ENGINEERING TEAM PROJECT

Project Title: Evergreen Smart Dustbin

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TABLE OF CONTENTS

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ABSTRACT

A significant amount of waste is generated as result of rapid population increase, industrialization, and urbanization. The unmanaged disposal strategy adopted in our nation has resulted in the buildup of various types of waste. As a result, garbage litters the ecosystem and is deposited on open spaces, posing a serious environmental concern. As a result, waste management has become a major worry for society's health and well-being. Segregation allows garbage to be successfully reused and recycled, thus maximizes the value of waste. Therefore, having an automated waste management system, which does not implement at the moment, is critical. With that in hand, our plan is to develop a smart garbage segregator that can recognize different forms of waste and sort them into designated containers. This research presents a unique approach that uses the detecting action of different sensors incorporated on top of each compartment hole to separate metals, non-recycled waste (others), and plastics into corresponding bins. The essential component in this project is the Arduino Mega, which allows us to control the entire process with ease and simplicity. To detect and identify various sorts of garbage, the sensing units include an IR sensor, proximity sensor and LDR. The IR sensor detects the presence of waste and may also be used to verify the bin's level whether the capacity inside is full for entry or otherwise it needs to be cleared. The sensors are linked to the automatic waste bin cover with the help of servo motor, which opens approximately 180 degrees when the sensor detects certain types of garbage and closes when the sensor detects other types of waste (respective to their compartments). The Evergreen Smart Dustbin's appearance is digitally appealing, making it ideal for usage in public spaces and tourist attractions such as theme parks.

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND OF PROJECT

In many industrialized and developing countries, including Malaysia, inappropriate municipal solid waste (MSW) management is a major issue in both urban and rural regions. Municipal solid waste, often known as trash or rubbish, is made up of ordinary goods such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries that we use and then discard (Onel et al., 2014). This is found in our homes, schools, hospitals, and workplaces. According to research (Joschka Müller, 2021), in 2020, 85% of Malaysia's municipal solid waste was disposed of in ecologically harmful ways. In comparison, the rate of municipal solid waste collection coverage in Malaysia was 80%. Malaysia now has solid waste generation per capita at 1.1 kilogramme per day. Every day, around 26,500 t of solid waste is disposed of nearly entirely through the country's 166 active landfills (Kamaruddin et al., 2017).

Recycling is the third component of the "Reduce, Reuse, Recycle" waste hierarchy and is a fundamental component in waste materials reduction. There are several types of recyclable materials, including various types of paper, glass, metal, and other materials. The different types of waste materials must be sorted, once recyclable materials are collected and delivered to a central collection facility. As a result, waste segregation is critical in order to lessen the strain on our planet.

This project proposes an innovation of the smart recycle bin. This project aims to keep the environment clean while being environmentally friendly. The main function of this product is to segregate recyclable wastes from the non-recyclables. By carrying out this project, a cleaner, safer, more hygienic environment and enhanced operational efficiency are to be expected.

1.2 PROBLEM STATEMENT

There are three main issues that have arisen as a result of the failure of waste disposal and recycle. Firstly, issue regarding dustbins that are placed in public areas such as theme parks, tourist destinations, playgrounds and many more. It is common that the dustbins are placed at far away from each other. This situation makes people tend to throw or leave their rubbish freely on the ground or at isolated places since they have missed the first dustbin, and yet to find another dustbin within their sight.

Other than that, there are millions of public dustbins out there that people use and are emptied in a few days by the public authorities. This results to overflowing dustbins if the person in charge is late to clean up the dustbin. This problem can get even worse in public area especially in tourist destinations since there will be a lot of people, hence contributes to a large amount of rubbish. Not only this will cause visual pollution, it also will cause air pollution and many other discomforts to other people.

Lastly, issue regarding public dustbin users throwing rubbish into a dustbin which is already overflowed. Since the dustbins are placed far away from each other and the public authorities also takes some time to clear up the rubbish bins, people have no choice but to throw their rubbish into an overflowed dustbin. Due to overflowed and uncleaned dustbins, bad smell arises, also toxic and unhygienic gases are produced which is way to support to the air pollution and to some harmful disease which are easily spreadable.

1.3 OBJECTIVES AND SCOPE

Project Objectives:

Based on the problem statements discussed above, the objectives of this project are:

i. To design a smart dustbin that would aid in keeping our environment clean while also being environmentally friendly.
ii. To design a smart dustbin that is able to move around by a controller, able to automatically detects the garbage level and sends message to respective authorities for the garbage cleaning, also able to segregate recyclable wastes from the non-recyclable ones.

Project Scope:

Our selected Engineering Team Project (ETP) themes for this project are Sustainable Goal Development (SDG) number 7 and 11. The goals and targets that will be highlighted by our project are SDG 7.2 and 11.6.

Table 1.3: Sustainable Development Goals & Targets

SUSTAINABLE DEVELOPMENT GOALS	**GOALS & TARGETS**
7 Ensure access to affordable, reliable, sustainable and modern energy for all	**7.2**

	By 2030, increase substantially the share of renewable energy in the global energy mix
11 Make cities and human settlements inclusive, safe, resilient and sustainable	**11.6** By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

1.4 LITERATURE REVIEW

According to Mazzanti et. al (2008), solid waste management has become one of the most pressing environmental issues. This is especially true in metropolitan areas, where the population is quickly expanding, and the volume of waste created has been increasing like never before (Kathira & Mohd Yunus, 2008). Based on Population Division Department of Economic and Social Affairs, United Nation Secretariat, as of 2009, the world's current population is 6.8 billion people, with about half of them living in urban areas. With this population and affluence, waste creation rises proportionally and necessitating a need for a proper waste management especially in rural and urban areas (Mazzanti & Zoboli, 2008). Not only that, urbanization and industrialization of the world have led to the new lifestyles and behaviours, which has an impact on waste composition such as the shifting use of organic material to synthetic material that could survive much longer for example, plastic. Unknowingly this could lead to other natural disasters if it not handled properly.

In Malaysia, waste issues are commonly associated with poor waste management, and both the federal and local governments are desperately looking for long-term solutions to handle overloaded wastes that do not exceed their budgets or have a negative influence on the public's health. A research by Hamid et. al. (2010), stated that, to deal with the country's average daily waste output of 0.8 kg/capita, the Malaysian government needs to spend RM0.06 (or US$0.016) per kilogram garbage each day. With a population of 23 million people (according to the 2000 census), this equates to RM400 million (US$105 million) every year. With this much of a cost, it is true that this is more or less has become a burden for government financially. Limited budgets, a lack of effective waste disposal sites resulting in landfill pop-ups, apathy among the people towards waste reduction and recycling, and illegal garbage dumping are all common waste management limitation and issues in Malaysia (Hussein & Chu, 2010). More than that, this inadequate solid waste management leads to more problems such in contamination of the air, land, and water, resulting in not only environmental deterioration but also a growing list of human health issues. Contaminated surface and ground water sources may occur from unethical waste management. Organic wastes disposed of in landfills emit greenhouse gases, and untreated leachate pollutes the soil and water sources around them, including groundwater.

Humans produce waste on a daily basis. As a result of population expansion and increased economic activity, more garbage will be created and if waste is not properly handled, it will negatively impact our environment, health, and economy over time. Malaysians suffer from a severe lack of public awareness and environmental education, which contributes to the main country's waste management problem (Krausz, 2015).

According to Krausz (2015), years of awareness campaigns, public forums, and corporate social responsibility initiatives have failed to make an impact due to a lack of public response since roughly 1988. The throwaway culture has become significant in our communities, without considering its consequences especially to the surroundings. Waste discarded in inappropriate areas may cause sewage and drain systems to get clogged, resulting in water accumulation and the growth of numerous viruses and parasites, leading to the spread of various illnesses. As a consequence, society is forced to live in unsanitary conditions due to this cause. Another core factor that contributes to the cause, is food waste generation among communities. Based on study held by Jereme and Siwar (2016), Malaysians throw away up to 930 tonnes of uneaten food every day. This is the equivalent of wasting 10kg of rice per day. Furthermore, in Malaysia, unconsumed food wastage has increased in the last few years; this does not include leftover food. Expired bread, eggs, and old or rotting fruit make up the majority of the unconsumed food. For example, food waste is becoming more prevalent, with organic kitchen waste such as leftover food accounting for over half of the 31,000 tonnes of solid garbage created daily by Malaysians (Jereme, 2016). Therefore, it can be said that practically all of the food wastes created in Malaysia is disposed of in landfills, including garbage from households, businesses, restaurants, food courts, and night markets, as well as waste from the canned food industry. Table 1 displays data on food waste collected from various sources.

The advancement of information technology and smart cities technology has been implemented in a variety of applications, including in waste management. One of the most important approaches to waste management is recycling. Recycling is the collection and processing of undesirable resources in order to convert them into new products while reducing the quantity use of the newly raw materials. A study by Mohd Helmy and Aeslina (2015) stated that, in 2015, Malaysia has an extremely low recycling rate (5%) when compared to other nations. However, the Ministry of Housing and Local Government aims to have a 22 percent recycling rate by the year of 2020. An efficient application of the 3R (reduces, reuses, recycles) ideas and practices in solid waste management is thus emphasized in ensuring that the recycling program's targeted goals are met. Increased efforts to promote the 3R programme were made to encourage the lowering of wastes going into landfills in order to preserve and conserve natural resources, the environment and energy.

Table 1: Food waste generated in Malaysia

Estimated food waste generated in Malaysia	Generation rate		
Sources of food	(tonnes/day)	(tonnes/year)	Percent
Households	8,745	3,192,404	38.32
Wet and night markets	5,592	2,040,929	24.50
Food courts/restaurants	5,319	1,941,608	23.35
Hotels	1,568	572,284	6.87
Food and beverages industries	854	311,564	3.41
Shopping malls	298	108,678	1.30
Hypermarkets	291	106,288	1.28
Institutions	55	26,962	0.32
Schools	45	21,808	0.30
Fast food/chain shops	2521	808	0.26
Total	**22,793**	**8,331,589**	**100**

Figure 1.4: Recycle collection program by NGO

According to Perbadanan Pengurusan Sisa Pepejal (PPSPPA), even though the facilities such as recycling bin and recycle collection program have been implemented, citizens understanding, and awareness of waste recycling are still worrying. Composting and recycling are two examples of alternative solid waste management methods that most homeowners are unaware of (Samdani & Choudhary, 2017). To minimize trash volume, some households burn their garbage in an open area causing such unpleasant plumes of smoke and fumes threatening the environment. Despite the fact that the gases produced from this action are pollutants, this approach only clears the amount of trash piles for a short period of time until the garbage starts to build up again. This shows how important to have an improvised method for a proper developed waste management in relation to encourage the communities to recycle. However, the recycling program are still ongoing, even at its own pace by certain people in Malaysia. Figure 1 depicts the existing scenario of recycle collecting program that are still being conducted by the communities until now.

CHAPTER 2 PROCEDURE & ANALYSIS

2.1 APPLICATION OF DESIGN THINKING

Design thinking is a human-centered paradigm for solving ill-defined or unknown complicated challenges. It incorporates people's demands, technological potential, and commercial success requirements using tools from the designer's toolbox. The design thinking approach is divided into five steps:

i. **Empathize**

Gaining an empathetic knowledge of the problem to address is the first step in the Design Thinking process. This involves consulting experts to learn more about the subject of concern, as well as observing, engaging, and empathizing with people to better understand their experiences and motivations, as well as studying the physical environment to gain a more personal understanding of the issues at hand.

ii. **Define**

During the Define stage, the information created and gathered will be put together during the Empathize stage. This is where observations will be analyzed and synthesized in order to define the core problems that have been identified up to this point. The problem should be defined as a problem statement in a human-centered manner.

iii. **Ideate**

During the third stage of the Design Thinking process, ideas are ready and started to generate. The users and their needs are understood in the Empathize stage, and the observations have been analyzed and synthesized in the Define stage, and ended up with a human-centered problem statement.

iv. Prototype

A prototype was constructed based on the chosen idea. A prototype is basically a scaled-down version of a commercialized product which incorporates the potential solutions identified in the previous stages to investigate the ideas that have been generated.

v. Test

The prototype was tested rigorously for its workability. The prototype was working perfectly as what we have programmed.

2.2 METHODOLOGY

2.2.1 Procedures/ Work Flow

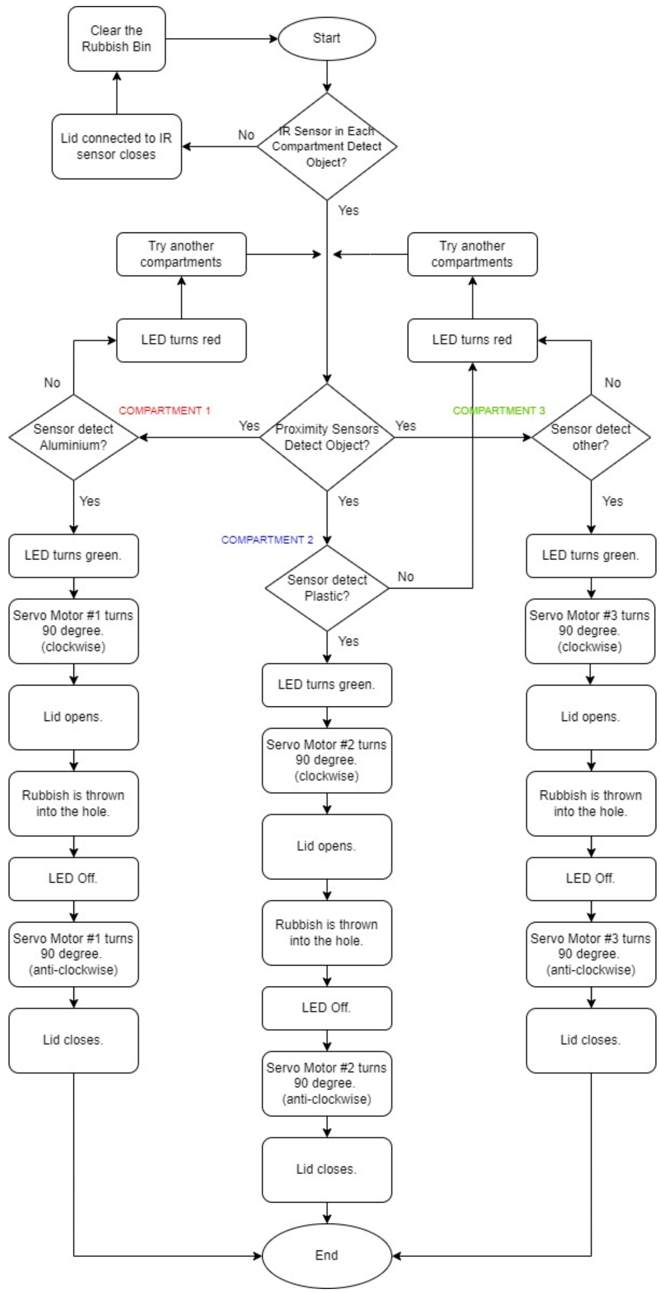

Figure 2.2.1: Work Flow

2.2.2 Identification of Suitable Hardware and Software

Hardware

Table 2.2.2.1: List of Hardware Used

No.	Item	Description
1	Ultrasonic Sensor	Used to detect the level between the trash and the ultrasonic sensor.
2	Inductive Proximity Sensor	Used for positioning and detection of metal objects such as iron, steel, aluminium and copper.
3	Infrared Sensor	To allow the infrared light from LED reflects off of the object when an object comes close.
4	Moisture sensor	To detect wet nonmetal rubbish.
5	USB Micro B cable	Transfers data from one connection to another.
6	SG90 Micro Servo Motor	Lightweight motor with high output power.
7	RGB lights 5mm (Red, Green)	To indicate if the bin is powered on or off.
8	Rocker Switch (2 pin)	Switch used to connect or disconnect an electrical circuit.
9	Arduino Mega 2560	A programmable board that can turn read inputs and turn it into outputs.
10	5W Solar Panel	Converts solar energy into electrical energy.
11	Power Bank	Stores energy for the operation of the smart bin.
12	Jumper Wire	Transmits signals between different electronic components.
13	Breadboard	Used as the base of circuit

Software

Table 2.2.2.2: List of Software Used

No.	Programme	Description

1	Arduino	Used to write and upload computer code to the physical board.
2	Autodesk Fusion 360	Used to design and draw 3D diagrams.

2.2.3 Materials Used and Justification

It is important that the material used in this project ensures the highest possible standard for the finished product without being too costly. Therefore, these are the selected materials required to make our product.

Table 2.2.3.1: List of Materials Used and Justification

Types of Material	**Purpose**	**Justification**
Corrugated box	Used as the container inside the prototype body	• Cost-effective • Maximum protection • Lightweight • Flexible
Acrylic	Used for the body of the prototype	• Excellent dimensional stability and durability • Lightweight • UV and impact resistance

2.2.4 Fabrication Choices and Justification

Table 2.2.3.2: List of Fabrication Choices and Justification

No.	**Fabrication choices**	**Justification**
1	Drilling	Used to make a circular hole using a different sizes of drill bits.

2	Laser cutting	Enables us to cut complex shapes without the need for tooling.
3	Welding	Fusion of two or more parts by using heat.
4	Soldering	Used to join metals together by melting with a hot iron and creates an electrical bond when cooled.

2.3 Fundamental of Engineering Analysis

2.3.1 Engineering Analysis - Electrical Engineering

2.3.2.1 USB Solar Charging Board Panel

A USB Solar Charging Board is a type of solar panel which has a property to convert and supply solar energy into electrical energy as power supplies to the main components of the prototype. It has high efficiency output which can supply efficiently to the power bank.

Specifications:

Table 2.3.2.1: description of USB solar charging board panel

Material	Polycrystalline Silicon
Size	88x142mm
Net Weight	0.055 kg
Working Voltage	5.0V
Output Power	5.0W

From the Electric Power formula, P=VI where P=Power, V=Voltage and I=Current, we can obtain the current by substituting the values of the power and voltage from the solar panel’s description.

$P = V * I$

$I = P \div V$

$I = 5 \div 5 = 1A$

Therefore, the output current of the solar panel is 1A.

2.3.2.2 PN-951 Power Bank

Portable Power Banks are made up of a specific battery housed in a customised casing with a particular power control circuit. They enable the user to store electrical energy (in a bank) and then utilise it to charge a device afterwards. In this project, the PN-951 is powered by the solar panel to be use for the main components inside the smart dustbin.

Specifications:

Table 2.3.2.2: description of PN-951 Power Bank

Model	PN-951
Capacity of Li-ion battery	3.7V
Capacity of the Bank	10000mAh
Rated Output	≥ 6300mAh
Input Voltage	5.0V
Output Voltage	5.0V
Input Current	2.0A
Output Current	2.1A

- Time Taken to Charge Power Bank

In order to calculate the time taken to charge the power bank, the formula below can be used :

Time taken to charge = (mAh of your Powerbank)/(mA of the Charger or Adapter)+10%

$$Time\ taken\ to\ charge = \frac{(mAh\ of\ the\ bank)}{(mA\ of\ the\ charger)} + 10\%$$

Since the power bank is 10kmAh and the solar panel output is 1A = 1000mA, the time taken to fully charge the power bank is :

$$\text{Time taken} = (10000\text{mAh} / 1000\text{mA}) + 10\%$$

$$\text{Time taken} = 10\text{h} + (10 * 10\%)$$

$$\text{Time taken} = 10\text{h} + 1\text{h}$$

$$\text{Time taken} = 11 \text{ hours}$$

- Real Capacity of a Fully Charged 10000mAh Power Bank

In real condition, a power bank only has about 66% or two-thirds of its stated capacity and the reason is the difference in voltage. The capacity of the power bank Li-ion Battery is 3.7V but the required voltage supplied to the Arduino Mega board is 5V.

A power bank with 3.7V and 10000mah battery will be having power of 37000 mWh

$$\text{P} = \text{VI} = 3.7(100000) = 37000\text{mWh}$$

Due to the reason that Arduino Mega uses 5V, we have to divide the watt hours by 5V.

$$37000\text{mWh} / 5\text{V} = 7400\text{mAh} \quad (\text{P/V} = \text{I})$$

Besides that, we also consider the condition where 10% energy loss in the cable wires by assuming the power bank has 90% efficiency.

$$7400\text{mAh} * 90\% = 7400\text{mAh} * 0.90 = 6660\text{mAh}$$

Therefore, since the output current for the power bank is 2.1A and the real capacity is 6660mAh, the total time that the fully charged power bank can be used to supply power to Arduino Mega if without any charging is :

$$\text{Total Time} = \text{Capacity} / \text{Current Used}$$

$$\text{Total Time} = 6660\text{mAh} / 2.1\text{A}$$

$$\text{Total Time} = 6660\text{mAh} / 2100\text{mA}$$

$$\text{Total Time} = 3.17\text{hours}$$

2.3.2.3 Arduino IDE

This is the sample code that was used in this project from the Arduino IDE programme. The rest of the code may be found in the appendices.

```
void RGB_color_2(int red_light_value, int green_light_value, int blue_light_value)
{
  analogWrite(red_light_pin_2, red_light_value);
  analogWrite(green_light_pin_2, green_light_value);
  analogWrite(blue_light_pin_2, blue_light_value);
}

void RGB_color_3(int red_light_value, int green_light_value, int blue_light_value)
{
  analogWrite(red_light_pin_3, red_light_value);
  analogWrite(green_light_pin_3, green_light_value);
  analogWrite(blue_light_pin_3, blue_light_value);
}

void setup()
{
  //RBGLed
  pinMode(red_light_pin_1, OUTPUT);
  pinMode(green_light_pin_1, OUTPUT);
  pinMode(blue_light_pin_1, OUTPUT);
  pinMode(red_light_pin_2, OUTPUT);
  pinMode(green_light_pin_2, OUTPUT);
  pinMode(blue_light_pin_2, OUTPUT);
  pinMode(red_light_pin_3, OUTPUT);
  pinMode(green_light_pin_3, OUTPUT);
  pinMode(blue_light_pin_3, OUTPUT);
  RGB_color_1(255, 255, 255);
  RGB_color_2(255, 255, 255);
  RGB_color_3(255, 255, 255);
  //Servo Motor
```

Figure 2.3.2.3: Arduino Code

2.3.2 Engineering Analysis - Mechanical Engineering

2.3.2.1 Automated Guided Vehicle

The Automated Guided Vehicle (AGVs) are load carriers that travel around a facility's floor with or without the assistance of a driver or operator. A combination of Arduino and sensor-based navigation systems control their movement. AGVs enable safe load transportation because they operate on a predictable course with precisely regulated acceleration and deceleration and have automated obstacle detecting bumpers. This project use AGV as a carrier to move around the prototype in a certain distance controlled remotely by user.

The following below are the components included to operate AGV:

- 1 x Maker UNO (Simplifying Arduino for Education)

- 1 x Maker Drive: Dual H-Bridge Motor Driver for Beginner
- 2 x 3 - 6VDC Dual Axis TT Gear Motor (with pre-solder wires)
- 2 x Rubber Wheel for TT Gear Motor (63mm x 15mm)
- 2 x IR Line Tracking Module
- 1 x HC-SR04 Ultrasonic Ranging Module
- 1 x Breadboard Mini (35mmx42mm)
- 1 x 40 ways Male to Female Jumper Wire
- 1 x 40 ways Male to Male Jumper Wire
- 1 x 4xAA Batteries
- 1 x 4xAA Battery holder

2.3.2.2 Circuit Design the AGV

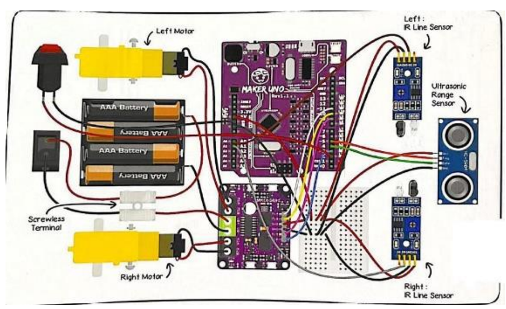

Figure 2.3.2.2: AGV Circuit

2.3.2.3 The Efficiency of AGV

It is critical to understand the AGV's efficiency in order to assess whether it's suitable for real-world applications. The time taken to travel a specific distance and the acceleration are determined whether the prototype is suitable with the AGV system. The dustbin container and AGV were tested to travelled in 10 meters with its force and acceleration.

Parameters:

Table 2.3.2.3: parameters of AGV

Distance Travelled	10 m
Weight of AGV	0.509 kg
Weight of Dustbin Container	2.050 kg
Weight of AGV + Dustbin Container	2.559 kg
Theoretical Maximum Speed of AGV with 6V Battery	1.39 m/s
Single AA Battery Voltage	1.5V (6.0V for 4 batteries)

*Theoretical value of maximum speed reference: (kidselectriccars.co.uk)

- Time taken for a single AGV to travelled

In order to calculate the time taken travelled by the AGV, the formula of velocity below can be used :

$$Velocity = \frac{Distance\ travelled\ by\ AGV}{Time\ taken\ of\ travel}$$

Since the 10-meter distance travelled is divided by the velocity of the AGV with 6V total voltage, the time taken for the single AGV to travelled 10-meter distance is therefore,

$$Time\ taken, T_1 = 7.19s$$

- Acceleration of a single AGV

In order to calculate the acceleration, the formula of acceleration is used as below:

$$Acceleration\ of\ AGV, a_1 = \frac{Maximum\ velocity\ of\ a\ single\ 6V\ AGV, v}{Time\ taken\ for\ a\ single\ AGV\ to\ travelled, T_1}$$

Therefore, the acceleration of the single AGV is $a_1 = 0.19\ m/s^2$

- Acceleration of the prototype by AGV

  In order to calculate the acceleration of the whole moving prototype, the force of the AGV need to be determined by:

$$Force\ of\ AGV, F_1 = (mass\ of\ AGV, m_1) \times (acceleration\ of\ AGV, a_1)$$

  From this, the value of $F_1 = 0.09N$

  Therefore, acceleration can be calculated by,

$$\begin{aligned} &Force\ of\ AGV, F_1 \\ &\quad = (mass\ of\ prototype\ with\ AGV, m_T) \\ &\quad \times (acceleration\ of\ AGV, a_2) \end{aligned}$$

  Therefore, the acceleration of prototype with AGV system is $a_2 = 0.035\ m/s^2$.

- Time taken for the prototype with AGV to travelled

  In order to calculate the time taken of prototype with AGV, T_2, the new velocity of the AGV with prototype is determined.

$$Acceleration\ of\ AGV + prototype, a_2$$

$$= \frac{Maximum\ velocity\ of\ a\ single\ 6V\ AGV, v_2}{Time\ taken\ for\ a\ single\ AGV\ to\ travelled, T_1}$$

Therefore, the velocity of prototype with AGV, $v_2 = 0.25\ m/s$

With value of v_2, the time taken for the prototype with AGV to travelled can be determined by

$$Velocity\ of\ prototype + AGV, v_2 = \frac{Distance\ travelled, D}{Time\ taken\ of\ travel, T_2}$$

Therefore, the time taken for the prototype with AGV to travelled is $T_2 = 40s$

2.3 BUSINESS AND ECONOMIC ANALYSIS

2.4.1 Capital Cost Considerations

The cost of building a smart dustbin prototype is included in the project's capital cost. Capital cost is a defined price plus one-time costs that might be considered an asset.

Table 2.4.1: Capital Cost Consideration

ITEM	QUANTITY	PRICE PER UNIT (MYR)	PRICE TOTAL (MYR)
5VDC HC-SR04 IR Sensor	1	3.50	3.50
10-30VDC Inductive Proximity Sensor NPN NO	2	14.90	29.80

Capacitive Sensor 5VDC	1	26.50	26.50
Arduino Mega 2560 R3-Main Board	1	95.00	95.00
Solar Panel System	1	13.90	13.90
Breadboard	3	2.70	8.10
SG90 Micro Servo Motor	3	15.00	45.00
Jumper Wire M-M/M-F/F-F	3	12.00	36.00
Automated Guided Vehicle	1	110.00	110.00
Acrylic Body	1	355.00	355.00
LED Super Bright 5mm Green	5	0.20	1.00
LED Super Bright 5mm Red	5	0.20	1.00
		Total	**724.80**

2.4.2 Operational Cost Considerations

Operational cost considerations are the cost incurred on day-today operation of the device.

Table 2.4.2: Operational Cost Consideration

No.	**Items**	**Cost per day (MYR)**	**Number of days**	**Total cost (MYR)**
1	Electricity cost	0.70 for first 200kWh	7	4.92
2	Manpower cost	25	7	175
			Total	179.92

2.4.3 Product Feasibility

To analyze whether the project is feasible to be produced, a feasibility plan is required to be conducted based on three different evaluations which are based on the economic feasibility plan, operational feasibility plan and technical feasibility plan. The feasibility plans of the product have been concluded based on the discussion and research done on the design concept of the product.

2.4.3.1 Economic Feasibility of plan

To ensure that our project is feasible to build, it is important for us to conduct an economic feasibility plan to know the target market of the product. In Malaysia, the usage of smart dustbin is not being implemented commonly yet as compared to other countries such as Japan and China. Therefore, our project which is the smart dustbin can lead to a long-term effect to the environment once it is widely implemented by the government. Besides that, the contribution of this “Evergreen Smart Dustbin” to trigger the cyclic economy allow it to have a wide market in Malaysia. Based on our research on Internet, the recycling activity in Malaysia is not widely implemented by the citizens in Malaysia yet and therefore this product is important to make a change for a better environment in our country. While for the building of prototype, the analysis on the materials and components used should be done to make sure that the product is priced reasonably and suit the market needs. Due to the limited budget, our plan is to search for cheaper alternatives of materials to make the product as affordable as possible so that the product can be produced in large amount for community use.

2.4.3.2 Operational Feasibility of plan

The Evergreen Smart Dustbin is a product that can differentiate between recyclable material and non-recyclable materials from the rubbish thrown by people. Only the correct rubbish can be thrown into the correct holes of the rubbish bin. To ensure that this product is feasible in terms of operational, we had considered on several factors such as reliability, usability and sustainability.

The reliability of the device is high as we will have different types of sensors to sense the existence of rubbish and differentiate the recyclable materials such as aluminium and plastics to avoid any problems to occur. Besides that, the usability of the product is high also as it can be placed at any place in Malaysia especially on the tourist attractions such as theme park, sea side and others. Lastly, the product has high sustainability as it has two types of power supply which are the solar power and electricity. In overall, the product has high reliability, usability and sustainability and thus it can be built.

2.4.3.3 Technical Feasibility of plan

In the technical feasibility plan, we will be considered on the methods to convert our ideas based on the sketching of the diagram into the prototype. We need to simulate the project by using animations and AUTOCAD to have a clearer overview on the product before we can manufacture the prototype. Besides that, several fabrication processes are required too to produce the prototype and the members can conduct the fabrications process in the lab in campus after attending the safety briefing given by the workshop's technician. Lastly, the knowledge regarding the circuit components and software which is programming is required to be possessed by the team members as well. Circuit Theory and soldering technique is required to build up the circuit while the ability of designing code is required to write a program in Arduino. After discussing among the team members, the member from different engineering courses have sufficient knowledge in solving the above issues.

CHAPTER 3 RESULTS

3.1 TECHNICAL SPECIFICATION

1. Ultrasonic Sensor

Ultrasonic Sensor is a type of sensor that can be used to determine distance to an object. The ultrasonic sensor's working principle is inspired from the principle of echolocation used by animals such as bats and dolphins. The ultrasonic sensor is different with the infrared sensor as the reading of ultrasonic sensor is not affected by light and object's surface colour since the ultrasonic sensor uses sonar which is the ultrasonic sound waves to determine the distance to an object. Ultrasonic sensors function by sending out a sound wave at a frequency above the range of human hearing and this is the reason why we don't hear any sound from the ultrasonic sensor even though it functions based on sound wave. In the ultrasonic sensor, the transducer acts as a microphone to send and receive ultrasonic pulses that relay back information about an object's proximity. Thus, the sensor can determine the distance to a target by measuring the time lapses between the sending and receiving of the ultrasonic pulse. In our prototype, the ultrasonic sensors contributed by acting as the leveling sensor inside out smart dustbin. It will detect whether the storage of the bin is full by obtaining the distance to the waste in the bin. When the distance between ultrasonic sensor and waste comes to a certain value, it implies that the bin storage is full.

2. Inductive Proximity Sensor

Inductive Proximity Sensor can be also known as the metal sensors that contain high-frequency oscillation circuit, detection circuit, amplifier circuit, the solution circuit and the output circuit in it. An inductive sensor uses the principle of electromagnetic induction to detect or measure objects. When there is power supplied to the inductive sensor, the oscillator in the high frequency oscillation circuit will generates an alternating electromagnetic field on the detection surface of the sensor. Therefore, when there is object with metal type placed with the detection range of the sensor, the eddy current inside the metal will absorbs the energy of the alternating electromagnetic field produced in the oscillator and the oscillation amplitude is reduced. In a more precise manner, the oscillator energy will change in two states where the detection circuit is converted to a level signal and second state is that the transistor circuit produces a switch signal. To convert detection circuit to a level signal, the trigger circuit will trigger the output transistor and the level signal from output transistor is then amplified by the amplifier circuit. Therefore, this electromagnetic effect is used to detect metallic objects since the metallic object is able to interact with magnetic field while for non-metallic substance, it does not interact with the magnetic field. In our prototype, this inductive proximity sensor definitely helps to differentiate whether the rubbish is metal or non-metal since our smart dustbin is segregating 3 types of waste which are the metal waste, dry waste and wet waste. The 3 wires of metal sensor are connected to the 5V voltage supply, Ground and also the I/O pin in Arduino.

3. Infrared Sensor

Infrared Sensor is the sensor that used to detect the existence of any obstacle or object with the detection range. The infrared sensor module also comes along with an on-board potentiometer that can be used to adjust the sensitivity of the sensor. By adjusting it to be more sensitive, the detection range of the sensor is longer until a certain limit. The infrared sensor functions based on the theory of light reflection where the obstacle is detected via infrared reflection. At the front of the infrared sensor module, there are IR LED Transmitter and Photodiode Receiver that comes in a pair. The IR LED Transmitter emits light that is within the range of Infrared frequency and the IR light is invisible to human since its wavelength with length from 700nm to 1mm is much higher than the visible light range. The IR LED is white or transparent in colour in order for it to give out the maximum amount of light. While the receiver which is the Photodiode will conduct when light falls on it. The Photodiode operated in reverse bias and it starts conducting the current in reverse direction when there is light falls on it. The amount of current flow should be proportional to the amount of light received by it. Photodiode looks like a LED but just with a black outer coating since the black colour is the most effective in absorbing light. Therefore, whenever there is object in front of the IR sensor, the object will block the infrared light emitted and the infrared light is reflected to the receiver. In our prototype, the infrared sensor module functions to detect the existence of any rubbish to be placed in the hole of the bin. The infrared sensor is important in our prototype as the metal sensor alone is not able to segregate between metal and non-metal because the metal sensor will assume non-metal is sensed even though when there is no object to be placed in front of it. The 3 pin interfaces of infrared sensor are the OUT connected to I/O pin, GND connect to ground and VCC connected to 5V source.

4. Moisture Sensor

Moisture Sensor is used to detect the moisture condition of an object. There are two parts in this sensor which are the sensor probes and the module board. The detecting surface will be the fork-shaped probe with two exposed conductors that act as a variable resistor where the resistance varies according to the water content in the object. The probes are used to pass current through the object in contact with it and the sensor will then reads the resistance value to obtain the moisture level of the object. The theory applied by this sensor is that higher moisture level will helps to conduct electricity more easily therefore results in a lower resistance and vice versa. Apart from the sensor probes, the module come with a comparator and adjustable potentiometer which can be used for the user to adjust the threshold to toggle digital output which actually meant for the sensitivity of the sensor. Both digital or analog output can be used for this moisture sensor. In our prototype, the moisture sensor are used for the compartments of dry waste bin and wet waste bin only. This is because the metal sensor and infrared sensor are not able to differentiate between the dry and wet non-metal. Therefore, the moisture sensor is placed on the lid of the hole. When the waste is placed on it, the moisture sensor is able to differentiate whether the waste is in dry or wet condition based on the water content in it.

5. SG90 Micro Servo Motor

SG90 Micro Servo Motor is a tiny and lightweight servo motor with high output power where it has the rotation angle to 180 degrees. In the SG90 Micro Servo Motor, there are plastic gears available in it that will help in the rotation. There are also servo horns that used to connect with the servo motor and different shapes of servo horn can be used for different function. In our prototype, the SG90 Micro Servo Motor is used to control the opening and closing of the lid for each hole. Suitable servo horn is chosen and the servo horn will stick with the lids so that the lids will follow the movement of the servo horns when the servo motor rotates. The suitable rotation degree can be set up in the Arduino code as well. The 3 pin interfaces of servo motor are the Signal connected to I/O pin, GND connect to ground and VCC connected to 5V source.

6. Arduino Mega 2560

Arduino Mega 2560 is a microcontroller board based on the ATmega2560. The Arduino Mega board consist of 54 digital input/output (I/O) pins (15 of them can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header and a reset button. In order to power-up the Arduino, we can connect it to a computer or to any power source such as power bank using USB 2.0 Cable Type A/B. In our prototype, the Arduino Mega is one of the most essential components and the prototype will not function at all without it. To allow the Arduino to function, we have to first download the Arduino IDE software on computer and design the code based on the functionality we want for our prototype. After the code is well designed, we then connect the Arduino to our computer and the completed coding can be uploaded to Arduino from the Arduino IDE software. After we uploaded the code into Arduino board, it will automatically save the code that we uploaded. Therefore, we can use any power source to power up the Arduino board to function for the prototype after the code is uploaded.

7. Solar panel

A solar panel is a collection of photovoltaic cells that are installed in a framework. Solar panels gather and convert pure renewable energy in the form of sunlight into electricity, which may subsequently be utilized to power electrical loads. Solar panels are made up of several solar cells, each of which is made up of layers of silicon, phosphorous (which gives negative charge), and boron (which provides the positive charge). In our prototype, the solar panel contributes to supply electrical energy to keep our prototype working. It is placed on the cap or head of the prototype to gather as many sunlight energy as it can. Solar panel is also used to charge the powerbank that is connected to Arduino board to supply power. The description of solar panel is as below:

Table 3.1.1: description of Solar Panel

Size	88*142mm
Power	5W
Working Voltage	5V
Material	Polycrystalline silicon
Colour	Black

8. Automated Guided Vehicle (AGV)

Automated guided vehicle (AGV), also known as an autonomous mobile robot (AMR), is a portable robot that navigates by using radio waves, vision cameras, magnets, or lasers to follow specified long lines or wires on the floor. They're most commonly employed in industrial settings to move heavy goods across a vast industrial structure, such as a factory or warehouse. In our prototype, the automated guided vehicle contributed in making our prototype moves around. The prototype was mounted on the AGV autonomously, and the AGV was programmed with an Arduino Uno to follow black route line detected by infrared sensor. In addition, an ultrasonic sensor was installed in the AGV to allow it to halt when it senses an obstruction in front of it. The technical specifications of AGV is as below:

Table 3.1.2: technical specifications of Automated Guided Vehicle

Distance Travelled	10 m
Weight of AGV	0.509 kg
Weight of Dustbin Container	2.050 kg
Weight of AGV + Dustbin Container	2.559 kg
Theoretical Maximum Speed of AGV with 6V Battery	1.39 m/s
Single AA Battery Voltage	1.5V (6.0V for 4 batteries)

3.2 ENGINEERING DRAWING

The Engineering Drawing was made using the Software: AutoCAD

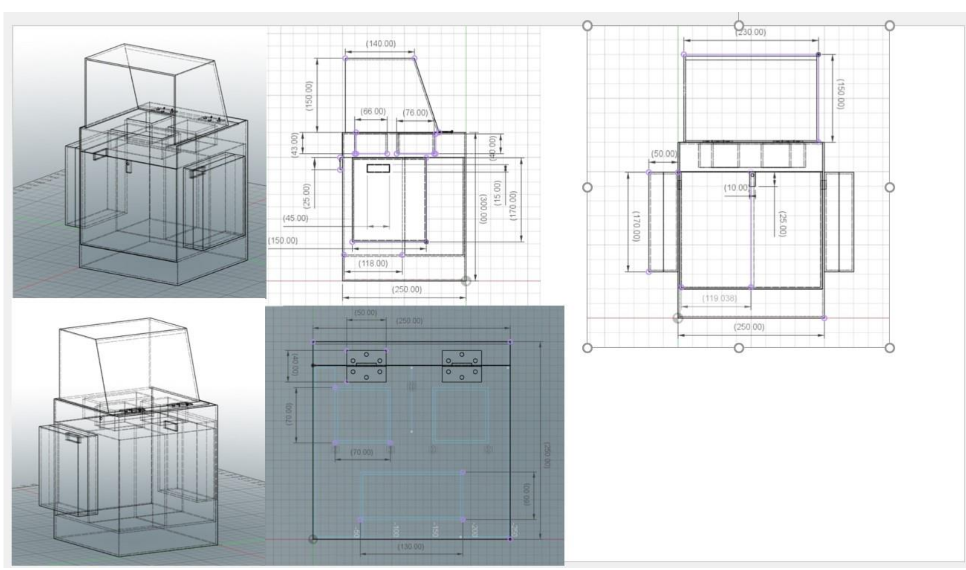

Figure 2.3: Engineering Drawing

3.3 PROJECT OUTPUT

The 3D Prototype was built using the Software: Autodesk Fusion 360

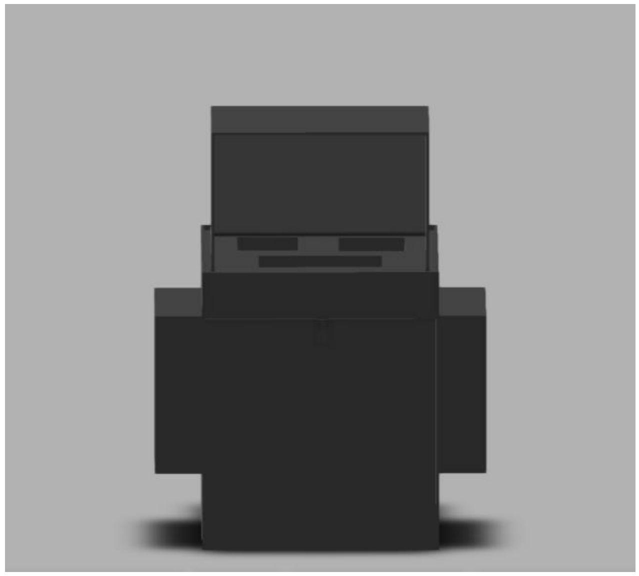

Figure 3.3.1: 3D Prototype

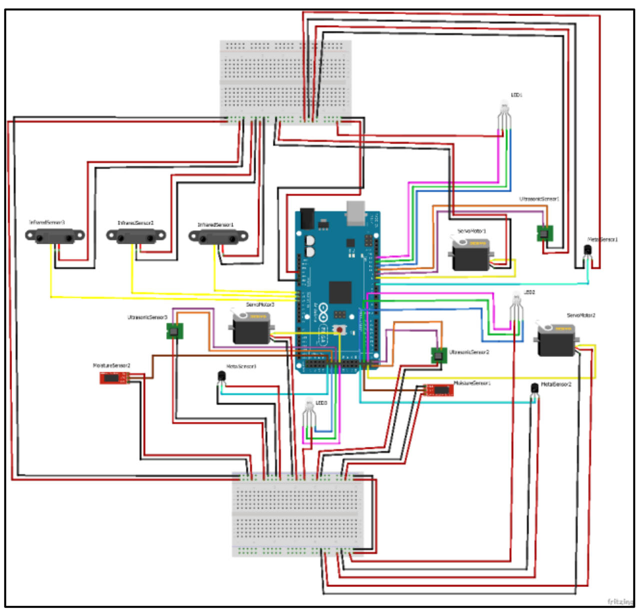

Figure 3.3.2:Circuit Diagram

3.4 DISCUSSION ON RESULTS

Our smart dustbin prototype was tested to ensure that it is working well. The testing was conducted to test if the prototype is able to segregate metal rubbish, dry nonmetal rubbish, and wet nonmetal rubbish. The prototype was also tested for its ability to move around and stop if there is any obstacle near the prototype

Figure *3.4.1: overall prototype*

Figure 3.4.2: metal, dry nonmetal, and wet nonmetal compartments

Firstly, the smart dustbin was powered on. When the IR sensor does not detect any object nearby, the lids that are connected to the IR sensor did not open, otherwise, when the sensor detected any object, for example a metal object like a drink can, the LED turned green and the servo motor in compartment 1 spun 90 degrees clockwise. When the lid was opened, the user can then toss the rubbish into compartment 1. The LED turned off when the user has tossed the rubbish in, and the servo motor rotated 90 degrees anticlockwise, closing compartment 1's lid.

Figure 3.4.3: Example when an aluminum drink can was tested on the first compartment

Figure 3.4.3 shows that the LED turned green and the lid was open when an aluminum drink can was brought close to the sensor at compartment 1.

The second compartment is for dry nonmetal objects. When a metal object was brought near to the sensor, the LED turned red and the lid did not open so the user has to try another compartment, which is compartment 1 to throw the metal rubbish.

Figure 3.4.4: Example when a wet nonmetal object was tested on compartment 2

Figure 3.4.4 shows a wet tissue that was tested on the second compartment. From the figure, it can be seen that the LED turned red and the lid did not open, indicating that the object is not a dry nonmetal object. After that, a ping pong ball which made of plastic material was tested on the second compartment. When the ping pong ball was brought near the sensor, the LED turned green and the servo motor spun 90 degrees clockwise, resulting the lid at compartment 2 to open. When the ping pong ball was thrown into the compartment, the LED then turned off and the lid closed.

Figure 3.4.5: Example when a dry nonmetal was tested on compartment 2

Afterwards, compartment 3 was tested for wet nonmetal objects. A metal object was first brought close to the sensor. The lid did not open after the LED flashed red, indicating that the object was not wet nonmetal object. Then a dry ping pong ball was brought near the sensor and when the sensor detected that it was not a wet nonmetal object, the LED turned red and the lid did not open. After that, the third compartment was tested with a wet tissue.

Figure 3.4.6: Example when a wet nonmetal object was tested on compartment 3

Based on Figure 3.4.6 the LED illuminated green and the servo motor turned 90 degrees clockwise when the wet tissue was brought close to the sensor, causing the lid to open. The servo motor twisted 90 degrees counterclockwise and the lid closed when the wet tissue was thrown into the compartment.

Other than that, we also tested on the moving feature of our prototype by attaching the prototype on an automated guided vehicle (AGV). The infrared sensor that was installed in the automated guided vehicle made the prototype able to move on black path. When an obstacle was put on the black path, the ultrasonic sensor in the AGV made the prototype stop moving.

From the result of our prototype test, we can conclude that we have succeed in making our prototype able to segregate metal rubbish, dry nonmetal rubbish, and wet nonmetal rubbish. We also succeed in making our prototype able to detect if the compartment is full so the lid will not open until the compartment is empty again. Our smart dustbin also able to move around and stop if there is an obstacle near it.

3.5 CONCLUSION

In conclusion, in recent years, municipal solid waste collection has remained relatively unchanged. The objective of this project is to create a smart dustbin that will help to maintain our surroundings clean while being ecologically friendly, and to design a smart dustbin that can be moved about by a controller, can automatically detect garbage levels and transmit messages to proper authorities for garbage collection, and can separate recyclable and non-recyclable wastes.

Here we are going to make some modifications that will lead to a cleaner environment. Evergreen Smart Dustbins are superior to ordinary rubbish bins due to their combination of intelligent waste monitoring and trash compaction technology. It is equipped with smart devices such as sensors, Arduino, and so on. When an object approaches the dustbin, the lid will automatically open, and it will close when a set amount of time has passed. The use of an advanced controller, such as Arduino, in conjunction with a GSM and GPS-enabled system improves the overall performance of the solid waste segregation and collection system. As a result, the smart dustbin has the potential to play a significant part in achieving a clean and green environment. Based on the output result, the cost for making Evergreen Smart Dustbin is around RM687.50.

3.6 RECOMMENDATIONS

Despite our project has been proved to detect garbage levels and transmit messages to proper authorities for dustbin cleaning, also being able to move around to collect rubbish, there are several recommendations to be made in order to add more value to our smart dustbin.

1. **Develop a crushing stage by piston** – to compress the wastes inside of the bin container and to increase the space of bin capacity.
2. **Decomposition on wet container** – to prevent moisture and odor from the wastes by using organic composting materials

CHAPTER 4 PROJECT MANAGEMENT

4.1 PROGRESS MONITORING (GANTT CHART)

Table 4.1: Gantt Chart

	Week											
Activity	1	2	3	4	5	6	7	8	9	10	11	12
Seminar 1												
Meeting among the team members												
Consultation with supervisor												
Introduction												
- Form a group with supervisor												
- Ice breaking (Introduction to team members)												
- Brainstorming ideas for project												
Idea/Concept Selection												
- Voting for group leader												
- Vote on the ideas to decide for project												
Seminar 2												
Project Development												
- Brainstorm innovations on selected idea												
- Decide on functionality and features of device												
- Analyze whether the project is useful for community												
- Decide on problem statement and objectives												
Seminar 3												
Overview of the Prototype												

- Sketching out the project decided as first draft												
- Determine the components and materials used												
- Further improve the project on features												
Seminar 4												
Extended Proposal												
- Distribute tasks for extended proposal												
- Perform survey to gauge customer need												
- Checking on the progress of extended proposal												
Designing												
- Come up with several designs for the project as alternatives design												
- Determine the criteria for selection of better design												
- AUTOCAD of selected design												
Methodology												
- Determine device operation (flowchart)												
- List out all suitable components, tools and software												
- Material Selection												
- Determine suitable fabrication												
- Plan for the circuit diagram and device assembly												
Seminar 5												
Economic Analysis												
- Cost considerations based on available budget												
- Determine alternatives in materials												

- Project feasibility and design research												
Extended Proposal Submission												
Seminar 6												
Progress of Creating Prototype												
- Build the prototype based on the finalized AUTOCAD drawing with measurement												
- Check the design for HSE compliance												
- Finalize the coding application												
- Engineering analysis												
Seminar 7												
Seminar 8												
Simulation of prototype												
- Suitable graphics to represent prototype												
- Video of the prototype simulation												
- E-poster for the project												
Seminar 9												
Submission of Design Concept												
Patent Form												
Final Report Draft												
- Distribute tasks for report												
- Checking on the process of Final Report												
PreSEDEX Online Submission												
- Video presentation												
- Oral group presentation												
- Poster presentation												
PreSEDEX Examiner Evaluation												
Final Report Submission												
Peer Evaluation Form Submission												

4.2 TASK ALLOCATION

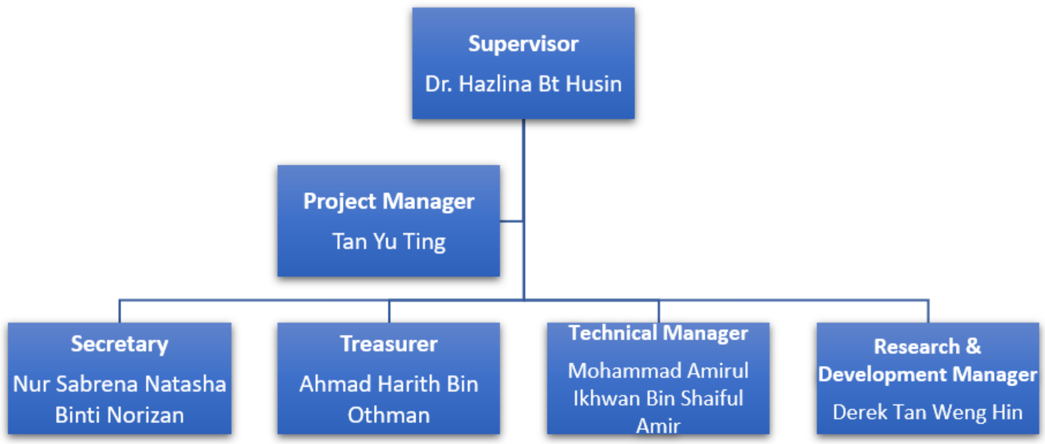

Figure 4.2: Organization Chart

Table 4.2: Task Allocation

Person In Charge	**Roles**
Tan Yu Ting ID : 19000505 Department: Computer Engineering	Project Manager ● Monitors the progress and the flow of the project. ● Schedules weekly meetings with supervisor and members. ● Distribute tasks to members and supervise the progress. ● Develop and design the coding for the project. ● Develop circuit connection for the project. ● Responsible to make final Decision.
Nur Sabrena Natasha Binti Norizan ID : 19000743 Department: Chemical Engineering	Secretary ● Maintain effective record and administration. ● Uphold the guideline and requirement of the project. ● Take note on every discussion during the meetings.

	● Responsible to prepare the minutes of every meeting. ● Conduct and analyze survey to determine customer and market need. ● Responsible in documentation such as reports and proposals
Ahmad Harith Bin Othman ID : 19000893 Department: Chemical Engineering	Treasurer ● Manage the finance of the project. ● Conduct capital and operational cost analysis for economic and business consideration. ● Suggest on the material selection and the alternatives based on the available budget. ● Survey current market price for the materials and components.
Mohammad Amirul Ikhwan Bin Shaiful Amir ID : 19000685 Department: Petroleum Engineering	Technical Manager ● Design the outlook and mechanism of the prototype. ● Finding and sketching for alternative designs. □ ● Responsible in the features of remote control for the prototype. ● Determine the criteria to be considered in selecting final design. ● Determine suitable materials, software and tools required.
Derek Tan Weng Hin ID : 19000371 Department: Mechanical Engineering	Research & Development Manager ● Responsible in tasks of researching and implementing the new idea. ● Develop and improve the current ideas ● Simulate the prototype in AUTOCAD. ● Work with Technical Manager to design basic

	prototype mechanism. ● Work with Technical Manager in selecting the suitable materials and tools.

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APPENDICES

```
#include <Servo.h>


//hole 1： metal

//hole 2： dry

//hole 3： wet


//Ultrasonic
#define echoPin_1 10
#define trigPin_1 9
#define echoPin_2 23
#define trigPin_2 22
#define echoPin_3 42
#define trigPin_3 40
long duration1;
int distance1;
long duration2;
int distance2;
long duration3;
int distance3;

//RBGLED
int red_light_pin_1 = 13;
int green_light_pin_1 = 12;
int blue_light_pin_1 = 11;

int red_light_pin_2 = 24;
int green_light_pin_2 = 26;
int blue_light_pin_2 = 28;
```

```
int red_light_pin_3 = 39;
int green_light_pin_3 = 41;
int blue_light_pin_3 = 43;

//Moisture Sensor
int moist_sensor_1 = 27;
int moist_sensor_2 = 44;

//Servo motor
Servo servo1; //8
Servo servo2; //25
Servo servo3; //38

//Inductive Sensor
int inductive_1 = 7;
int inductive_2 = 29;
int inductive_3 = 45;
int state= LOW;
int inductive_value_1 = 0;
int inductive_value_2 = 0;
int inductive_value_3 = 0;

//IR Sensor
const int IRSensor_1 = A0;
const int IRSensor_2 = A1;
const int IRSensor_3 = A2;
int IR_value_1 = 0;
int IR_value_2 = 0;
int IR_value_3 = 0;
```

```
//Buzzer
int buzzer = 50;

void RGB_color_1(int red_light_value, int green_light_value, int blue_light_value)
{
  analogWrite(red_light_pin_1, red_light_value);
  analogWrite(green_light_pin_1, green_light_value);
  analogWrite(blue_light_pin_1, blue_light_value);
}

void RGB_color_2(int red_light_value, int green_light_value, int blue_light_value)
{
  analogWrite(red_light_pin_2, red_light_value);
  analogWrite(green_light_pin_2, green_light_value);
  analogWrite(blue_light_pin_2, blue_light_value);
}

void RGB_color_3(int red_light_value, int green_light_value, int blue_light_value)
{
  analogWrite(red_light_pin_3, red_light_value);
  analogWrite(green_light_pin_3, green_light_value);
  analogWrite(blue_light_pin_3, blue_light_value);
}

void setup()
{
  //RBGLed
  pinMode(red_light_pin_1, OUTPUT);
  pinMode(green_light_pin_1, OUTPUT);
```

```
pinMode(blue_light_pin_1, OUTPUT);
pinMode(red_light_pin_2, OUTPUT);
pinMode(green_light_pin_2, OUTPUT);
pinMode(blue_light_pin_2, OUTPUT);
pinMode(red_light_pin_3, OUTPUT);
pinMode(green_light_pin_3, OUTPUT);
pinMode(blue_light_pin_3, OUTPUT);
RGB_color_1(255, 255, 255);
RGB_color_2(255, 255, 255);
RGB_color_3(255, 255, 255);
//Servo Motor
servo1.attach(8);
servo1.write(0);
servo2.attach(25);
servo2.write(0);
servo3.attach(38);
servo3.write(0);
//Inductive Sensor
Serial.begin(9600);
pinMode(inductive_1,INPUT);
pinMode(inductive_2,INPUT);
pinMode(inductive_3,INPUT);
//Moisture Sensor
pinMode(moist_sensor_1, INPUT);
pinMode(moist_sensor_2, INPUT);
//IR Sensor
pinMode (IRSensor_1, INPUT);
pinMode (IRSensor_2, INPUT);
pinMode (IRSensor_3, INPUT);
//Utrasonic
```

```
  pinMode(trigPin_1, OUTPUT);
  pinMode(echoPin_1, INPUT);
  pinMode(trigPin_2, OUTPUT);
  pinMode(echoPin_2, INPUT);
  pinMode(trigPin_3, OUTPUT);
  pinMode(echoPin_3, INPUT);

  Serial.begin(9600);
  delay(2000);
}

void loop()
{
  //hole 1
  RGB_color_1(255, 255, 255);
  digitalWrite(trigPin_1, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin_1, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin_1, LOW);
  duration1 = pulseIn(echoPin_1, HIGH);
  distance1 = duration1 * 0.034 / 2;
  Serial.println(distance1);
  IR_value_1 = analogRead(IRSensor_1);
  inductive_value_1 = digitalRead(inductive_1);
  if(distance1 < 16)
  {
    Serial.println("METAL BIN STORAGE FULL!!");
    RGB_color_1(0, 255, 255);
  }
```

```
else if(IR_value_1 < 500 && inductive_value_1==0 && distance1 > 15)
{
  Serial.println("THIS IS NOT METAL");
  RGB_color_1(0, 255, 255);
}
else if(IR_value_1 < 500 && inductive_value_1==1 && distance1 > 15)
{
  Serial.println("METAL DETECTED");
  RGB_color_1(255, 0, 255);
  servo1.write(80);
  delay(1000);
  servo1.write(0);
  delay(500);
  RGB_color_1(255, 255, 255);
  delay(500);
}

//hole 2
RGB_color_2(255, 255, 255);
digitalWrite(trigPin_2, LOW);
delayMicroseconds(2);
digitalWrite(trigPin_2, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin_2, LOW);
duration2 = pulseIn(echoPin_2, HIGH);
distance2 = duration2 * 0.034 / 2;

IR_value_2 = analogRead(IRSensor_2);
inductive_value_2 = digitalRead(inductive_2);
if(distance2 < 16)
```

```
{
  Serial.println("DRY BIN STORAGE FULL!!");
  RGB_color_2(0, 255, 255);
}
else if(inductive_value_2==0 && distance2 > 15)
{
  Serial.println("METAL DETECTED");
  RGB_color_2(0, 255, 255);
}
else if(IR_value_2 < 500 && inductive_value_2==1 && distance2 > 15 && digitalRead(moist_sensor_1) == 0)
{
  Serial.println("WET NON-METAL DETECTED");
  RGB_color_2(0, 255, 255);
}
else if(IR_value_2 < 500 && inductive_value_2==1 && distance2 > 15 && digitalRead(moist_sensor_1) == 1)
{
  Serial.println("DRY NON-METAL DETECTED");
  RGB_color_2(255, 0, 255);
  servo2.write(80);
  delay(1000);
  servo2.write(0);
  delay(500);
  RGB_color_2(255, 255, 255);
  delay(500);
}

//hole 3
RGB_color_3(255, 255, 255);
digitalWrite(trigPin_3, LOW);
delayMicroseconds(2);
```

```
digitalWrite(trigPin_3, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin_3, LOW);
duration3 = pulseIn(echoPin_3, HIGH);
distance3 = duration3 * 0.034 / 2;

IR_value_3 = analogRead(IRSensor_3);
inductive_value_3 = digitalRead(inductive_3);
Serial.println(distance3);
Serial.println(inductive_value_3);
if(distance3 < 16)
{
  Serial.println("WET BIN STORAGE FULL!!");
  RGB_color_3(0, 255, 255);
  //buzz();
}
else if(inductive_value_3==1 && distance3 > 15)
{
  Serial.println("METAL DETECTED");
  RGB_color_3(0, 255, 255);
}
else if(IR_value_3 < 500 && inductive_value_1==0 && distance3 > 15 && digitalRead(moist_sensor_2) == 1)
{
  Serial.println("DRY NON-METAL DETECTED");
  RGB_color_3(0, 255, 255);
}
else if(IR_value_3 < 500 && inductive_value_1==0 && distance3 > 15 && digitalRead(moist_sensor_2) == 0)
{
  Serial.println("WET NON-METAL DETECTED");
  RGB_color_3(255, 0, 255);
```

```
    servo3.write(80);
    delay(1000);
    servo3.write(0);
    delay(500);
    RGB_color_3(255, 255, 255);
    delay(500);
  }
  delay(500);
}
```