS output is constant. These data are updated in the website automatically after a certain time period.

Case 2: Update in mobile phone

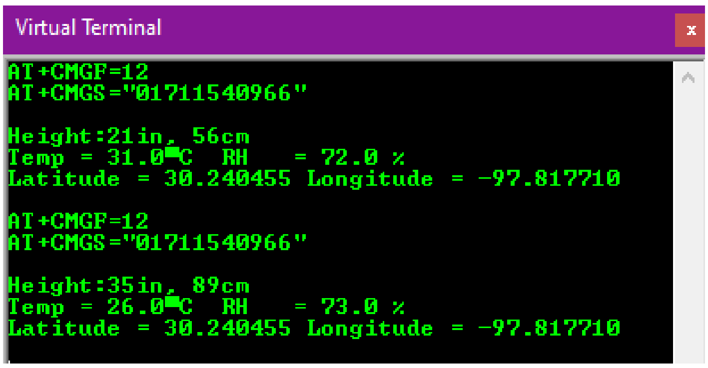

Fig. 20. Sending Data to mobile phone

This above result denotes the smartphone application. We have tried to simulate this as a mobile phone. All the information has been sent to the mobile phone by the GSM module which makes the user aware of the current situation inside the bin. We can see the phone number where the update was sent. After a certain period of time the information in the application gets updated. For example, height, temperature, humidity and location data are sent to the user whose phone number is 01711540966.

4.2.2 Optimization ofExisting Approach 2

This is the second design approach that we have simulated in Proteus.

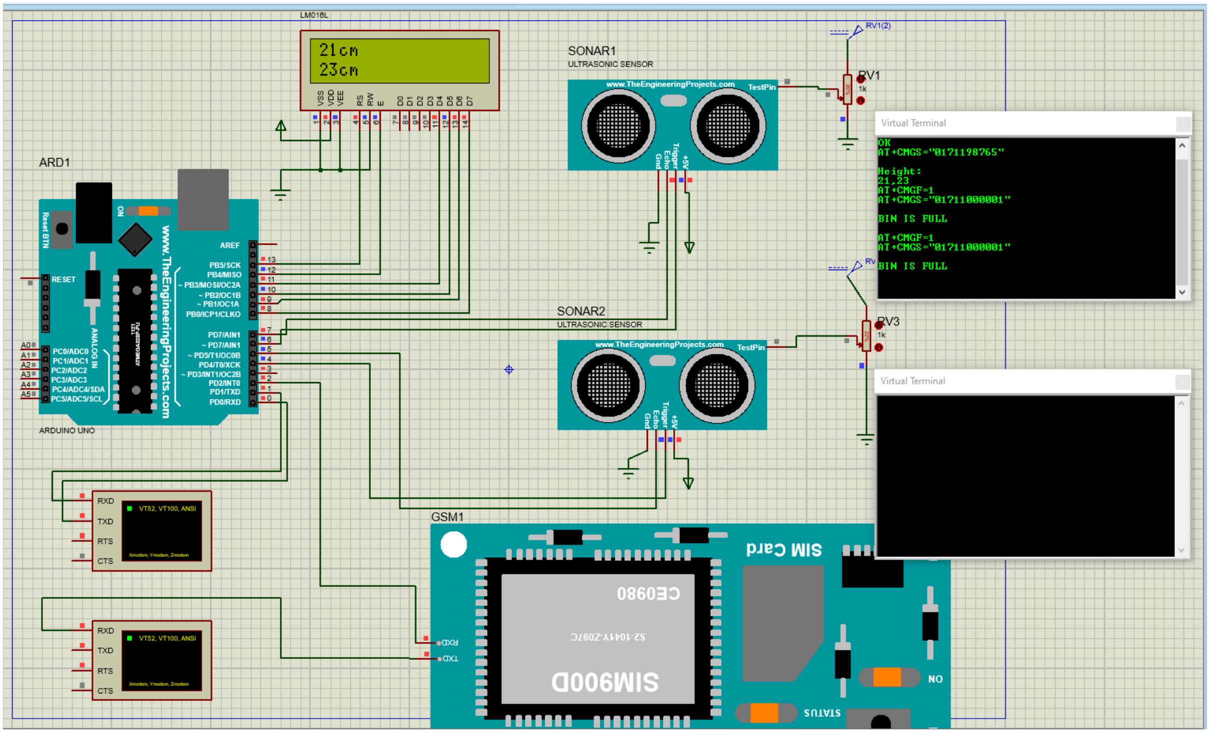

Fig. 21. Schematic diagram of IoT based solid waste management system for smart city.[18]

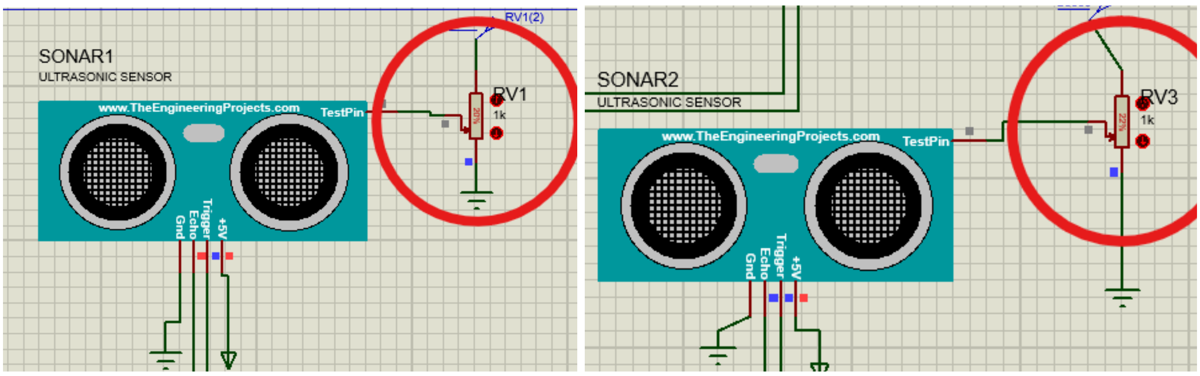

Fig. 22. Two ultrasonic sensors for waste level detection.

Here, two ultrasonic sensors are used for accurate reading of the waste level. The waste level is simulated by two potentiometers connected to the Test pin of the Ultrasonic sensors.

Case 1: Update in display

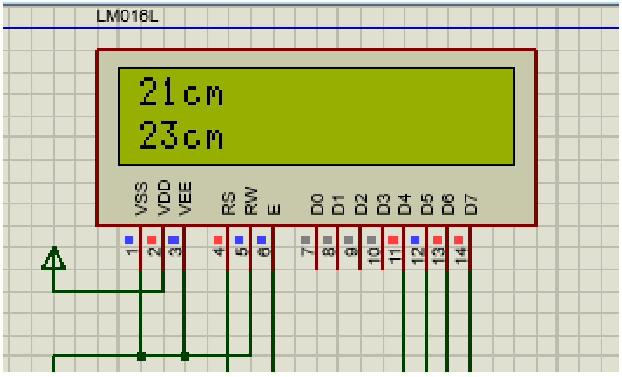

Fig. 23. Status of the bin in LCD display

This figure shows a 16x2 LCD with some calculated result from the schematic diagram of approach 2. From the schematics design we know that two ultrasonic sensors are connected in the design for better reading of the waste height. So, they collect data and the code has been written in such a way that the result will be sent through Arduino Uno to the LCD monitor and be displayed. Here the results for 2 sensors are 21cm and 23 cm.

Case 2: Update in display

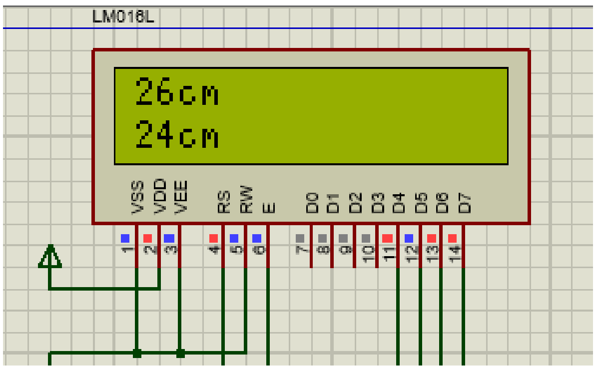

Fig. 24. Status of the bin after some waste is thrown in LCD display

This figure shows a 16x2 LCD with some calculated result from the schematic diagram of approach 2. The data has been updated from the previous data. For the previous case it was 21 and 23 cm but now the output data is 26 and 24 cm.

Case 3: Sms when overload

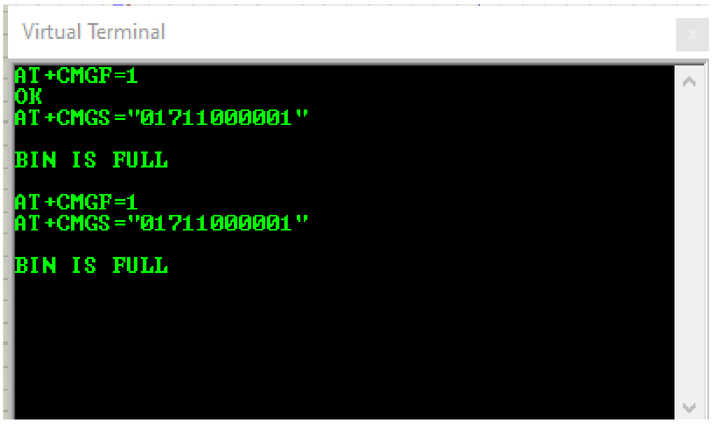

Fig. 25. Sending SMS when bin is overloaded

This shows the information that has been sent to the mobile phone by the GSM module which makes the user aware of the current situation inside the bin. We can see that a phone number is given inside the code. Whenever the waste height crosses 26 cm, a message is sent to the user saying the "BIN IS FULL".

Case 4:Status check via sms

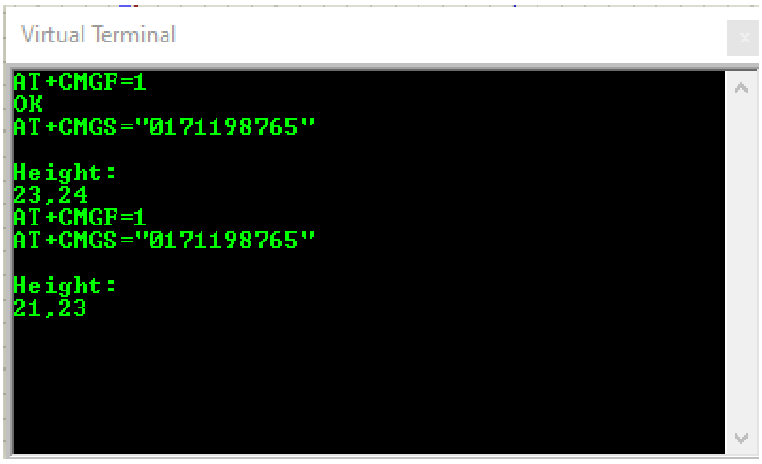

Fig. 26. Sending SMS of the status of the bin

This information has also been sent to the mobile phone by the GSM module about the waste level of the bin. This information is important as without being closer to the bin we can check whether the bin is full or not. For this the user has to send a sms to the bin denoted as "R" to send sms and in return the bin will send a return sms showing the "Height". Here we can see the height is 21 and 23 cm.

4.2.3 Optimization of Proposed Approach

This is the schematic design according to the proposed approach.

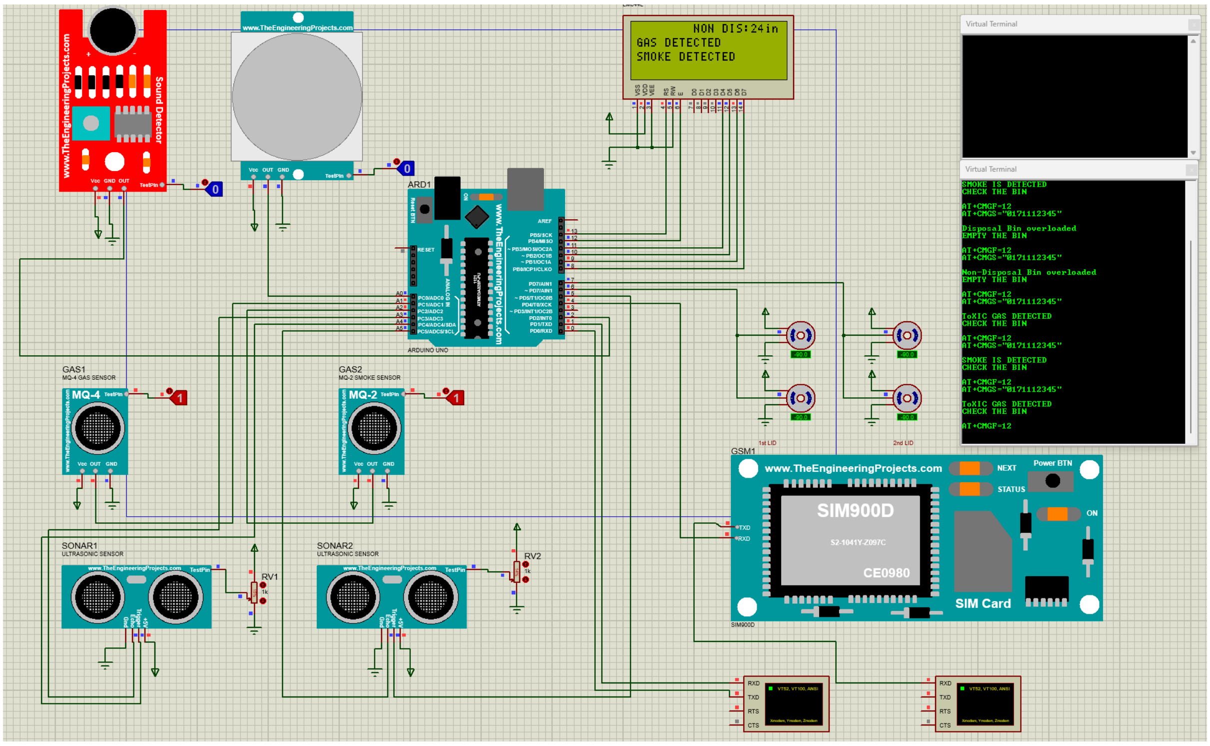

Fig. 27. Schematic diagram of the proposed approach.*

*Due to some software complications we could not simulate the weight detection system in the simulation.

Case 1: Non-Disposal unit bin operation

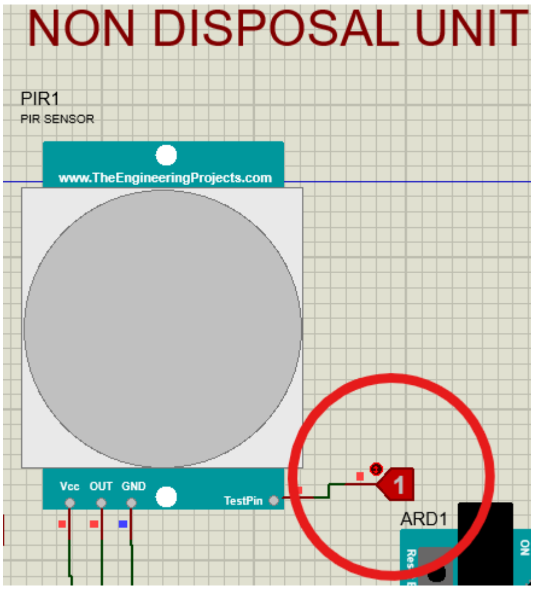

Fig. 28. Toggling of PIR Sensor

In This figure we can see a PIR sensor that has been used in our proposed design approach. This sensor is connected with 2 servo motors which will be used to open and close the non-disposal unit lid. A logic toggle has been used to simulate the active status of the sensor. The logic toggle has been set to '1' to make the sensor active for operation.

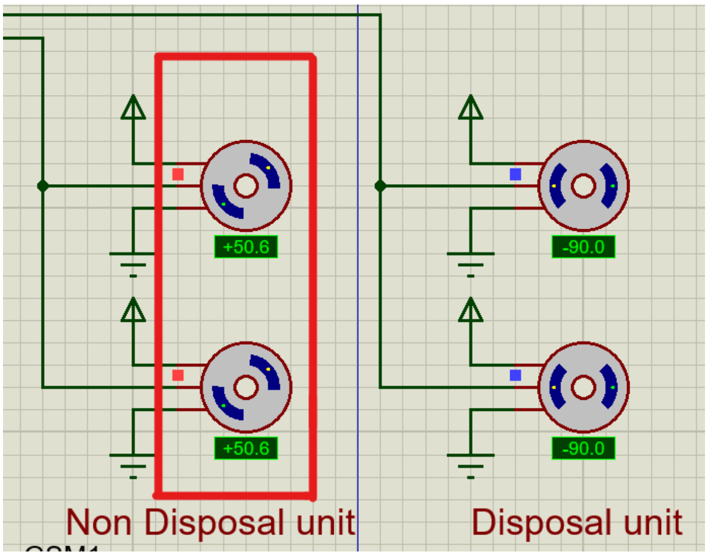

Fig. 29. Movement of motor

This figure shows the connected servo motors with the PIR sensors that will operate the lid of the non-disposal compartment. We can see that when the logictoggle of PIR sensor is set '1'(Sensor active) then the motor starts rotating which means the lid is opening. After a certain delay the motor moves back to its previous position which means the bin is closed.

Case 2: Disposal unit bin operation

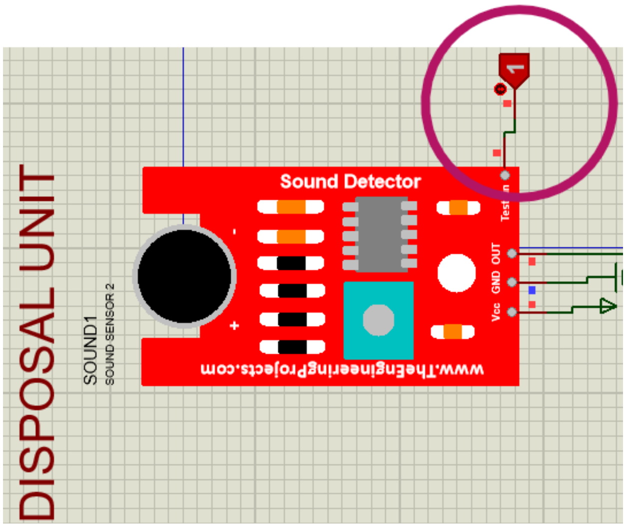

Fig. 30. Toggling of sound sensor

This figure shows a sound sensor that is connected with the lid of the disposable unit compartment and will be used to open and close that. The value of logic toggle '1' means that the sensor is active.

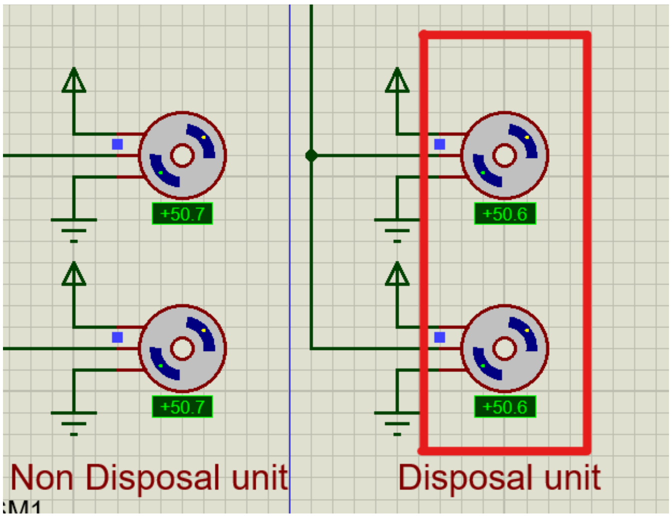

Fig. 31. Movement of motor

This figure shows the connected servo motors with the sound sensors that will operate the lid of the disposable compartment (2nd lid in picture). We can see that when the logic toggle of the sound sensor is set '1'(Sensor active) then the motor starts rotating which means the lid is opening. After a little delay the motor moves back to its previous position which means the bin is closed.

Case 3: When waste overloads (For Disposal Unit)

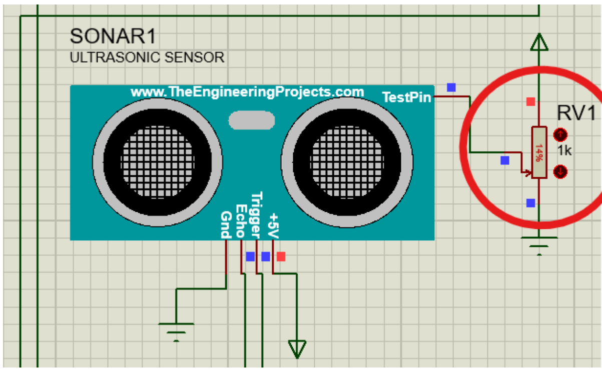

Fig. 32. Ultrasonic sensor in the disposal unit

Here, the ultrasonic sensor's level is simulated by a potentiometer. When we increase the value of the potentiometer, the waste level for the disposal unit increases.

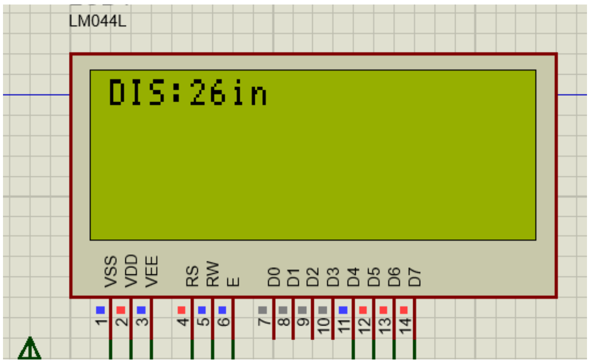

Fig. 33. Status of the bin in LCD display

This 20x4 LCD display has been used in schematic design to show results. From the upper figure we can see that the ultrasonic sensor result is 26 inches which is the maximum waste level.

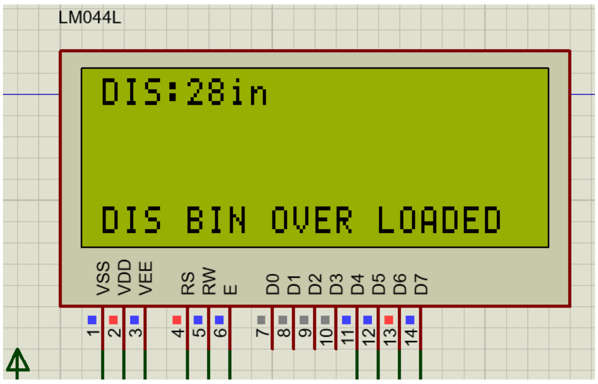

Fig. 34. Displaying the status of the bin when disposal unit is overloaded in LCD

This figure is the updated version of the previous data where ultrasonic sensor (disposal unit) reading was 26 inches. From the upper figure we can see that the ultrasonic sensor result is 28 inches which has crossed the maximum waste level. So the message "DIS BIN OVER LOADED" is seen in the LCD display.

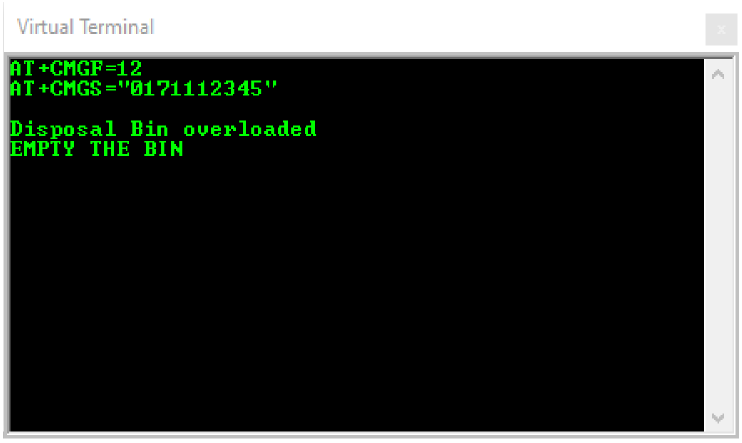

Fig. 35. Sending SMS when the disposal unit of the bin is overloaded

We have used a SIM900 GSM module in our schematic diagram to send messages to the user's mobile phone. From the previous LCD display we came to know that the disposal unit sensor reading has crossed the maximum waste level so the bin is overloaded. That same information has been sent to the user by the GSM module. An instruction is also given to empty the bin.

When waste overloads (For Non-Disposal Unit)

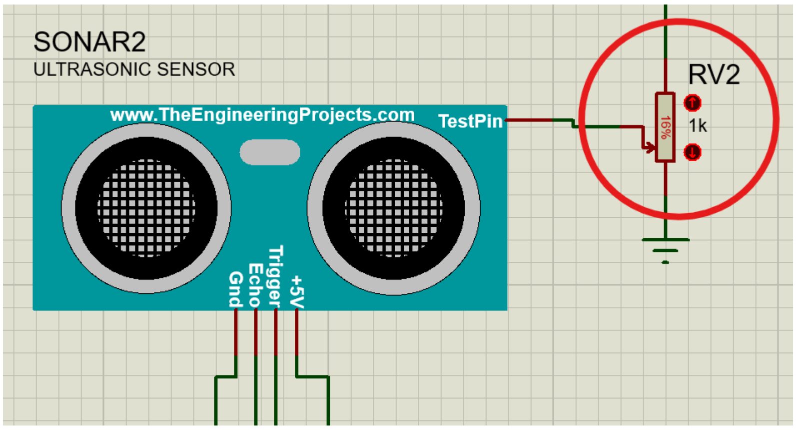

Fig. 36. Ultrasonic sensor in the non disposal unit

Similarly, for the non disposal unit, the ultrasonic sensor's level is simulated by a potentiometer. When we increase the value of the potentiometer, the waste level for the non disposal unit increases.

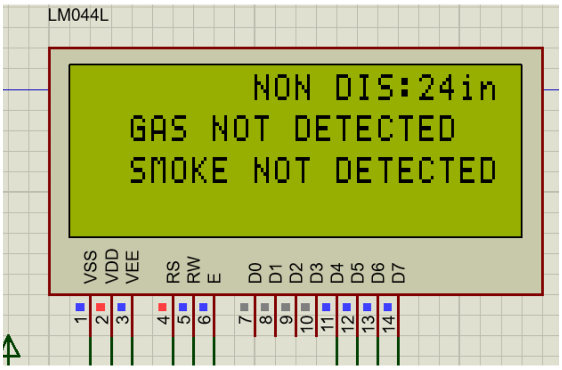

Fig. 37. Displaying the data from the gas and smoke sensors on LCD

The figure shows some results displayed in a 20x4 LCD monitor. From the schematic diagram we know MQ-2(smoke) & MQ-4(gas) are used. Here we can see that the waste level is 24 inches inside the non-disposal unit. The gas and smoke sensors could not detect the presence of fire or gas.

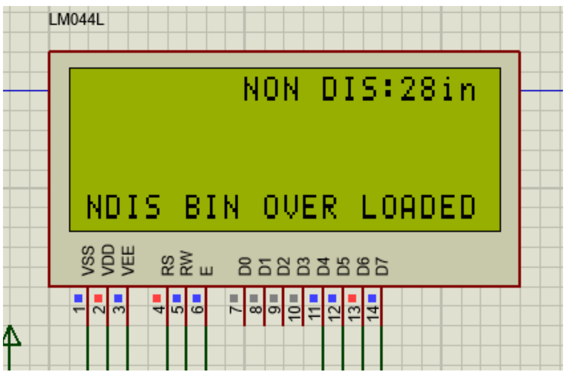

Fig. 38. Displaying the status of the bin when non disposal unit is overloaded in LCD

This figure shows waste level information through a 20x4 LCD display. From the upper figure we can see that the ultrasonic sensor (Non-disposal unit) result is 28 inches which has crossed the maximum waste level 26 inches. So the message “NDIS BIN OVER LOADED” is seen in the LCD.

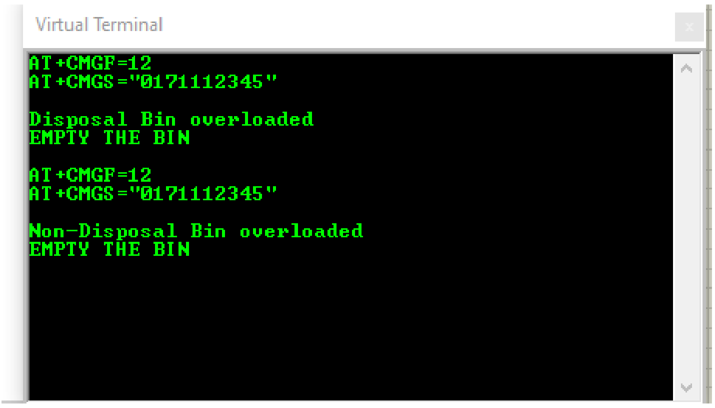

Fig. 39. Sending SMS when the non disposal unit of the bin is overloaded

From the previous LCD display we came to know that the non disposal unit sensor reading has crossed the maximum waste level so the bin is overloaded. That same information has been sent to the user by the GSM module. An instruction is also given to empty the bin.

Case 4: Status check via SMS

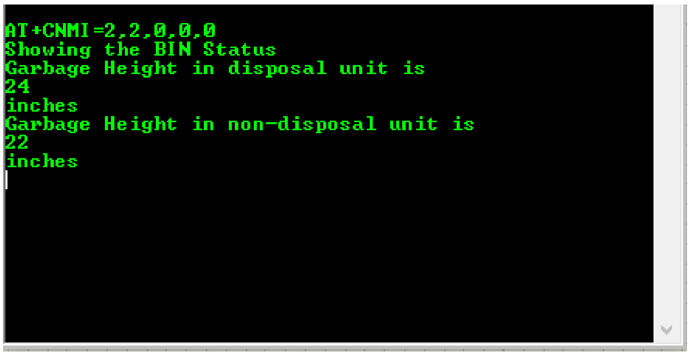

Fig. 40. Sending the status of the bin via SMS

We have used 2 ultrasonic sensors for two different compartments (one in disposal unit, another in non-disposal unit). In the upper figure we can see the information from 2 sensors at the same time that has been sent to the user's mobile phone. For this the user has to send a sms "R" and the bin will send a return sms that shows the status of height of the two compartments. Here disposal unit height was 24 inches and non-disposal unit height was 22 inches. So, the user can check the status of the bin wherever he is.

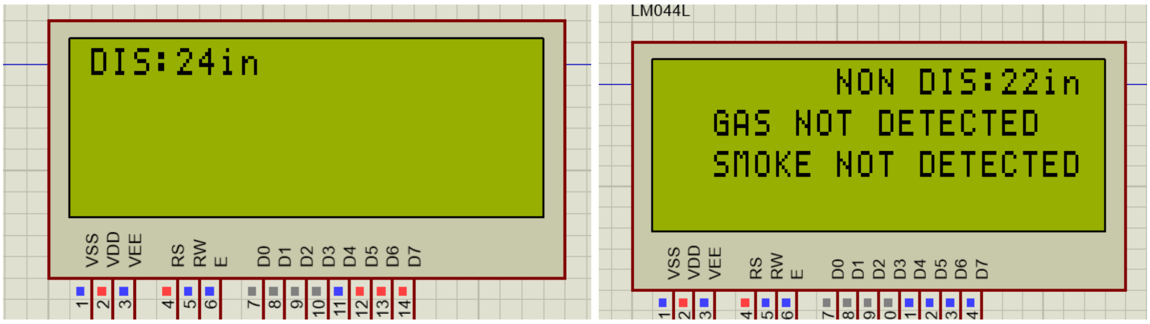

Fig. 41. Showing the status of the bin on LCD

In the LCD figure we can see sensor results from the disposal and the non disposal unit. This validates the previous message that was the status check. We can see that the waste level for the disposal unit was 24 inches and the non disposal unit was 22 inches.

Case 5: Gas detection

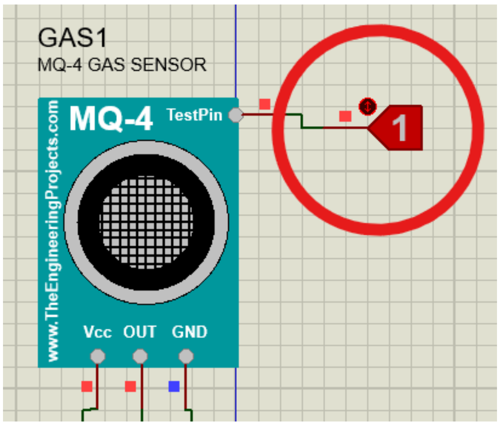

Fig. 42. Gas sensor triggered.

Here we can see the MQ-4 gas sensor is simulated using a logic toggle for triggering. We have used logic toggle in schematic for activating the gas sensor and set the value 1.

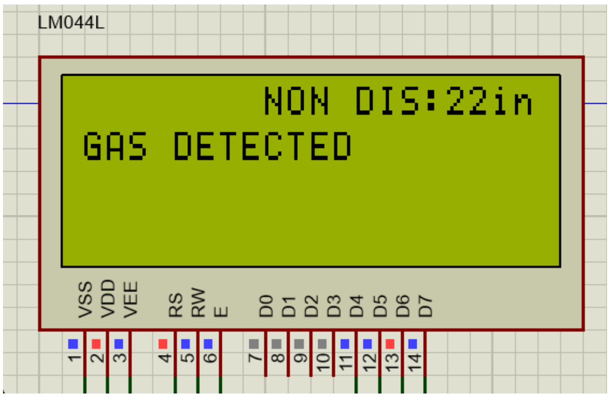

Fig. 43. Detection of toxic gas on LCD

When we activate the gas sensor, it detects methane gas presence inside the disposal unit and the display shows "GAS DETECTED".

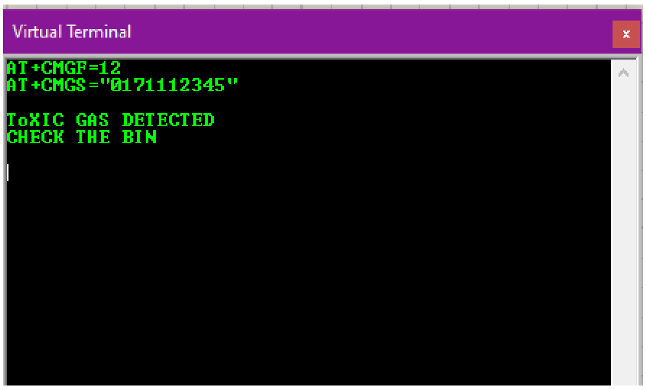

Fig. 44. Sending SMS for detection of toxic gas

From the previous LCD monitor we have detected excess methane gas inside the disposal unit. In this figure we can see a message of that data sent by the GSM module.

Case 6: Smoke detection

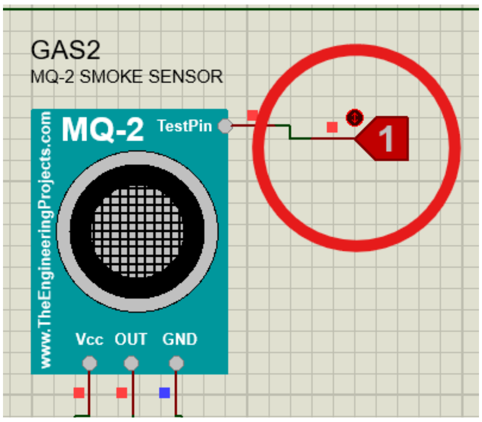

Fig. 45. Smoke sensor triggered.

In the above picture the MQ-2 smoke sensor is visible. Here, we have used logic toggle in schematic for activating the smoke sensor and set the value 1.

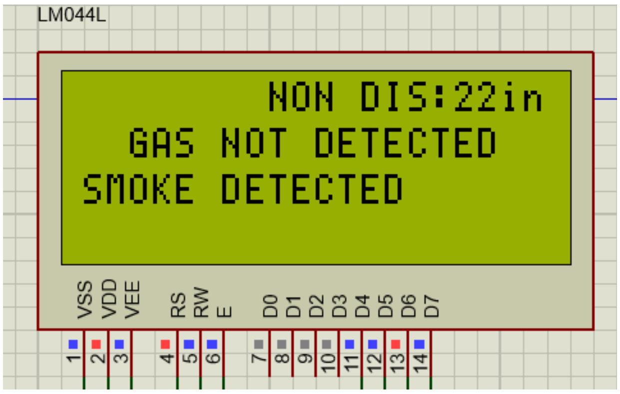

Fig. 46. Detection of smoke on LCD

When we activate the smoke sensor, it detects smoke presence inside the bin and the display shows “SMOKE DETECTED”.

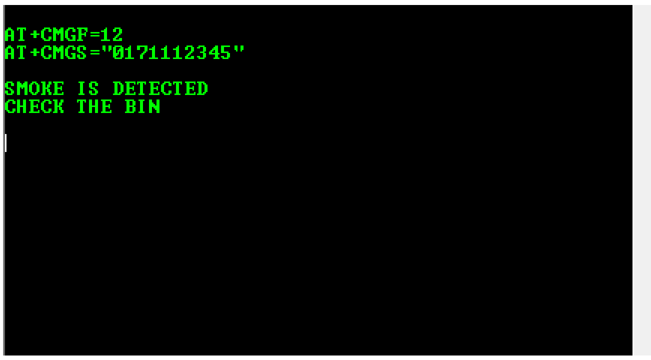

Fig. 47. Sending SMS for detection of smoke

In this figure we can see a message of the previous LCD display data sent by the GSM module to the user’s phone that smoke is detected and to check the bin.

4.2.4 3D Designing of proposed approach:

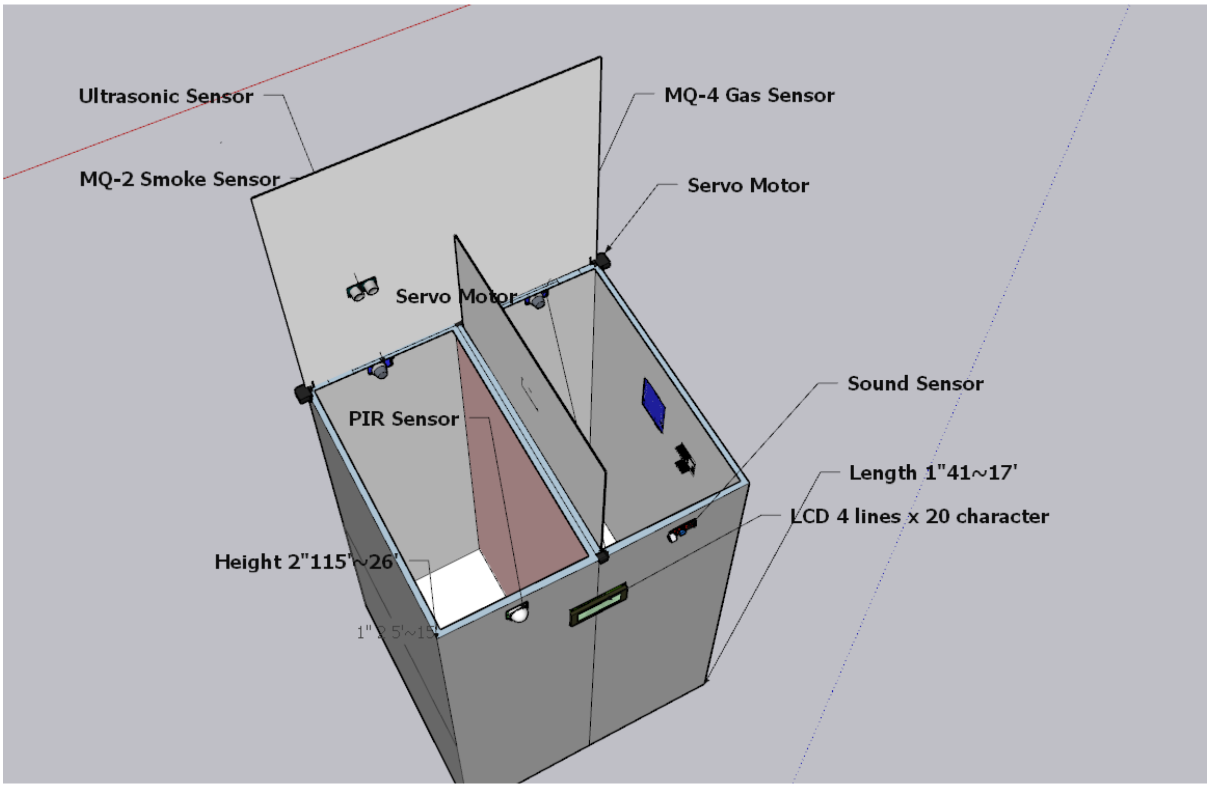

Fig. 48. 3D view of the bin (Top View)

The 3D model has been designed by using SketchUp. In the figure we can see that the PIR sensor has been installed in the front side of the box. A 20x4 LCD screen as well as a sound sensor are also set there. The whole bin structure measurement is 17x15x26 inches. An Arduino Uno has been installed on one side of the bin. Two servo have been attached with two lids to open and close when required. We can see two sensors (MQ-2&MQ-4). We faced some problems when setting the servo motor with the lids as the lids were not sealing one unit properly. Then we go for community help from youtube tutorials and come to know what will be the solution and apply that. The sketchup was a friendly software that we found every component easily. The measurement for the bin has been taken from several research paper studies. We have set the PIR sensor in the front part to detect human presence easily.

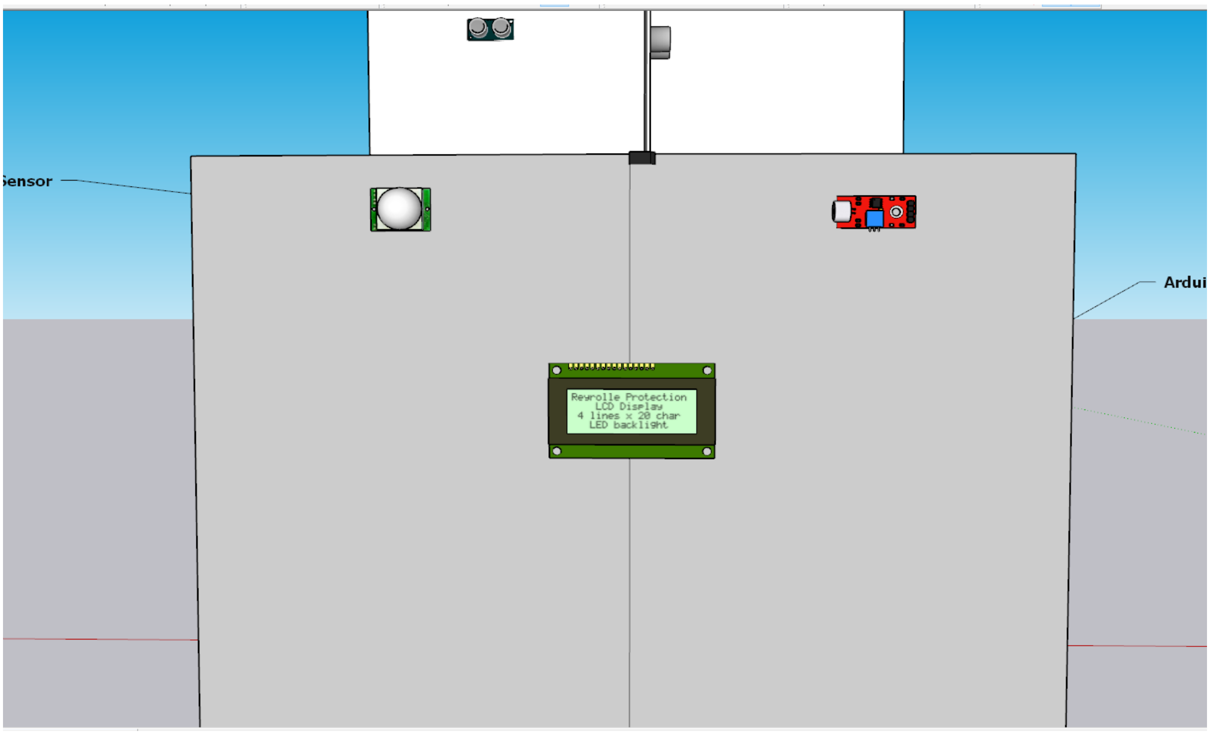

Fig. 49. 3D view of LCD, PIR and Sound sensor

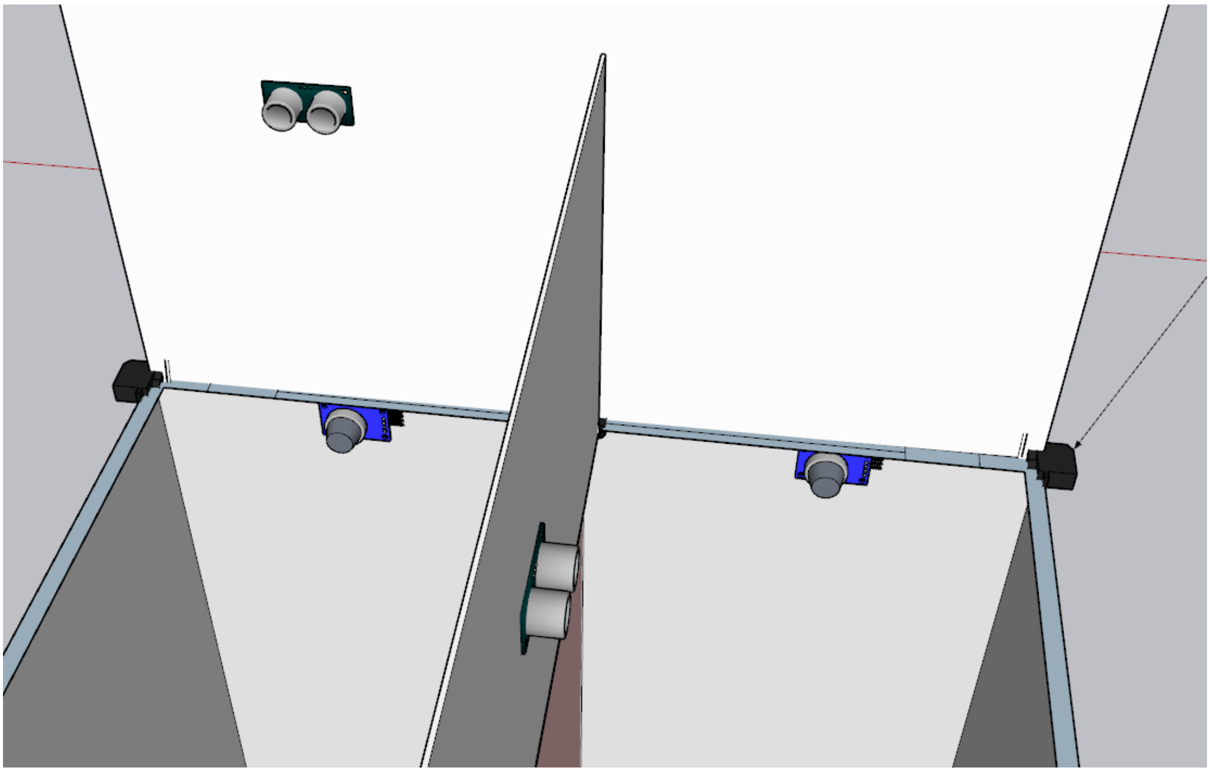

Fig. 50. 3D view of ultrasonic sensor, Smoke sensor, gas sensor and motor

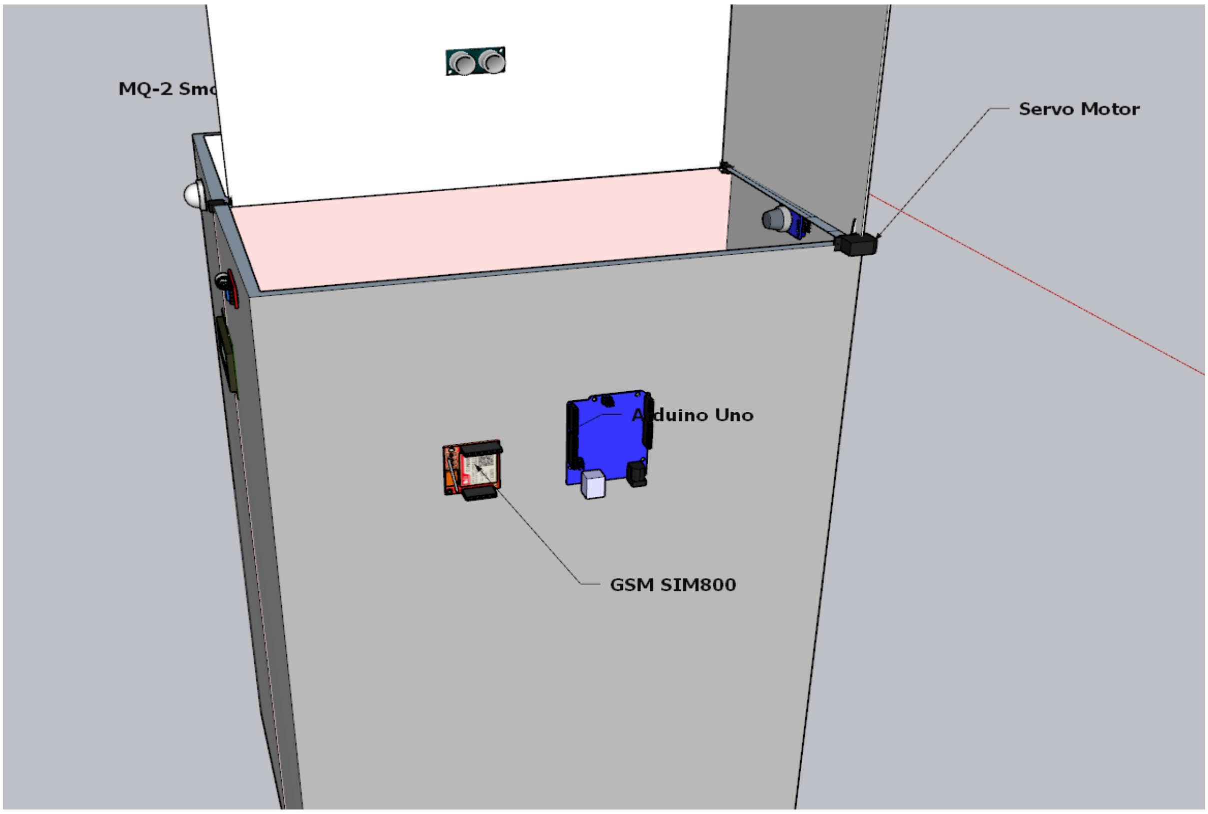

Fig. 51. 3D view of GSM module, Arduino and motor

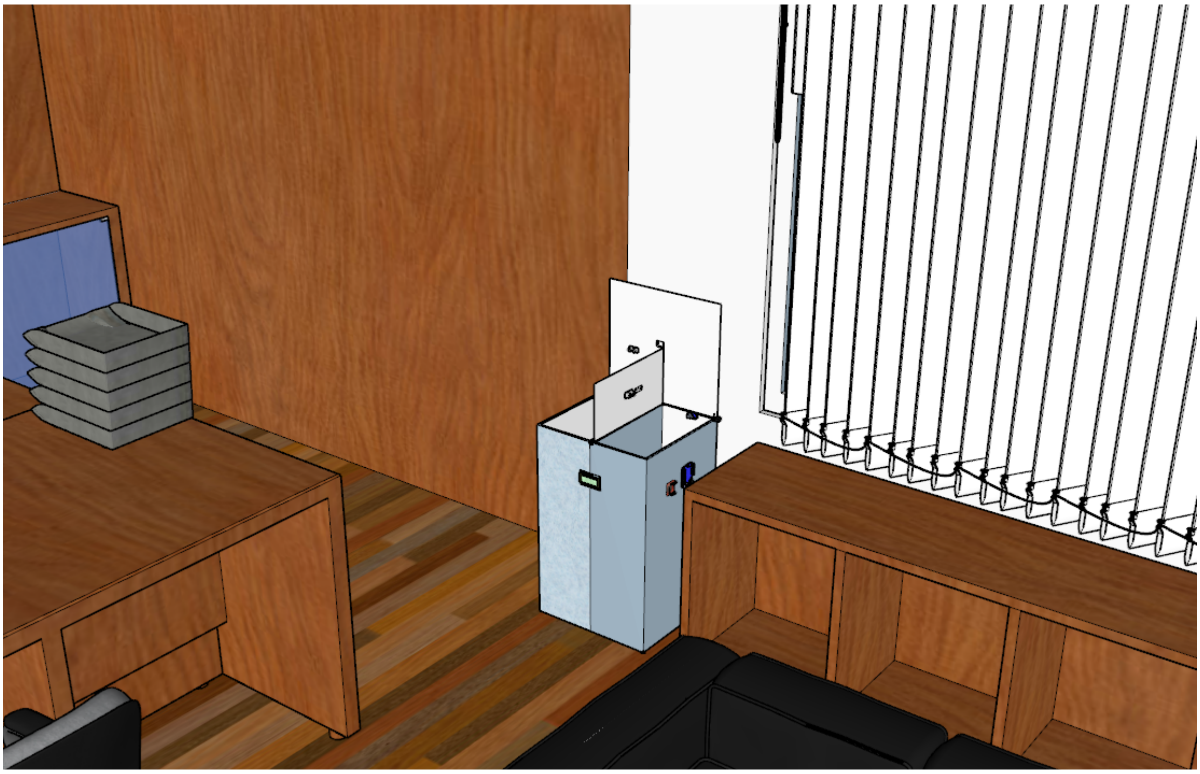
Fig. 52. 3D view of the bin in an office

The figure shows the 3D image of a smart waste bin inside the office. This office template was given inside the sketchup software.

4.3 Identify optimal design approach

TABLE VIII. Identifying the optimal design through analysis

Criteria	Design Approach 1	Design Approach 2	Design Approach 3	Preferred Design Approach
Avoid Human contact	No	No	Yes	Approach 3
Fire and Smoke detection	No	No	Yes	Approach 3
Toxic Gas Alert	No	No	Yes	Approach 3
Display	No	Yes	Yes	Approach 3
Double chamber	No	No	Yes	Approach 3
Portability	Yes	Yes	Yes	All
Cost	Cheap	Cheap	Expensive	Approach 1,2
Data collection	Yes	Yes	Yes	All
Mobile data visualization	Yes	Yes	Yes	All
Notification System	Yes	Yes	Yes	All

Due to the presence of toxic substances and microorganisms that threaten human health, protecting public health is of utmost importance when handling waste. While evaluating various design strategies, it is essential to prioritize safety measures. Our project utilizes a system that detects human presence and operates without physical contact, unlike design approaches 1 and 2, which lack features to prevent human contact. This method eliminates the need for human contact with waste, thereby ensuring a safe environment.

Using a variety of sensors, batteries, and other components in the container can result in short circuits and potentially start a fire. In addition, dry materials such as paper, bags, and plastics can exacerbate the situation by fueling the flames and causing accidents. Therefore, fire safety is an essential factor that must not be neglected. Despite this, design approaches 1 and 2 lack smoke detectors for detecting potential fires. Our initiative, on the other hand, includes a smoke sensor that provides real-time data to prevent such incidents. In addition, we have implemented a toxic gas detection system to detect toxic methane gas and promptly alert users, assuring the highest level of safety.

It is essential to separate different categories of waste in order to reduce government spending on waste management systems and improve environmental safety. Unfortunately, neither design approach 1 nor 2 provide distinct compartments for waste separation. However, design approach 3 addresses this issue by separating disposal and non-disposal waste into distinct rooms. This strategy allows us to ensure efficient recycling practices, which can have substantial economic and environmental effects. By effectively segregating waste, we can reduce the amount of waste sent to landfills and promote environmentally and economically sustainable practices.

Portability is an essential feature for any container, allowing for simple installation in any location. Fortunately, the three designs presented here are highly portable, making the installation process straightforward and uncomplicated.

Customers' primary consideration when purchasing a product is the price. Although design approaches 1 and 2 may appear to be more cost-effective, they lack vital safety sensors and offer few features. Our initiative, on the other hand, includes a variety of components that ensure stakeholders' needs are met, and accidents are avoided. Although the budget has increased, the added features make the product more user-friendly. Each of the three designs collects data using sensors that are then processed by microcontrollers and displayed on a web server. However, design approaches 1, 2 and 3 propose mobile data visualization, which shows data on a mobile device, thereby reducing the effort required to access a server.

After thorough consideration of all three designs, it is clear that approach 3, despite being slightly more expensive, provides essential features for ensuring safety, creating a user-friendly environment, and saving the government money.

4.4 Performance evaluation of developed solution

TABLE IX. Performance evaluation of Proposed Approach

Requirements	Expected Outcome	Validation
Compartments	Two separate chambers for disposable and non-disposable wastes	Validated
Touchless Operation	Opening and closing of the bin by sound and motion sensor.	Validated
Toxic gas detection	Detects the gas through gas sensor and shows the output in the LCD screen and also sends an sms to the concerned personnel	Validated
Weight	Weight detection could not be simulated because of limited resourses	Not Validated
Height detection	Detects the height through ultrasonic sensor and shows the output in the LCD screen and also sends an sms to the concerned personnel	Validated
Fire protection	Detects the fire by smoke sensor and shows the output in the LCD screen and also sends an sms to the concerned personnel	Validated
Navigation system	A GPS module incorporated provides navigation information in order to choose the most efficient way for collecting the waste by the dump trucks.	Not Validated
Notification System	A GSM module sends the required notification to the concerned personnel in times of a prompt.	Validated
Output Display	A 20x4 LCD Display on the bin shows the particular information of the bin such as waste level, smoke detection, gas detection etc.	Validated
Real time monitoring of data	A web page is required to display the real time data of the bin for the users	Validated

4.5 Conclusion

In conclusion, a comprehensive evaluation of three design approaches, using multiple criteria and considering both stakeholder demands and practical testing data, has led us to conclude that the third design approach we proposed not only meets but also exceeds the desired objectives.

Chapter 5: Completion of Final Design and Validation.

5.1 Introduction

The completion of our final design incorporates the implementation of our desired features and functionality of the project in order to achieve our requirements as proposed. It is of utmost importance to implement the project as designed with little to no variation. Furthermore, the validation of output and evaluation of feedback has to be conducted to assess the performance of the project.

5.2 Completion of final design

5.2.1 Methodology:

In order to implement the optimal design we have used the following steps:

i. We are using four 3.7V 1500mAh Li-Ion batteries mounted on a battery case to power every component of the project.

ii. For safety, we are using a 2A glass blow fuse that is connected on the positive terminal of the power supply and goes to ACS712-5A current sensor. From the current sensor, the connection is parallelly extended to a 5V relay module and five MP1584EN DC-DC BUCK modules.

iii. To open and close the main lid we are using a 12V DC 6 inch linear actuator which is connected to a 4 Channel 5V Relay Board Module. The two input pins of the module are connected with the digital pin 2 & 3 of the arduino and the positive and negative terminal of the actuator is connected to the relay itself.

iv. To open the disposal unit's lid we are using an MG995 metal servo motor with a mounted 25T metal servo arm that pushes the lid upwards. The PWM signal for the servo comes from the digital pin 11 of the arduino.

v. We are using three HC-SR04 ultrasonic sonar sensors to measure waste level in the disposal unit, the non-disposal unit and to open both lids. These sensors are connected from digital pins 4 to 9 of the arduino.

vi. For the disposal unit we are using MQ-4 gas sensor and for the non-disposal MQ-2 smoke sensor. The analog data comes directly from the sensors and is read through A0 and A1 pins of the arduino.

vii. To display data we are using a 20 by 4 LCD display mounted on the front side of the bin. The SDA & SCL of the I2C are connected to analog pins A4 & A5 of the arduino.

viii. We are using ESP32 to connect the device to “Blynk” IoT platform to visualize the sensor's data and device status through mobile application and website.

ix. Of the five MP1584EN DC-DC BUCK modules, the first buck module is set to 11V that powers the arduino itself. Arduino has a DC barrel jack and needs 9 to 12V to operate. The second buck module is set to 5V and it powers the ESP32 as it needs 5V to operate. The third buck module is set to 6V and it powers the MG995 servo motor. The motor typically needs 4.8V to 7.2V to operate. The last buck module is set to 5V and it powers all the Ultrasonic sensors, MQ sensors, current sensor, relay module & LCD display.

5.2.2 Developed Prototype:

According to our 3D design, we have developed the prototype with pvc boards. We have maintained the 17x15x26 inch structure. On the front side LCD display and an ultrasound sensor is placed. Ultrasound sensor 3 detects the presence of the user. If a person is in front of the sensor for 5 seconds, the top lid will open.

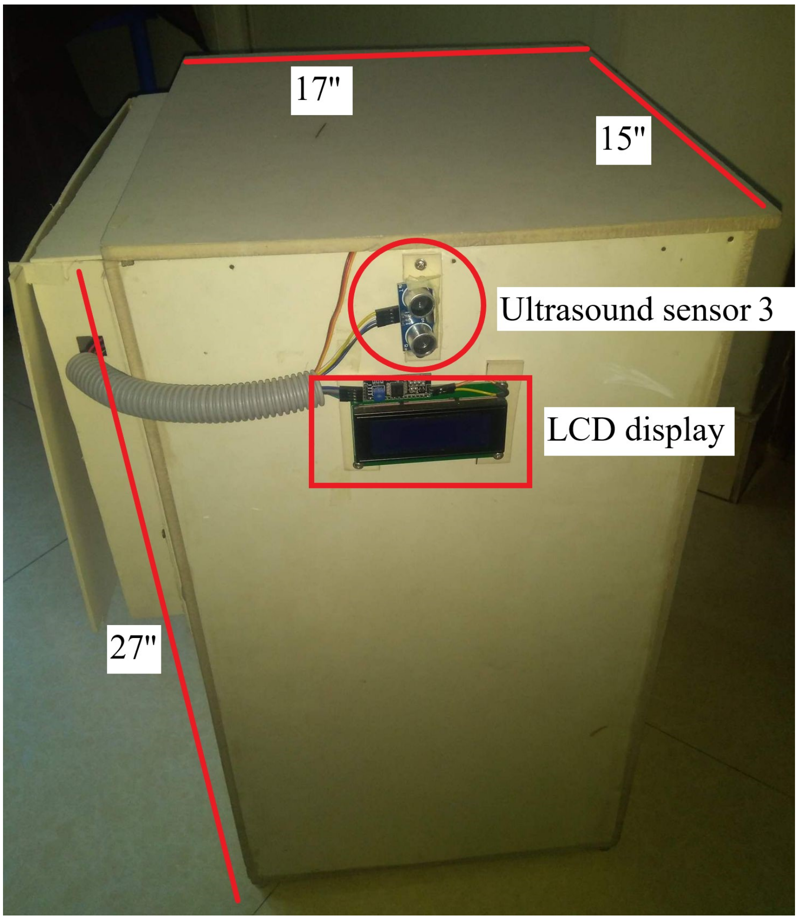

Fig. 53. Front view on the bin

The electrical components are mounted on the side of the bin and have its own cover.

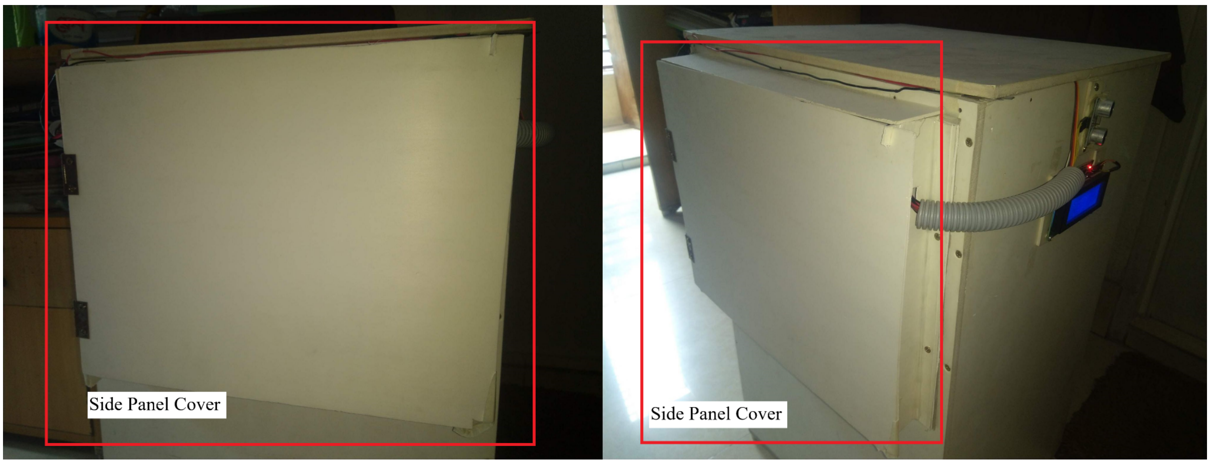

Fig. 54. Side view of the bin.

Inside the side panel we can see the following components.

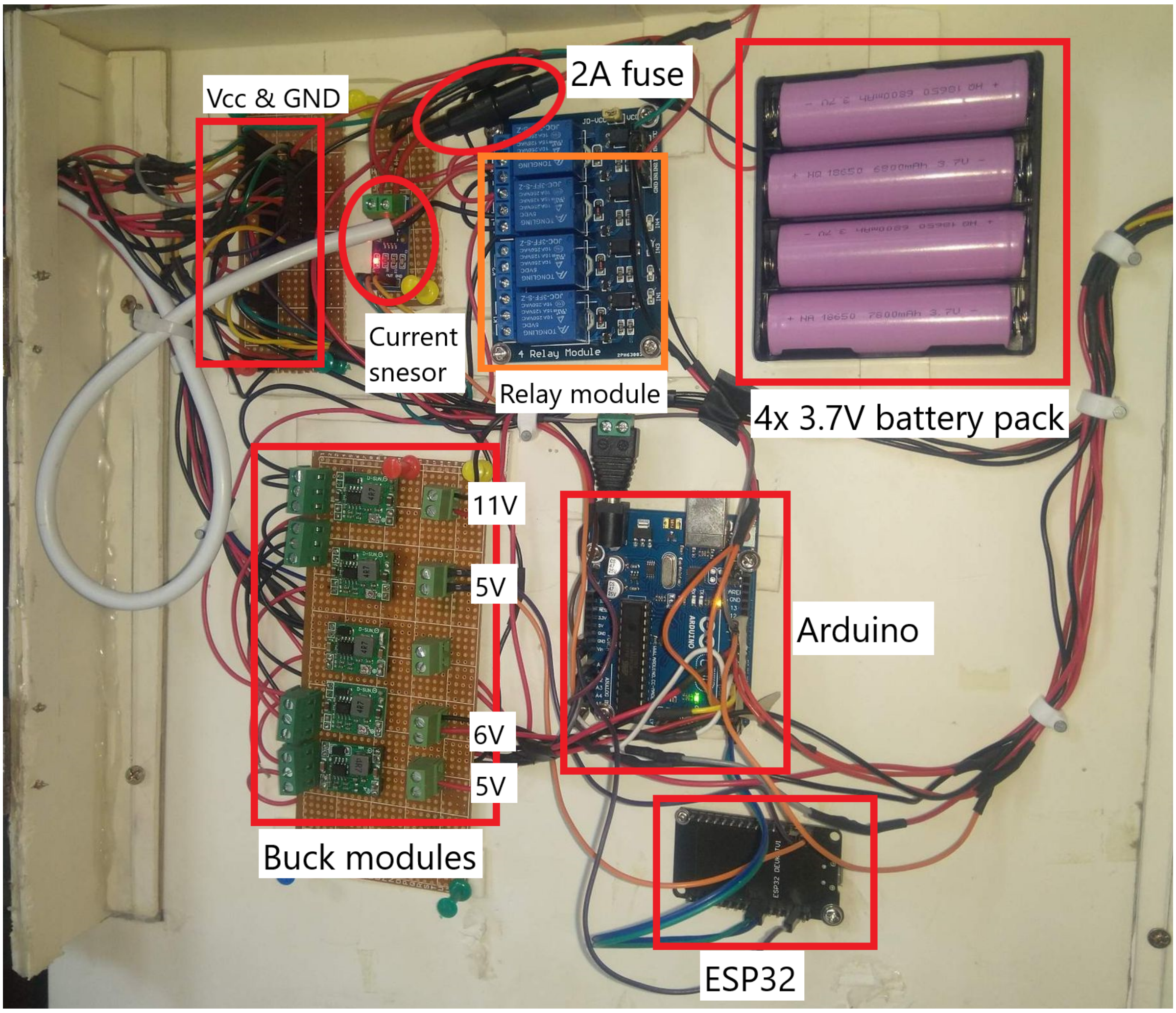

Fig. 55. Internal electronic component of the bin

Here we have used four 3.7 Volt batteries. For a single battery's State of Charge (SoC) is 100%, the voltage is 4.2. And when SoC is 0% the cutoff voltage is 3 Volt. For four batteries, when SOC is 100% the voltage is about 16 volt & cutoff is selected at 12 volt. When the battery life reaches 12 volt, the whole system shuts off.

In our system the linear actuator draws the most amount of current. Its maximum current draw is less than 2 amps. For that we are using a 2 amp blow fuse.

To measure current and voltage we are using ACS712 current sensors and a voltage divider made of 10K ohm resistors. Arduino's analog pin A2 collects current data and A3 collects voltage data.

The relay module is used to control the actuator. As the actuator has a DC motor, positive polarity extends the actuator and negative polarity retracts the actuator. The relay module switches the current polarity. The actuator's positive terminal is connected to the top relay and negative terminal to the bottom relay. When ultrasound sensor 3 detects any human presence, arduino sends turns on the top relay and positive current flows through the actuator and the actuator extends. And after a certain delay the bottom relay turns on and negative current flows, thus the actuator retracts. There is a feedback pin on the lid and when the bin closes the relay module shuts off.

To power all the sensors, display, arduino, esp32 & motor we have used MP1584EN DC-DC BUCK modules. The buck modules get power from the power supply directly. We have used connectors so that any busk module can be turned off when needed. The buck module is two channel output with output voltage is from 0.8 to 20 Volt and output current is 1.8 amp. We are using one output channel only for each component so that current draw does not exceed 1.8 amp. When the battery is fully charged the input of the buck module is 16 Volt. It gets stepped down to the required amount.

All the sensor's data pins are connected to the arduino and the Vcc and GND pins are connected to the output of the last buck module. The connection is extended from the module to a veroboard where header pins are soldered and shorted together in two separate lines. From there all the sensors and display gets their power. The GND line is the common ground for all components i.e arduino, esp32, sensors, motor, relay, all buck modules and display.

The Arduino and the ESP32 get power from the first and second buck module. Arduino’s DC barrel jack is supplied with 11 volts and ESP32’s Vin pin is supplied with 5 volts to operate. For serial communication between the arduino and esp32 we have connected pin 0(RX) and 1(TX) with ESP32’s pins TX2 and RX2.

The MG995 servo motor gets power from the third buck module. The servo needs 4.8 to 7.2 volts to operate. We are supplying the servo with 6 volts. It gets a PWM signal from the arduino. When the user puts his hand near the “Ultrasound sensor 1” about 2 to 10 cm, the servo pushes the disposal unit lid to open up.
When the main lid of the bin is open we see the Non-disposal unit is open to the user.

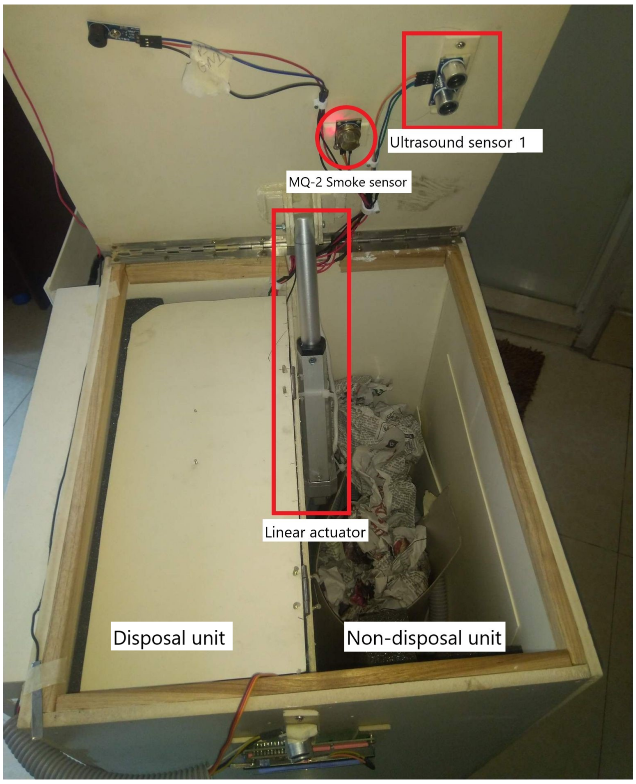

Fig. 56. View when the main lid is open.

The "Ultrasound sensor 1" and "MQ2 smoke sensor" are mounted on the lid. The linear actuator is mounted on the partitioned panel between the two compartments. When "Ultrasound sensor 3" detects any user presence the actuator opens the main lid. It takes about 8 seconds to extend the actuator. Then it stays in that position for 15 seconds. At that time the user throws waste in the bin and then the bin closes. Again it takes 8 seconds to retract the actuator.

When the Disposal unit's lid is open we see the following.

Fig. 57. View when the disposal unit lid is open.

In the Disposal unit we have mounted "Ultrasound sensor 2" and "MQ4 gas sensor". The servo motor opens the disposal unit lid. When the mail lid is open for 15 seconds and the user puts his hand near the "Ultrasound sensor 1" only then the servo goes to 90 degrees and pushes the disposal unit lid to open. It stays open for 10 seconds for the user to put disposable waste in the bin. After that the servo returns to 0 degree and thus the disposal bin's lid closes and the main lid closes.

5.3 Evaluate the solution to meet desired need

5.3.1 Functional & Non-functional verification of the prototype

The desired needs and their evaluation are assessed as follows:

i. Touchless Operation: Ultrasound sensor 3 detects the user from 0 to 40 cm up to 5 seconds and then opens the main (outer) lid. The disposal unit's lid is opened when the user puts his hand near ultrasound sensor 1. This whole process is touchless.

Fig. 58. Main lid opening.

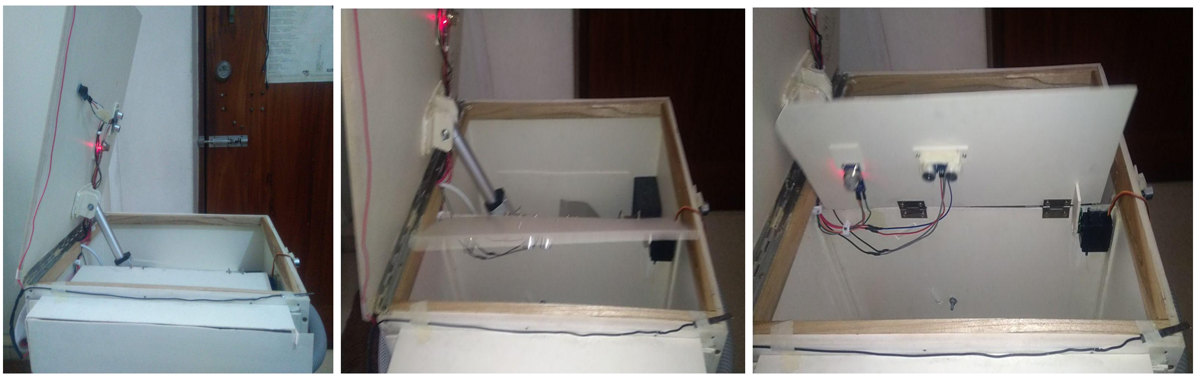

Fig. 59. Opening of disposal units lid.

ii. Notifying users: The 20 by 4 lcd display shows the status of the bin in real time. It shows the disposal bin and non-disposal bin waste level percentage, presence of gas and smoke inside the bin, voltage, current and power consumption of the whole system and battery percentage. The adjacent image shows that the non-disposal unit is filled to 56% capacity, whereas the disposal unit is only filled to 18% capacity. In addition, there are no signs of gas or smoke, and the electrical parameters, such as current, power, and voltage, can be observed. The battery is at 91% capacity, allowing users to determine whether recharging is required or not.

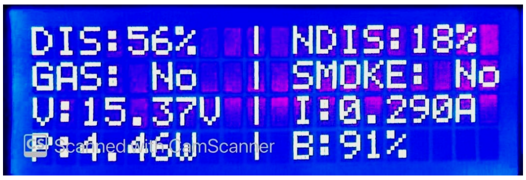

Fig. 60. LCD Display at normal state.

iii. Indication of low power: When the battery reaches cutoff voltage the whole system shuts off. The LCD display shows that message to the user when the battery is too low.

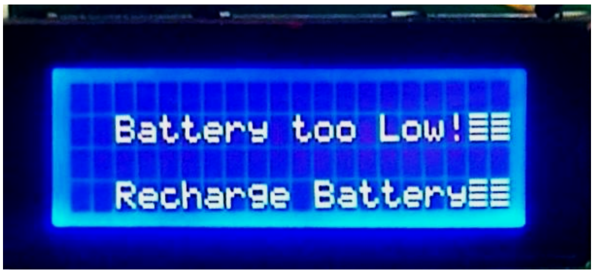

Fig. 61. LCD display showing low battery.

iv. Volume detection: When the disposal bin is 90 percent filled with waste the LCD shows "DIS BIN OVERLOADED" message in the display.

Fig. 62. Disposal bin is filled

When the non-disposal bin is 90 percent filled it shows "N-DIS BIN OVERLOADED" in the LCD display.

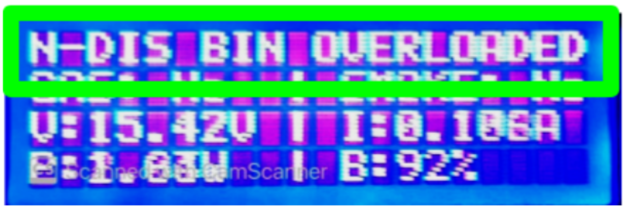

Fig. 63. Non-disposal bin filled.

v. Toxic Gas detection: MQ-4 gas sensor detects toxic gas that accumulates inside the disposal unit. When the analog value of the sensor exceeds 150 it means that gas is present inside the disposal unit. The LCD display shows that by "GAS: YES". Otherwise it shows "GAS: NO" indicating gas is not present.

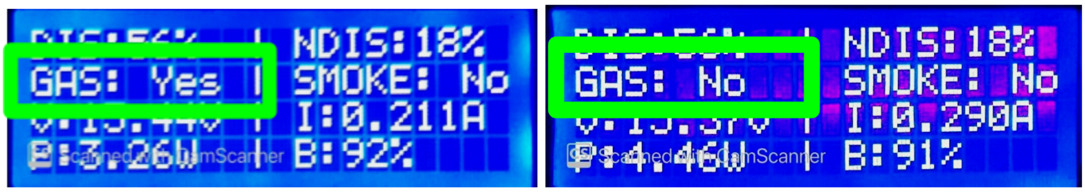

Fig. 64. Gas is detected

vi. Smoke detection: MQ-2 smoke sensor detects carbon monoxide gas that can produce if any fire hazard occurs inside the bin. When the analog value of the sensor exceeds 120, that would indicate the presence of fire. The LCD will show “SMOKE: YES”, otherwise it will show “SMOKE: NO” on the display.

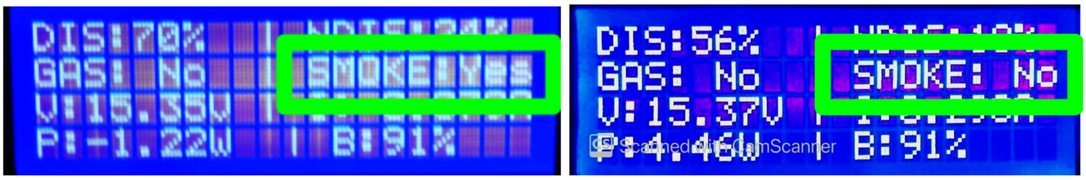

Fig. 65. Smoke is detected.

vii. Data Transfer to Web Server: In order to transfer data from the bin to the web server we are using ESP32 and Blynk cloud server. Through this we can see the real time data of the bin both in a smartphone app as well as in the cloud website.

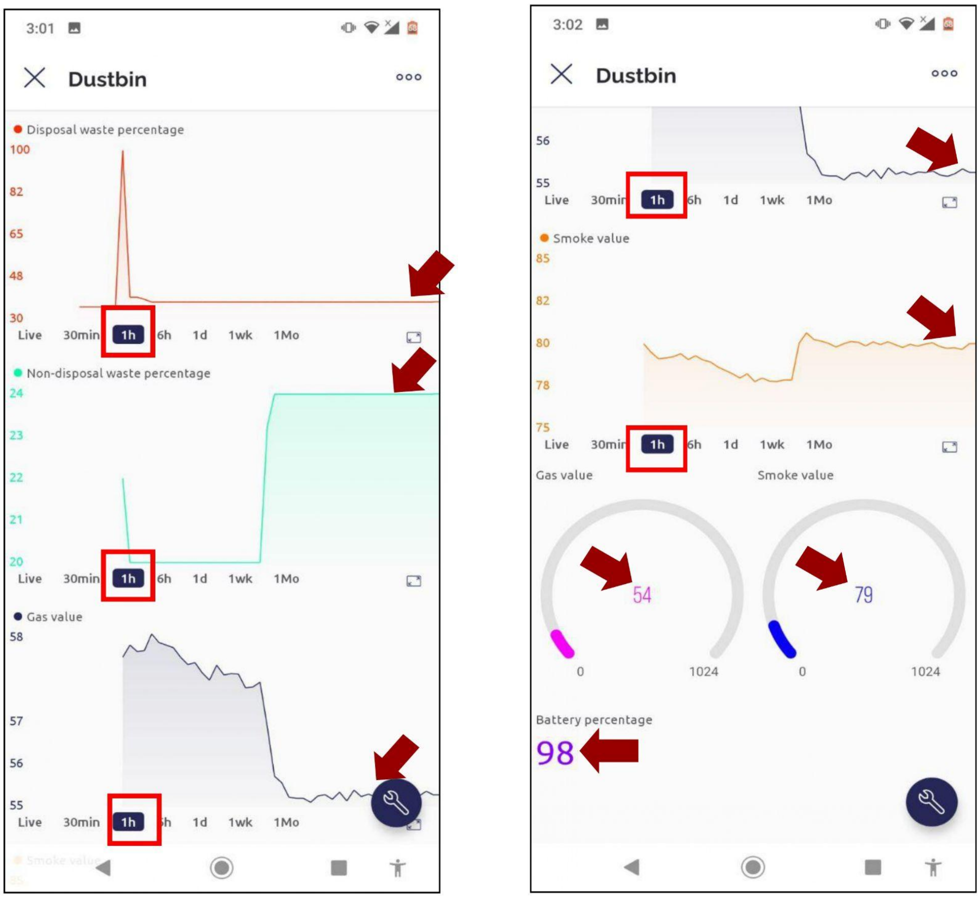

Fig. 66. Blynk smartphone app

The above two figures illustrate the status of the whole bin for the last 1 hour. We can see that the disposal unit waste percentage was almost full at one point and reduced to 35%, whereas the non-disposal unit is only 24% fill-up. In addition, a gradually reduced gas level is visible in the graph. And in the gauge we can see the current gas value is 54 right now. Furthermore, we can see the current smoke level reading of 79. Lastly, the battery percentage is also visible which is 98 percent.

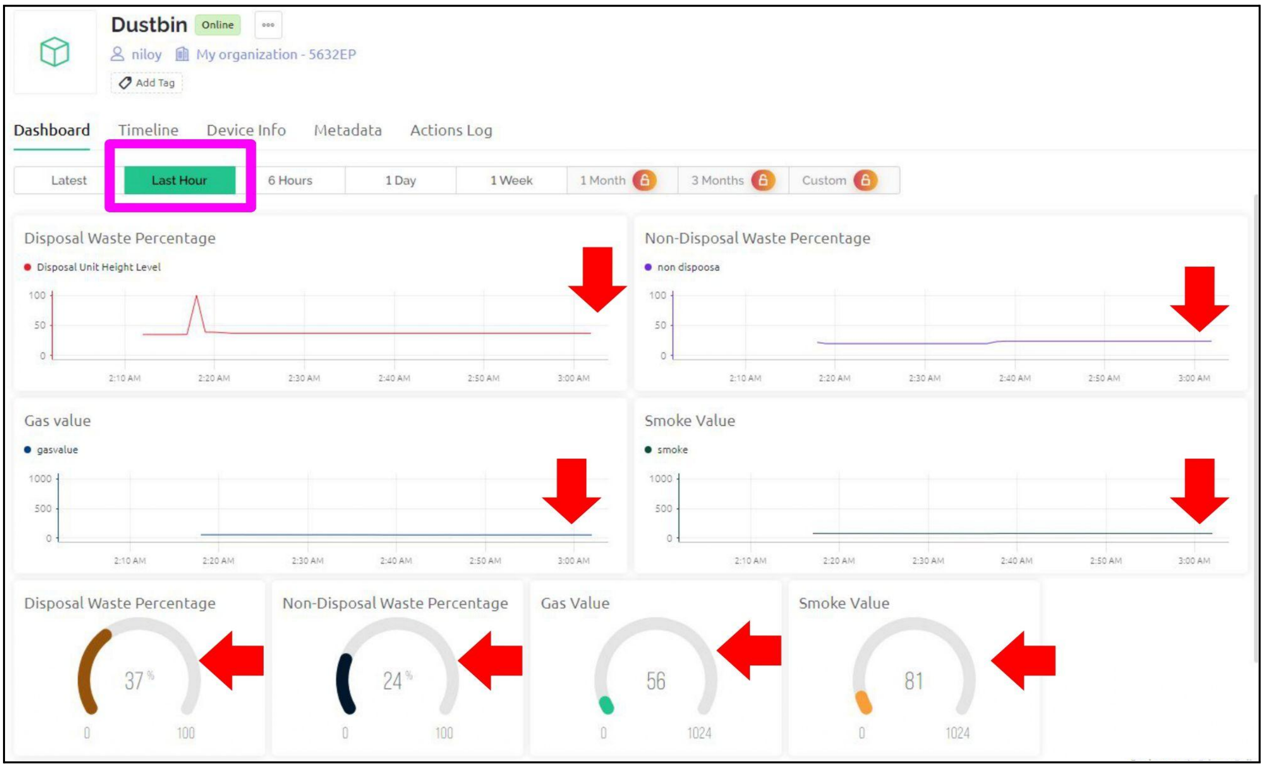

Fig. 67. Blynk Server website last hour data

The above image shows the Blynk server website that can be accessed through any computer. It can display latest, last hour, 1 day, or week data in different formats. We can see that in the last hour the disposal unit has achieved 37 percent of its capacity, while the non-disposal unit has reached 24 percent. In addition, a trace quantity of gas has been detected, resulting in a reading of 56. Furthermore, the smoke value is 81.

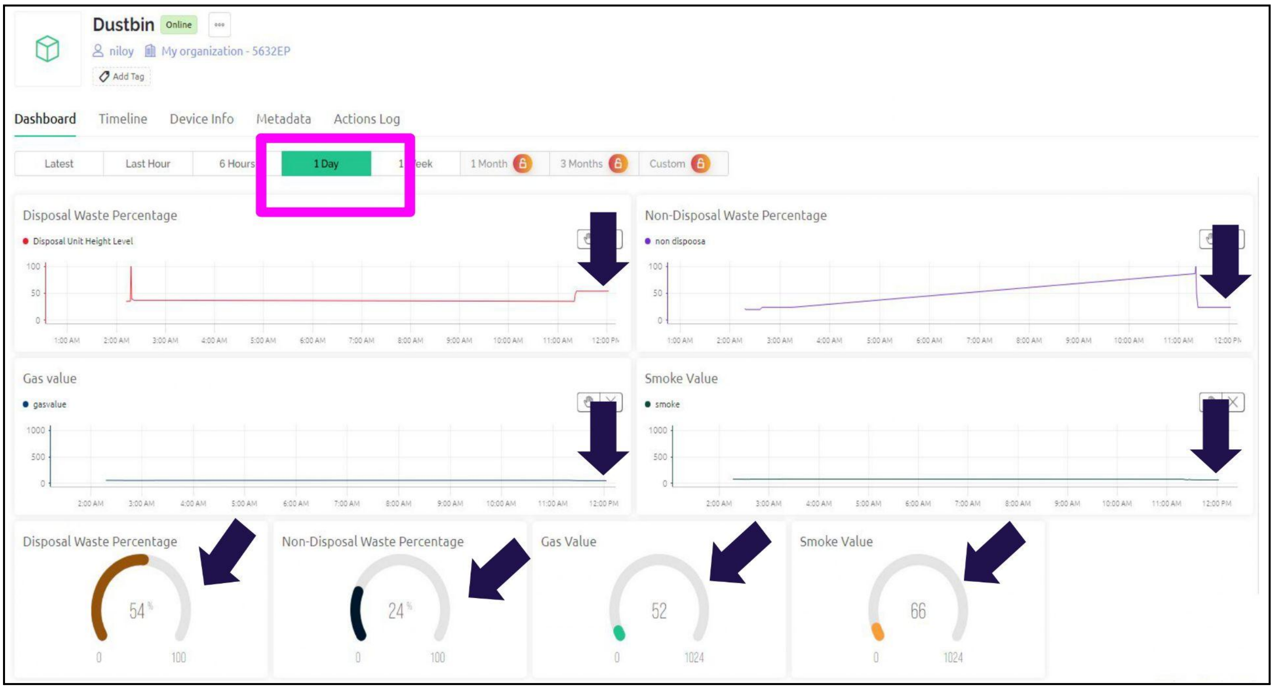

Fig. 68. Blynk Server website 1 day data

Lastly this image shows 1 day data of the smart bin. We can see the non-disposal unit gradually got filled to 90% and was reduced to 24%.

5.3.2 Comparison of the prototype with proposed design

TABLE X. Design and Prototype phase comparison

Features	Design Phase	Prototype (Implementation Phase)
Triggering the lids	Firstly it was designed such that the main lid would be triggered to open by a PIR sensor. The inner chamber lid would be triggered by a sound sensor.	The design was modified as the PIR and sound sensor could create complications. For example: The office space may have pet animals which may unintentionally trigger the sensor and cause the waste bin to open. Furthermore, the sound sensor could also be mistriggered. In order to solve this issue, ultrasonic sensors were used so that the user has to stay at a certain distance for a small instance of time and as such the bin lid can be opened without triggering it unintentionally
Opening mechanism of lids	The main lid was supposed to be lifted by 2 servo motors (MG996R). The inner lid was also to be lifted by 2 servo motors of the same category.	It was sufficient to use one servo motor (MG996R) for the inner lid. However, due to the position of the servo motor at the base of the bigger outer lid, it was unable to lift it. Hence, we opted to a stronger option which was the Linear Actuator (12V DC 4 inch stroke)
Networking	In the design phase, we planned to incorporate the GSM module for sending SMS and data.	This device was changed and ESP 32 was used instead since we were having complications implementing the GSM module in our project as there were numerous bugs concerning the 'Delay Function' of the GSM module.
SMS Function	We designed to send SMS to the required personnel whenever there was a required alert.	Unfortunately, we were unable to implement the sending of SMS. However, as an alternative we implemented the real time monitoring of data on 'Blynk' webspace from where the alerts and the bin status can be monitored.
Safety Module	N/A	Two additional safety measures were incorporated which are the Fuse and the current sensor.

Moreover, in the design phase, we discarded the idea of adding a load sensor which was originally proposed. The prominent reason was the load sensor measures in a small area on top of which the load is placed. However, in our case the surface area was much larger. As such, the modification would have hampered the project and caused problems for other sensors and components. As a result, the functionality of measuring load was discarded.

5.4 Feedback from Defence

We had a display of our design in front of all the faculty after finishing the entire project. When the panel judge for this showing contacted us, we defended our whole design. four panels, each with three judges, came to talk to us.

Panel 1: The members of Panel 1 appreciated our proposal and recommended adding wheels to make the bin more convenient to carry and transport. They've also advised that we install a handle so the smart waste bin can be handled easily.

Panel 2: The panelists from Panel 2 questioned us about the sensors employed, how they contribute to the project's stated goal, and how the project as a whole operates, and they all gave their approval. They inquired about the bin's method of separating biodegradable garbage from non-biodegradable waste and advised that we color-code the interior of the bin to make it easier to distinguish between the two types of waste.

Panel 3: The team's design of smart bins with separate compartments for disposal and recycling was well received by the third panel. Furthermore, the proposed concept of incorporating an additional compartment for injecting bacteria to turn food waste into compost was considered innovative and valuable. This new feature allows food waste to be recycled into fertilizer, helping to promote sustainability and reduce waste. By integrating composting into smart trash cans, the team demonstrates their commitment to sustainability and the circular economy.

Panel 4: The team's presentation was well received by Panel 4, who expressed satisfaction with the overall performance and the way the poster was presented. However, one panel member expressed concern about Inkjet paper used for the poster. Judges noted that even though the quality of the poster has been up to the mark, the reflections from the material made it difficult to read the content. It has been suggested that the lighting in the room may also contribute to the difficulty in reading the contents. As soon as the panel members changed positions, the contents of the poster became readable. The team will take this feedback into consideration in future presentations, ensuring that the materials used in the poster are suitable for lighting conditions and improving the readability of the content.

5.5 Conclusion

In summary, final design implementation is a critical step in meeting proposed project requirements. To minimize variation and ensure optimal performance, it is important to execute your design exactly as intended. Successful implementation of design features and functions allows the project to meet desired requirements and goals.

In addition, it is imperative to validate project results, evaluate feedback and evaluate performance. This process provides insight into the effectiveness of the project, identifies areas for improvement, and enables necessary changes to optimize project functionality. The implementation of the final design and subsequent verification and evaluation process enable the project team to achieve successful results that meet project objectives. Adherence to proposed requirements and precise execution of the design ensure that the final product achieves the desired results. Ultimately, verification and evaluation of feedback ensures that project performance meets or exceeds stakeholder expectations.

Chapter 6: Impact Analysis and Project Sustainability.

6.1 Introduction

A project should use impact and sustainability analysis to make sure that the project has a positive impact on the environment, society and economy, in which it will be implemented. This is usually done to avoid any unfavorable outcomes that can harm anything in the process of trying to accomplish the desired goals. Not to mention, the analysis should also deem it acceptable not only for the present but also the future for continued use and diftribution of the product.

6.2 Assess the impact of solution

1. Legal:

In this project, a variety of sensors will be incorporated, including weight sensors, motion sensors, PIR sensors, smoke sensors, and others. Each of these sensors has a maximum operating temperature. The manufacture of these sensors is subject to the limitations established by higher authorities, who have also made a patent requiring obedience to these limitations. Maintaining all the safety measures established by authorities will be our primary concern as we develop this project. The environment around us may be kept safe and healthy by taking those precautions, and doing so will also have a lessening effect on the law because breaking these regulations may result in legal action.

2. Social and cultural:

The people who live in a society will have a higher level of living thanks to this system. A smart trashcan installed in the park or main entrance of the community will make the area cleaner. It will also be simpler for the municipality to manage the rubbish from a single location. The society as a whole will be cleaner and healthier

3. Health:

The fact that this smart waste bin may be opened without touching it eliminates several health problems. People don't need to contact it, preventing the transmission of diseases. Additionally, it has a scent detecting mechanism that will guarantee a decrease in air pollution because some gases that are detrimental for your health emit smells that are offensive. Therefore, stopping the spread of this odor and removing the garbage at the appropriate time helps to lower air pollution

4. Safety:

The use of advanced systems in the construction of this garbage can lowers the likelihood that any accident, including a fire mishap, would occur. To lessen the risk of a fire, this smart waste bin contains a separate chamber for keeping any combustible garbage

6.3 Evaluate the sustainability

The SWOT analysis matrix will be used for sustainability since it will help us better grasp how to assess the components. Strength, Weakness, Opportunities, and Threats is how SWOT is fully abbreviated. The variables of the SWOT analysis will now be discussed.

TABLE XI. SWOT Analysis

Analyzing the sustainability of the smart waste bin		
INTERNAL **STRENGTHS**		INTERNAL **WEAKNESSSES**
Providing healthy environment		Many integrated systems are present so chances of short circuit is more
Smell detector helps in smell detection and this prevents air pollution as odor produces methane gas that might harm the environment		Budgets constraints
Fill-level sensors helps to detect the amount of trash present in the bin		This bin will be occupying huge space
Use of jute bag instead of plastic ones helps in protecting environment		Availability of all sorts of equipments
Fleet management platform		Non optimized truck route
Compartments for disposing different sort of trash		Non uniform waste distribution of waste in the bin
EXTERNAL **OPPORTUNITIES**		EXTERNAL **THREATS**
Improved efficiency		Low and slow adoption in developing countries
Reducing number of bins required and fits everywhere		Providing suitable environment for all the sensors
Encouraging recycling process		Risk of invading privacy
Using jute polybag will help in rising employment		Small capacity

6.4 Explanation of SWOT analysis

6.4.1 Internal strengths of the project:

To promote a healthy environment, the no contact sensor has been included to this smart waste bin. This no-touch policy might have saved our lives during the COVID scenario in addition to providing protection against the transmission of further viruses. Additionally, this bin features a scent detector that detects odors, alerts users through signals when to discard garbage, and also works to stop odors from spreading and causing gas emissions. Due to the fact that paper takes up more room than actual waste, this project also includes fill level sensors that measure the actual quantity of trash that is present in the bin. Once more, we are utilizing jute bags rather than plastic ones, which are also helping the environment. In order to make the recycling process go smoothly, we are also introducing the concept of distinct compartments for varied waste disposal. Finally, the fleet management platform allows for the monitoring of smart trash bin locations from a single dashboard, allowing for real-time data-driven optimization of the collection route and schedule. This might increase operational effectiveness, especially for remote site collection, and lower vehicle emissions.

6.4.2 Internal weakness:

The flaws are only highlighted in relation to the design objectives. Given that this container will take up a lot of space, the commercial sectors may have severe problems as a result. Budgetary restrictions also apply in this case since highly integrated sensors are expensive. As a result, it's possible that the cost of this bin will be somewhat more than average, which might be a serious flaw. Additionally, because these systems are integrated, there is a potential of a short circuit if the current overflows, which might harm the bins' internal components as well as produce electric shock. Inefficient truck routes result in the usage of too much gasoline. Additionally, as a result, some bins may wind up being overfilled while others may end up being underfilled. Bins that are overstuffed harm the environment and are unsightly. The majority of smart sensors only employ distance measurement to gauge how full garbage bins are, thus if trash has been placed unevenly in one area compared to another, the sensors may indicate that the bin is full when it is actually only halfway full.

6.4.3 External opportunity:

This project's key opportunity is to give clients a single bin rather than a bunch of bins. To facilitate garbage collection from a single location, a sizable volume of rubbish will be kept in this one container. Again, because of its size and design, it fits perfectly and is simple to install anyplace. As the recycled materials are already sorted before being discharged, the double compartment system aids in the recycling process. This serves to lighten the workload on the workforce, allowing us to employ that workforce for other tasks. Additionally, since jute is an easily cultivated crop in our nation and the jute industry is highly developed, switching to jute poly bags from plastic ones not only helps the environment but also our economy. Overall, this whole process increases efficiency since we are disposing of the garbage at a specific moment, which also eases the burden on the person in responsibility.

6.4.4 External threats:

The greatest challenge to this one's adaptation is that it will be a novel mechanism, making it nearly impossible for a large population to adjust to it everywhere. Additionally, a suitable state must exist there for all types of sensors to function actively, which is why keeping a suitable condition is crucial. Since the entire system will be run by software, privacy invasion may play a significant role. All privacy-related aspects must be verified and safeguarded. The idea can be in danger since the dumpsters might not have as much capacity as a larger region.

6.5 Conclusion

In conclusion, impact analysis and sustainability evaluations are highly sought after in any project to determine its impact on the environment, society and economy and ensure that the project is developed and deployed in a safe and responsible manner. This results in not only the ability for stakeholders to more cautiously take steps, but to also help devise solutions to more robust strategies to help mitigate them.

Chapter 7: Engineering Project Management.

7.1 Introduction:

Engineering project management is the process of leading a team with the intention of completing a complex engineering problem considering several criteria such as planning, budget estimation, component availability, proper scheduled timeline, task assignment and progress monitoring. In this process, technical engineering skills combine with project management techniques to create a comprehensive project plan which keeps a project progressing.

7.2 Define, plan and manage engineering project

7.2.1 Defining Project Management:

Engineering is a diverse and challenging field that entails planning, coordinating, and implementing complex engineering initiatives. Before starting work, engineers should create a solid plan and introduce that to the teams who are working on the project to fulfill the project goals. Ignoring this phase can cause various types of problems in the future. Skills like technical expertise, leadership skills, and the capacity to manage resources effectively are required to ensure the project's success. Effective engineering project management requires identifying objectives, developing a comprehensive project plan, managing risks, and communicating with stakeholders. Due to the increasing complexity of engineering projects and the demand for efficient use of resources, effective project management is now essential for the success of these endeavors. From the beginning, we tried our best to show all types of managerial skills to introduce a final prototype. Our team members were aware of their duties from the start, which helped us to maintain the budget and create a standard prototype by providing high-quality components. We also followed legal codes and ensured risk analysis properly to avoid accidents. Overall we had excellent teamwork.

7.2.2 Project management in planning and proposal preparing phase

Finding a complex engineering problem was quite challenging in this part as it was difficult to find a real-life problem that could be solved. Luckily we found out that most offices have to waste a lot of time and money on waste management purposes which motivated us to select the idea of making a smart waste bin for office space. After choosing the topic, we gathered relevant research papers using university-provided open Athens accounts and divided them among group members. After gathering design ideas, we talked with the stakeholders and identified their requirements. We had directly selected 2 Multiple Design Approaches based on our literature review and created another approach by adding the preferred features of stakeholders. After sorting the design issue, we provided a project plan, calculated budget, ethical considerations, risk management, expected outcomes, and applicable codes. We justified it by proving that our selected problem was a complex engineering problem.

7.2.3 Gantt Chart for phase 1

Prior to beginning work on phase 1, we developed a Gantt chart in order to plan out the appropriate division of work and identify any potential areas of oversight that might hamper advancement.

Tasks	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	week 12	Week 13
Finding Complex Engineering Problem	Fuad,Seeam,Naimur,Tasnia												
Research Paper collection		Seeam	Tasnia										
Multiple Design Approach			Fuad,Tasnia,Seeam,Naimur										
Draft Concept Note				Seeam	Fuad								
Progress Slide						Fuad							
Methodology and Project Plan							Naimur,Fuad,Seeam,Tasnia						
Risk Management and Safety consideration									Fuad,Naimur				
Final proposal report				Fuad		Naimur		Tasnia		Seeam			
Proposal Slides													Tasnia

Fig. 69. Phase 1 Gantt Chart.

7.2.4 Project management in design & development phase

In this phase, our job was to analyze three design approaches based on various criteria and, in the end, select the optimum one. We divided the work among group members to develop simulation files and write codes for getting results. We created a 3D simulation of our proposed approach and selected coding platforms, designing tools, and simulation tools based on criteria chosen by all group members. The platform with a significant positive side got selected. We surveyed to understand the stakeholders' thoughts on our product. We selected the optimum design based on criterias like power calculation, stakeholders demand, and other factors like safety issues and risk management.

7.2.5 Gantt chart for phase 2:

Prior to beginning work on phase 2, we developed a Gantt chart for proper utilization of team work and complete tasks within time.

Tasks	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Design 1	Seeam	Fuad											
Design 2		Fuad	Tasnia										
Design 3			Tasnia	Naimur									
Identify Problems and Constraints					Seeam								
Design Modification based on prolems						Naimur	Fuad	Tasnia					
Comparing Data									Seeam				
Writing report	Fuad	Fuad	Tasnia	Seeam	Naimur	Fuad	Tasnia	Fuad	Fuad	Naimur	Seeam	Seeam	Tasnia
Optimal design selection and modification										Fuad	Seeam		
Presentation												Naimur	Tasnia

Fig. 70. Phase 2 Gantt Chart.

7.2.6 Project management in completion and execution phase

This was the last phase of our FYDP (Final Year Design Project), where we had to implement the optimum design selected in the FYDP-D phase. First, we collected all the components according to the budget and material list. As the actuator was unavailable in the market, we had to order from abroad. Additionally, we created some small parts using a 3D printer. We built the body for the bin with the help of a carpenter. Finally, the assembly of components was the central issue. We divided work among ourselves; we had to show proper team works by soldiering various parts, connecting wires, and debugging codes to get desired output. After relentless work, we completed the project.

7.2.7 Gantt chart for phase 3:

Here is the Gantt chart before beginning work on phase 3, we developed for time management

Tasks	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11
Project Development	Tasnia, Fuad, Seeam										
Database Development			Fuad, Seeam								
Project Test 1				Naimur, Seeam							
Project Test 2						Fuad, Tasnia					
Project Test 3								Seeam, Fuad			
Project Observe									Seeam, Fuad, Tasnia, Naimur		
Project Debugging										Fuad, Tasnia	
Project Report & Presentation			Seeam, Fuad, Tasnia, Naimur								

Fig. 71. Phase 3 Gantt Chart.

7.3 Evaluate project progress

Through group meetings, we were able to address the majority of the issues that arose during the course of our work, as this allowed for the exchange of ideas that provided solutions and fostered the development of creative problem-solving skills. However, there were times when we encountered obstacles that ATC panel members helped us overcome. We had weekly meetings with ATC panel members, and their advice greatly assisted us in completing the project correctly and minimizing errors. In addition, we recorded all topics discussed at ATC panel meetings in a logbook, which helped us work formally and keep track of our activities. Before beginning the project, we constructed a gantt chart for each phase, which allowed us to complete the work on time.

7.4 Conclusion

In a practical workplace, engineers will face difficulties like budget shortage, limited supply, and work distribution where they have to show their situation management skills to overcome the obstacles and achieve desired goals. In our Final Year Design Project (FYDP), we faced many challenges. However we solved them successfully by team meeting and ATC panel members guidance.

Chapter 8: Economical Analysis.

8.1 Introduction

Economic analysis is the systematic examination of financial decisions and policies. It employs economic theories and quantitative methods to evaluate the effects of various economic factors, such as commodity production, consumption, and distribution. Financial analysis assists decision-makers in making informed choices by providing them with insights into the economic implications of their actions.

8.2 Economic analysis

Here is our project budget:

TABLE XII. Budget of the developed prototype

Components	Probable Model	Quantity	Price
Gas Sensor	MQ-4	1	160
Ultrasonic Sensor	HC-SR04	3	360
Relay	4 channel relay module	1	210
Smoke Sensor	MQ-2	1	157
ESP32	Devkit 1	1	600
LCD Display	LCD Module 20x4	1	528
Vero Board	N/A	2	24
Servo Motor	MG995	1	580
Header pin	Male/Female	4	50
Jumper wire/cable	Jumper wire	80	190
Arduino	ARD-00028	1	990
Current Sensor	ACS712-5A	1	200
Buck Converter	MP1584	5	300
Battery	3.7V	4	400
Linear Actuator	RBD-1639	1	4000
Total			8749

8.3 Cost benefit analysis

The process of evaluating the costs and benefits of a proposed undertaking or decision. It is a methodical process that allows us to weigh the potential costs and benefits, enabling us to make informed decisions and rank initiatives based on their expected returns.
We have selected some criteria for cost benefit analysis:

1. Time and Cost Saving:

As the smart waste bin will provide two compartments for separating disposal and non disposal waste, it will reduce the cost for separating different types of wastes in modern cities. For example, Dhaka city corporation has already released their plan to implement a project for separating disposable and non disposable waste which will cost around 192 crore BDT. However, implementing this project will already solve that problem and save public money. The data collected from the smart waste bin enables the smart application to display a more convenient route. Garbage vehicles use this application to reach the full bins, thereby reducing their time on the road and traffic congestion.

2. Sustainability

Overflowing trash cans substantially pollute the environment, endanger communities, contaminate areas, and negatively affect public health. Ordinary bins are already implemented in a number of cities; they are lightweight, inexpensive, and simple to install, but they lack the technological sophistication to promote sustainability. The smart bin not only makes waste collection and management extremely convenient, but also contributes to the preservation of a trash-free and sustainable environment for the general public. The system of waste collection and the optimized route offered by smart bins eliminate the danger of overflowing while minimizing CO_2 emissions. Not only offices but also municipalities can reduce their ecological footprint and achieve the Sustainable Development Goals (SDGs) through the use of smart bins.

3. Improved Efficiency

The availability of information enables the user to make better and quicker judgments when using smart devices. Similarly, the sensors in smart waste bin inform waste collectors of the bin's condition, allowing them to empty the container in a specific location before it begins to overflow. The use of smart bins in cities can challenge the current waste hierarchy, disrupting patterns of high costs and inefficiency, thereby enhancing the performance of waste management systems.

8.4 Evaluate economic and financial aspects

Since our initiative will provide specific locations for waste disposal, it will reduce the government's costs associated with separating disposable and non disposable waste. Thus, public funds can be conserved and allocated to other sectors such as education and health. In addition, if the location-sharing features can be implemented on a large scale, the dumping truck will only be notified when the bin is full, thereby reducing traffic congestion and petroleum consumption. It will aid in time and fossil fuel savings. As Bangladesh imports all types of metals from abroad, the smart bin will assure recycling of metals and plastics, saving foreign reserve funds and minimizing environmental impact by reducing plastic production.

8.5 Conclusion

Economic analysis is the systematic examination of economic decisions and policies. It helps us make decisions from an economic standpoint, because an initiative that is not feasible cannot ultimately benefit the community. Sometimes we analyze based on pricing comparisons, while other times we prioritize long-term success. Due to the fact that our project is a combination of various designs and there is no similar product on the market, we have chosen sustainability, time and cost, and efficiency for our cost-benefit analysis and provided financial and economic achievement.

Chapter 9: Ethics and Professional Responsibilities

9.1 Introduction

To ensure that a project is ethical, legal, and responsibly handled, ethics and professional responsibilities play a crucial role in the development of a project. The considerations revolve around ethical standards, regulatory requirements and possible impacts on all potential stakeholders.

9.2 Identify ethical issues and professional responsibility

The design that we are proposing is a trash bin and it will be grabbing a lot of attention from common people. As we are planning to set it up in small places like office or residential playground or a small residential building we are mainly specifying its coverage of being limited. This might stir a question in mind that how possibly this bin will be helpful in collecting all trash? The local people will start comparing its budget to its operating skills and might also feel that its operating skills are overrated in comparison with its price.

In this trash bin, we are using a lot of sensors and also some computer generated activities. The sensors that are being used here need to have a proper license and be labeled by the authority so that we can know the limit of its operation.

If there is a recyclable material in the garbage, unethically discarding it prevents it from being effectively recycled.However, by categorizing your garbage, you may dispose of each type of waste at the appropriate approved disposal location.In order to save the people who handle your garbage time, separate the plastic bottles, papers, food waste or wrappers, and tin cans, and identify each one.This implies that recyclable materials may be distinguished from non-recyclable ones.

Each sensor is constrained by a set of codes, which are deeply ingrained components of our entire system. All of these systems are interrelated, thus protecting and preserving all of their data is equally vital. Therefore, data security is extremely important from an ethical point of view.

9.3 Apply ethical issues and professional responsibility

Consent Form

This Official Consent made on 10th December 2022 by and between **(name of the consenter)** who consents to the following statement “To install a Smart Bin for office use” on their property

The Consenter agrees to hold Tasnia Rahman, Seeam Monon, Fuad Fahimul Hoque and Naimur Rashid is free from all legal, financial, and other liabilities, including those of their agents, employees, successors, and assigns, as well as those of their respective heirs, personal representatives, affiliates, successors, and assigns, as well as any and all other parties, firms, or corporations that may be held accountable or that may be asserted as being responsible, whether or not named, but all of whom expressly deny any responsibility to the undersigned. If any and all claims, damages, actions, causes of action, or lawsuits of any kind or nature, which have or may have, arising out of or in any way connected with any and all harms and damages of any kind to both individuals and property, as well as any and all harms and damages that may arise in the future.
It is understood and agreed that this Agreement is made and received in full and complete settlement and satisfaction the causes of action, claims and demands mentioned herein that this Consent contains the entire Agreement between the parties, and that the terms of this Agreement are contractual and not merely a recital.

Furthermore this Consent shall be binding upon the undersigned and his respective heirs, executors, administrators, personal representatives, successors and assigns.

This Consent shall be governed by the laws of the State of Bangladesh

This Consent has been read and fully understood by the undersigned and has been explained to my teammates.

Consenter’s (digital) signature: **Date:**

Consenter’s Name:

Releasee’s Signature **Date:**

1.
2.
3.
4.

Fig. 72. Consent Form

9.3.1 Risk Management and Contingency Plan

- **Identification of Risk**

While we are working on the project as a whole, there is some risk involved. These dangers are divided into two main groups, and even within these two categories there are several subcategories. The entire incident may be summed up as follows.

1. **Risks of electric shock**
    - Sensors
    - Wires
    - Electrical components
    - Damp Condition

2. **Chances of fire**
    - Papers
    - Gas emission
    - Jute polybag

- **Survey questions related to risk management:**

1. How likely are you to receive electric shock from a sensor?
    a. Rare
    b. Unlikely
    c. Possible
    d. Likely
    e. Almost certain
2. What are the chances of getting electrocuted by open wires?
    a. Rare
    b. Unlikely
    c. Possible
    d. Likely
    e. Almost certain
3. How damp conditions may risk your life?
    a. Rare
    b. Unlikely
    c. Possible
    d. Likely
    e. Almost certain
4. How the electrical components a threat to your life?
    a. Rare
    b. Unlikely
    c. Possible
    d. Likely
    e. Almost certain
5. What possibilities are there that paper waste can catch on fire?
    a. Rare
    b. Unlikely
    c. Possible
    d. Likely
    e. Almost certain
6. What is the likelihood of gas emission starting a fire?
    a. Rare
    b. Unlikely
    c. Possible
    d. Likely
    e. Almost certain
7. How often do we use jute polybag?
    a. Rare
    b. Unlikely
    c. Possible
    d. Likely
    e. Almost certain

Fig. 73. Survey questions related to risk management

- **Order of risks**

Table XIII. Risks of electric shock

	Likelihood & Consequences						
	1	2	3	4	5		
	Rare	Unlikely	Possible	Likely	Almost certain		
Sensors	**4**	**8**	**12**	**16**	**20**	Catastrophic	4
Wires	**3**	**6**	**9**	**12**	**15**	Major	3
Electrical component s	**2**	**4**	**6**	**8**	**10**	Moderate	2
Damp condition	**1**	**2**	**3**	**4**	**5**	Minor	1

Table XIV. Chances of fire

	Likelihood & Consequences						
	1	2	3	4	5		
	Rare	Unlikely	Possible	Likely	Almost certain		
Papers	**4**	**8**	**12**	**16**	**20**	Catastrophic	4
Gas emission	**3**	**6**	**9**	**12**	**15**	Major	3
Jute polybag	**2**	**4**	**6**	**8**	**10**	Moderate	2
	1	**2**	**3**	**4**	**5**	Minor	1

Risks:

- Low = 1-5
- Moderate = 6-10
- High= 11-15
- Extreme= 16-20

The four individuals in this group are responsible for conducting the whole survey.

9.3.2 Risk response matrix

Table XV. Risk response matrix with contingency plan

Risk events	Response	Contingency	Trigger	Responsibility
Electric shock	● Heavy insulation addition will reduce the current flow. ● Making sure no components should come in touch with water. ● Adequate grounding should be there always.	The main switch should be made of a relay and as soon as heavy current flows through it that relay will make the whole system shut down by itself.	● Faulty ground ● Water coming in contact with the electrical components.	Tasnia
Fire risk	● Faster initiation of short circuit ● Components should be shut off within 2 min of fire ● Proper fire alarm to detect slight ignite of fire	Fire extinguisher should be placed in case of any risky situation.	Detection of temperature change as well as smoke detector inside the bin	Fuad
Power system failure	Each sensor will be attached with an LED so if a single system fails that particular light will be lit up to inform the problem.	Maintenance over time and also proper record of maintenance should be kept to avoid damage of the sensors.	Voltage drops or sudden shut down of the whole system	Seeam
Software crash	● Restarting the system if we see any systemic disruption. ● Updated softwares must be used so that the whole process doesn't lag.	Contacting any service person to check whether the software is updated or not	● Data collection becomes unresponsive ● System comes to a halt requiring a hard reset	Naimur

9.4 Conclusion

To conclude, these are extremely important considerations in a project development lifecycle, as they help ensure the project is carried out in a responsible and ethical manner.

In conclusion, ethical and professional responsibilities are critical components of any project, as they help to ensure that the project is conducted in a responsible and ethical manner. By considering the potential impacts of the project on stakeholders and adhering to legal and ethical standards, project managers can promote the well-being of the community and ensure the success and sustainability of the project.

Chapter 10: Conclusion and Future Work.

10.1 Project summary/Conclusion

The purpose of our project is to create a clean and hygienic office environment with specially designed smart waste bins. Our approach involves using advanced technology consisting of multiple sensors and an Arduino Uno microcontroller. The smart bin has two compartments, one for disposal and one for non-disposable wastes. Waste level detection is done using ultrasonic sensors that accurately measure the amount of waste present in each bin section. Each of the compartments can be accessed without physical contact. The smart bin further detects any kind of smoke or toxic gas. If any anomaly or the waste level exceeds the limit then the state of the bin is displayed in the LCD display. Furthermore, the data can also be monitored in the web page. Smart waste bins aim to make waste management and disposal more efficient, organized and hygienic. This technology allows office staff to focus on their work without worrying about waste disposal. By using innovative solutions like this, we hope to promote a cleaner and healthier work environment.

10.2 Future work

The world faces increasing waste management challenges and there is an urgent need to develop sustainable solutions. In this respect, the integration of machine learning algorithms proves to be a game changer. By integrating sensors and cameras, real-time data of the waste bin can be monitored more precisely. Machine learning algorithms analyze this data to accurately predict waste volumes. Image processing can identify hazardous objects and notify if a disposable item is disposed of in the non-disposable chamber or vice versa. This will reduce human labour and make the work of personnel in charge of managing the waste bin more convenient. Furthermore, by incorporating GPS modules we can develop a navigation system which will help optimize the routes for garbage disposal trucks. Finally, the waste bins can be powered by solar in order to reduce carbon emissions.

In summary, the integration of machine learning algorithms, image processing, a developed navigation system and renewable energy sources can revolutionize waste management and make it more efficient, cost-effective, and sustainable. By harnessing technological progress and innovation, we can create a more sustainable future and address the growing problem of waste management. It is imperative that governments and businesses work together to implement these solutions and have a positive impact on the environment and society.

Chapter 11: Identification of Complex Engineering Problems and Activities.

11.1: Identify the attribute of complex engineering problem (EP)

P1:Depth of knowledge required:

Specialized knowledge is required to understand the function of sensors, designing and networking. In order to achieve that, many relevant research papers are being studied.The key part was selecting the relevant software for conducting the design of circuits and 3D display of the bin. For that,we had to go for a deep analysis of these softwares and then select the perfect one.

P2:Range of conflicting requirements:

Different conflicting requirements have to be dealt with such as a bigger sized bin is suitable for efficient usage but it will limit the office space and so on. So we decided the design in such a way so that it can meet the stakeholders requirements as well as perform the same way we studied in different research papers.

P3:Depth of analysis required:

Extensive research is required in order to design 3 different approaches for the project according to the requirement.We encountered quite a few analytical terminologies relating to various input and output parameters while working on software simulation. Knowing these terms was necessary before entering numerical numbers as input parameters and observing the output outcomes.

P6:Extent of stakeholder involvement and needs:

The smart waste bin has to be designed according to the requirements of the users mostly being office employees and also the personnel in charge of cleaning it. We have been thinking about adding more features based on the requirements of stakeholders.

P7:Interdependence:

Project Interdependency is a term used to denote a situation when two or more projects are related to each other in certain ways (they depend on each other somehow).The smart waste bin relies heavily on the waste level detection which is again dependent on the notification system.

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

Specialized knowledge is required to understand the function of sensors, designing and networking. In order to achieve that, many relevant research papers are being studied. This fulfills the requirement for P1.

Different conflicting requirements have to be dealt with such as a bigger sized bin is suitable for efficient usage but it will limit the office space. The lid also had an issue where the bigger design of the lid was too heavy for the servo, whereas a lid too small wouldn't meet the requirements. This fulfills the requirement for P2.

Extensive research is required in order to design 3 different approaches for the project according to the requirement. This fulfills the requirement for P3.

The smart waste bin has to be designed according to the requirements of the users mostly being office employees and also the personnel in charge of cleaning it. In addition to this, we have also taken surveys and consent forms to make sure our bins fulfill everyone's needs. This fulfills the requirement for P6.

The smart waste bin relies heavily on the waste level detection which is again dependent on the notification system. This fulfills the requirement for P7.

Attributes of Complex Engineering Problems (EP)

Attributes		Put tick (√) as appropriate
P1	Depth of knowledge required	√
P2	Range of conflicting requirements	√
P3	Depth of analysis required	√
P4	Familiarity of issues	x
P5	Extent of applicable codes	x

P6	Extent of stakeholder involvement and needs	√
P7	Interdependence	√

11.3 Identify the attribute of complex engineering activities (EA)

A1: Range of resource

A wide range of resources of funding, materials, knowledge on the equipment and requirements of the people are needed to design the project.We have gone through several research papers,gather information such as (software,hardware) and the required approaches and then we have completed the designs.

A2: Level of interaction

The level of interactive activity in this project is regarded as important. A wide range of knowledge is required from electronics, designing and networking.We also had to collect data through google docs form from the stakeholders.

A4: Consequences for society and the environment

The project aims to improve the atmosphere of the office hygienically and make the work of the employees less tedious. We have also focused on making the project environment friendly as much as we can. Also it will meet the demand of the stakeholders.

11.4 Provide reasoning how the project addresses selected attributes (EA)

For the successful implementation of a project such as ours, we need several resources, such as capital, hardware, tools, materials, etc. This is why we must maintain clear and effective communication with Brac University lab attendants, faculties and related authorities. For this reason, we fulfill A1 range of resource attributes.

To collect data, we firstly collected information from several websites regarding electronic sensors, actuators and microcontrollers. Later we settled in for our own data collection methods by logging sensor data into a web server known as Blynk. Here we get to see how our sensors behave to different stimuli and thus allow us to make fine tuned adjustments to our parameters which fulfills the A2 criteria.

After the successful completion of this project, the project will have an impact in both the society and environment, which is why we also need to fulfill the A4: Consequences for society and environment.

Attributes of Complex Engineering Activities (EA)

Attributes		Put tick (√) as appropriate
A1	Range of resource	√
A2	Level of interaction	√
A3	Innovation	x
A4	Consequences for society and the environment	√
A5	Familiarity	x

Note: Project must have some or all of the characteristics from attributes A1 to A5

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Appendix A

Log book

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

	Final Year Design Project (D) Fall 2022		
Student Details	**NAME & ID**	**EMAIL ADDRESS**	**PHONE**
Member 1	Md Fuad Fahimul Haque- 19221019	md.fuad.fahimul.haque@g.bracu.ac.bd	01631255460
Member 2	Seeam Monon- 19121098	seeam.monon@g.bracu.ac.bd	01312131466
Member 3	Tasnia Rahman- 22121097	tasnia.rahman1@g.bracu.ac.bd	01993156743
Member 4	MD Naimur Rashid- 19121051	md.naimur.rashid@g.bracu.ac.bd	01701328212
ATC Details:			
ATC 1			
Chair	Prof. Dr. Md. Mosaddequr Rahman	mosaddeq@bracu.ac.bd	
Member 1	Mohaimenul Islam	mohaimenul.islam@bracu.ac.bd	
Member 2	Aldrin Nippon Bobby	nippon@bracu.ac.bd	

Date/Time/ Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
Date:18.01.2023 Time: 12:30 PM Place:UB5 5th floor	1.Fuad 2.Seeam 3.Tasnia 4.Mohaimin Sir	1.Discussed about part selection 2. Redesigning blueprint for better movement of outer lid.	Task 1: All Task 2: Seeam & Fuad	Just a normal meeting.We selected the meeting slot for the entire semester. Decided on a design for lifting the lid
23.02.2023	1.Fuad 2.Seeam 3.Tasnia 4.Mohaimin Sir	1.Circuit building.	Task 1: All	

31.02.2023	1.Fuad 2.Seeam 3.Tasnia 4.Mohaimin Sir	1.Soldering open wires.	Task 1: All	
07.02.2023	1.Fuad 2.Seeam 3.Tasnia 4.Mohaimin Sir	1.Building base code for actuator operation	Task 1: All	
14.02.2023	1.Fuad 2.Seeam 3.Tasnia 4.Mohaimin Sir	1.Building code for reading sensor data	Task 1: All	
28.02.2023	1.Fuad 2.Seeam 3.Tasnia 4.Mohaimin Sir	1.Building code for Blynk data logging server	Task 1: All	
14.03.2023	1.Fuad 2.Seeam 3.Tasnia 4.Mohaimin Sir	1.Testing and Evaluating logged data	Task 1: All	Agreed that data is sound and we should continue to move on to finishing the code.
21.03.2023	1.Fuad 2.Seeam 3.Tasnia 4.Mohaimin Sir	1. Changing parameters based on collected data	Task 1: All	Some problems detected regarding servo motors. Solve the problems.
28.03.2023	1.Fuad 2.Seeam 3.Tasnia 4.Mohaimin Sir	1. Finalizing code integration after combining all sections.	Task 1: All	Design 2 completed. Instructions for design 3.
04.04.2023	1.Fuad 2.Seeam 3.Tasnia 4.Mohaimin Sir	1.Started writing report, completed chapters 2,3,4,5 and 6	Task 1: Tasnia	Design 3 completed. Power calculation instruction given.3D simulation instruction provided
11.04.2023	1.Fuad 2.Seeam 3.Tasnia 4.Mohaimin Sir	1.Added chapters 7,8,9 and 10.	Task1: Tasnia	
18.04.2023	1.Fuad 2.Seeam 3.Tasnia 4.Mohaimin Sir	1.Added chapters 11, References and Appendix	Task 1: Tasnia	3D design approved.
08.05.2023	1.Fuad 2.Mohaimin Sir	1.Finalized Thesis report.	Task1: Seeam,Tasnia	Feedback given

Related code/theory

```
#include <NewPing.h>

#include <LiquidCrystal_I2C.h>
```

```
#include <SoftwareSerial.h>
LiquidCrystal_I2C lcd(0x27, 20, 4);
#include <Servo.h>
Servo myservo;
int dispUpTime = 0;
int pos = 0;    // variable to store the servo position
float smokepin = A0;  //somke sensor pin
float gaspin = A1;  // gas sensor pin
float smokevalue = 0;
float gasvalue = 0;
const int buzzer = 10; //BUZZER
int lidFeedbackPin = 12;
int trig1 = 5;  //sonar disposal paper
int echo1 = 4;
int trig2 = 7;  // sonar food
int echo2 = 6;
unsigned long lastUp = 0;
unsigned long lastBatUp = 0;
int trig3 = 8;  // outside
int echo3 = 9;
NewPing sonar1(trig1, echo1, 200);
NewPing sonar2(trig2, echo2, 200);
NewPing sonar3(trig3, echo3, 200);
float distance1, duration1, distance2, duration2, distance3, duration3;
int analogPin = A2; // Current sensor output
const int averageValue = 120;
long int sensorValue = 0;  // variable to store the sensor value read
float v = 0;
float voltage = 0, current = 0;
```

```
float binP1 = 0, binP2 = 0;
//MILLIS funcrtion
unsigned long prevTime_T1 = millis();     //for LCD
long interval_T1 = 15000;                // every 15 sec
unsigned long prevTime_T2 = millis();     //for actuator
long interval_T2 = 10000;                 // for 10 sec
void stopSystem() {
  // Stop low voltage
  if (lastBatUp == 0 || millis() - lastBatUp > 10000)
    while (voltage < 12.8) {
      lcd.clear();
      lcd.setCursor(0, 1);
      lcd.println("  Battery too Low!");
      lcd.println("  Recharge Battery");
      lastBatUp = millis();
      delay(10000);
      updateVI();
    }
}
void updateFill() {
  if (digitalRead(12) == 0) {
    binP1 = sonar1.ping_cm();
    binP2 = sonar2.ping_cm();
    if (binP1 > 57) {
      binP1 = 0;
    }
    else {
      binP1 = ((57 - binP1) / 57.0) * 100.0;
    }
```

```
    if (binP2 > 51) {
      binP2 = 0;
    }
    else {
      binP2 = ((51 - binP2) / 51.0) * 100.0;
    }
  }
}
void disp1() {
  lcd.clear();
  //lcd.setCursor(0, 0);
  //lcd.print("DIS:" + String(binP1, 0) + "%  | NDIS:" + String(binP2, 0) + "%");
lcd.setCursor(0, 0);
if (binP1>90){
  lcd.print("DIS BIN OVERLOADED");
  }
  else if (binP2>90){
    lcd.print("N-DIS BIN OVERLOADED");
    }
  else{
    lcd.print("DIS:" + String(binP1, 0) + "%  | NDIS:" + String(binP2, 0) + "%");
    }
  lcd.setCursor(0, 1);
  if (gasvalue > 150) {                //Smoke trip
    lcd.print("GAS: Yes");
  }
  else {
    lcd.print("GAS: No ");
  }
```

```
  if (smokevalue > 150) {
    lcd.print(" | SMOKE:Yes");
    // tone(buzzer, 1000);
  }
  else {
    lcd.print(" | SMOKE: No");
  }
  lcd.setCursor(0, 2);
  lcd.print("V:" + String(voltage, 2) + "V | I:" + String(current, 3) + "A");
  lcd.setCursor(0, 3);
  lcd.print("P:" + String(voltage * current, 2) + "W  | B:" + String((voltage / 16.8) * 100, 0) +
"%"); //battary
}
void setup()
{
  updateVI();
  stopSystem();
  Serial.begin(9600);
  // lcd.init();
  lcd.begin();
  lcd.backlight();
  pinMode(smokepin, INPUT);   //somke pin as input
  pinMode(gaspin, INPUT);     // gas pin as input
  pinMode(buzzer, OUTPUT);                //buzzer
  pinMode(lidFeedbackPin, INPUT_PULLUP);
  /*
    sonar1();
    sonar2();
    sonar3();
```

```
  */
  //RELAY ACTUALTOR
  pinMode(2, OUTPUT);       // top relay
  pinMode(3, OUTPUT);       // 2nd relay
  digitalWrite(2, HIGH);    // off
  digitalWrite(3, HIGH);    // off
  myservo.attach(11);
  myservo.write(0);
  while (digitalRead(12) != 0) {
    closeLid();
  }
  updateFill();
  digitalWrite(3, HIGH); // EXTEND actuator
  digitalWrite(2, HIGH);
  disp1();
}
void openLid() {
  digitalWrite(3, LOW); // EXTEND actuator
  digitalWrite(2, HIGH);
  for (int m = 0; m < 40; m++) {
    delay(200);
  }
  digitalWrite(3, HIGH); // EXTEND actuator
  digitalWrite(2, HIGH);
}
void closeLid() {
  digitalWrite(2, LOW); //Close
  digitalWrite(3, HIGH);
  updateVI();
```

```
}
void handle2ndLid() {
  //Serial.println("Servo open");
  for (pos = 0; pos <= 90; pos++) { // goes from 0 degrees to 180 degrees
    // in steps of 1 degree
    myservo.write(pos);              // tell servo to go to position in variable 'pos'
    delay(15);                       // waits 15 ms for the servo to reach the position
  }
  int i = 0;
  while (i < 10) {
    delay(1000);
    //int sensorValue = digitalRead(pirpin);  //PIR
    //if (sensorValue == 1) {
    // i=5;
    //}
    i++;
  }
  //Serial.println("Servo close");
  for (pos = 90; pos >= 1; pos--) { // goes from 0 degrees to 180 degrees
    // in steps of 1 degree
    myservo.write(pos);              // tell servo to go to position in variable 'pos'
    delay(15);                       // waits 15 ms for the servo to reach the position
  }
}
void updateVI() {
  if (lastUp == 0 || millis() - lastUp > 1000) {
    //measure voltage
    voltage = 0;
    for (int l = 0; l < 30; l++) {
```

```
    voltage = voltage + analogRead(A3);
    delay(2);
  }
  voltage = voltage / 30;
  voltage = voltage * (5.0 / 1024.0) * ((2.62 + 9.65) / 2.62);
  voltage = voltage - 0.25;
  stopSystem();
  for (int i = 0; i < averageValue; i++)
  {
    sensorValue += analogRead(analogPin);

    // wait 2 milliseconds before the next loop
    delay(2);
  }
  sensorValue = sensorValue / averageValue;
  v = sensorValue * 5.0 / 1024.0;
  current = (v - 2.5) / (-0.185);
  //current= (-1.00)*current;
  //Serial.println("V:" + String(voltage, 3) + "   I:" + String(current, 3) + "mA");
  smokevalue = analogRead(smokepin);      //SMOKE SENSOR CODE IS HERE
  gasvalue = analogRead(gaspin);

  //binp1, binp2, smokevalue, gasvalue, battary String((voltage / 16.8) * 100, 0)

  Serial.println(String(binP1, 0) + "p" + String(binP2, 0) + "s" + String(smokevalue, 0) + "g"
+ String(gasvalue, 0) + "b" + String((voltage / 16.8) * 100, 0));
  lastUp = millis();
 }
 dispUpTime++;
```

```
  if (dispUpTime == 10) {
    disp1();
    dispUpTime = 0;
  }
}
void loop()
{
  if (sonar3.ping_cm() < 30) {
    //Serial.println("In detect");
    unsigned long detectTime = millis();
    int detect = 0;
    while (sonar3.ping_cm() < 30 && millis() - detectTime < 5000) {
      detect++;
      if (detect > 9) {
        break;
      }
      delay(500);
    }
    if (detect > 9) {
      openLid();
      for (int j = 0; j < 150; j++) {
        //  Serial.println("Loop:" + String(j) + " Dis:" + String(sonar1.ping_cm()));
        if (sonar1.ping_cm() > 3 && sonar1.ping_cm() < 10) {
          handle2ndLid();
        }
        else {
          myservo.write(pos == 0);
        }
        delay(100);
```

```
      }
      //Lid close
      while (digitalRead(12) != 0) {
        closeLid();
      }
      digitalWrite(3, HIGH); //
      digitalWrite(2, HIGH);
      updateFill();
    }
  }
  updateVI();
  stopSystem();
}
```