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E-bin: Smart Municipal Solid Waste Bin Designs

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Abstract: Almost all countries face similar issues regarding garbage management, such as the late collection of garbage, inefficient municipal solid waste management and disposal. Municipal Solid Waste Management (MSW) garbage bin designs found to have some flaws that are not as user friendly as it should be. The lid is so tight to open, improper opening lid handle design and the bin height are too tall especially for kids. Because of this, it makes bins more inaccessible. The problem is worsened with the fact that the collection schedule done by the municipal garbage contractor has occasionally delayed. On top of that, the bad habit of littering worsening this condition even more. This leads to the invention of the E-Bin, the Smart Dustbin that will overcome this problem. This project uses hardware such as a servo motor, ultrasonic sensors, LCD and RFID. Apart from that, Blynk Applications were used to make notification to the authorities regarding overloaded garbage bins that needed immediate cleanup. Apart from notifications, E-Bin also allows automatic lid opening through an ultrasonic sensor and enables users to collect reward points by throwing trash into a dustbin. In conclusion, E-Bin provides a solution for better trash issue management. In the future, the smart dustbin could be upgraded into a garbage locator that will use GPS technology which helps garbage collector contractors to locate and collect garbage from its location.

Keywords: Smart Dustbin, Internet Of Things, Garbage, Servo Motor, Municipal Solid Waste

1. Introduction

Garbage disposal is an issue in many nations worldwide since it is difficult to decompose, yet it is becoming more prevalent every year. Every year, over 2 billion tons of garbage are produced worldwide, and disposing of it is a significant issue. According to Our World in Data (OWD) statistics, the worldwide plastic industry employed 270 million tonnes in 2010, but garbage disposal was five million tonnes higher at 275 million tonnes [1]. According to the OWD, most of this plastic trash is generated by coastal people, particularly those living within 50 kilometers of the sea. In 2010, the area's

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trash totaled 9.5 million tonnes [1]. Around 4 billion people rely on unregulated or illegal waste disposal sites, which store more than 40% of the world's garbage. As a result, serious environmental pollution will occur in water, soil, and plants, open burning pollutant emissions will affect the atmosphere, SW will be released into water bodies, and marine litter will improve globally, increasing environmental contamination. [1,2,3]

Figure 1 below shows waste generation is rising globally by the amount of waste that has been generated by countries around the world. The blue circle in **Figure 1** shows the solid waste produced by the population in a year based on kilograms.

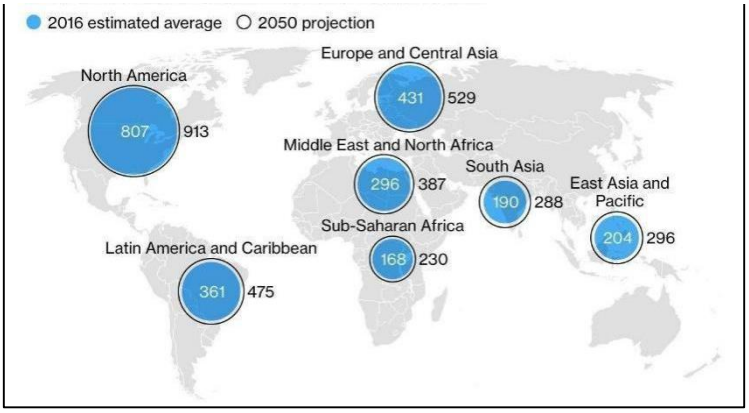

Figure 1: Kilograms of Solid Waste Creates a Year [1]

Litter is widespread in Malaysian cities, including plastic bags, wet wipes, tissues, smoking buds, and bottles strewn on the street floor. This is one of the most serious issues in Malaysia since our government does not address it forcefully through campaigns that failed at an early stage and are unable to maintain momentum among the population. Compared to its neighboring country, Singapore, Malaysia does not start imposing any harsh fines or warnings on litterers, which encourages residents to be irresponsible [4]. Malaysia's basic daily solid waste increased by 100.75 percent to 38,142 tonnes in 2018, up from 19,000 tonnes in 2005 [5]. Therefore, many studies have been carried out in addressing the growing problem of garbage by using smart dustbin technology. The production of smart dustbins can reduce the rate of waste disposal nowadays. An example of a project name that has been developed is Smart Garbage monitoring system using the Internet of Things (IoT). The smart dustbin developed today detects objects in front of the sensor to open the dustbin and detect whether the garbage is full. A notification will send a message on Blynk when the rubbish is full. The advantage of this development is that the cleaner will receive notification that the rubbish is full [6,7,8]. However, there is no disclosure to encourage the user to dispose of the rubbish.

Thus, this project aims to develop E-Bin, a smart dustbin, by improvising through added function in encouraging users to dispose of the garbage appropriately because of the problem of waste disposal everywhere faced by residents in residential areas. The improvement made is to give reward points to user's every time users throw out the rubbish using E-Bin. Points collected can be used in redeeming to purchase necessary items in selected stores. E-Bin is conceptualized in this study to encourage and facilitate the public to get rewards when disposing of their garbage properly. Nowadays, dustbin areas are increasingly numerous wastes and uncontrolled due to ineffective rubbish collection schedules. Therefore, the E-Bin is specially designed by sending information to the garbage carrier to inform once the dustbin is full. E-bin is developed using the Internet of Things (IoT) concept, which can be connected to the Internet and integrated with electronic components to detect garbage and send notifications on the Blynk application when the dustbin is full. There are three objectives for this study which are to develop a smart dustbin that detects motion for throwing rubbish and reward point collection, to notify the cleaner when the smart dustbin is full and to evaluate the efficiency of the smart dustbin for public use.

The next section discusses the related studies on the smart dustbin and smart devices developed for the general public use. While Section Three discusses the methodology used in this study, and Section Four focuses on the development of the E-Bin. Results of the E-Bin development were discussed in Section Five, followed by the conclusion and future works.

2. Literature Review

Based on [9], it is mentioned that plastic waste in Malaysia is a major contributing factor of environmental issues regarding waste issue in Malaysia. It is because the plastic itself in this country has highly used among the people. Even though, there is a campaign "no plastic bag" and suggestion to bring their bag or shopping bag when they go to shopping. There are still many people that purchasing plastic even when it cost them RM0.20 per plastic bag. Other than that scenario, it is mentioned that the people in Malaysia have increased the per capita amount usage of plastic bags [9,10,11]. The plastic bags were not good for the environment. In 2018 in our country Malaysia, there is a case that the plastic pollution was caused by the illegal import of plastic waste from other countries into Malaysia on a large scale and had a huge impact on our environment, which is the image of our country environment is not clean due to the plastic bags on land pollution. It takes a long time to recover the country from plastic wasteland pollution [12,13].

Other than that, it is stated that 60% of 32 million Malaysian people are still littering rubbish everywhere in public despite that there is a rubbish bin in the area. Plastic waste illegally imports from other developed countries is one of the causes of our country plastic waste, land pollution and dirty environment. Because of that, the City Council of Terengganu take action to compound RM50 to the public who is littering rubbish, and there is even a suggestion that the number of rubbish bins is increased in many areas so that no rubbish space is dumped everywhere [14]. Other than that, most garbage landfills in this country are very expensive to purchase for garbage disposal. Landfills can serve as time bombs as well as contamination of harmful chemicals from landfills that affect human health and the environment, [15] to reduce 40 per cent of solid waste from landfills based on Malaysia's proposal, and it will be achieved if new waste disposal technology is used. The local companies had the initiative to partner with German companies that use technology in solid waste management. [15] It is time for Malaysia, a developed country, to adopt high-tech solid waste management.

There is another dustbin technology that has been built and related to this project. The author built a project to solve the problem regarding the garbage issue, such as late garbage collectors collecting the full rubbish via the Wi-Fi signal transmission [16,17,18]. The author used an Arduino Mega board and Ultrasonic Sensor, while this E-Bin Smart Dustbin used an Arduino Uno. This kind of method to collect the garbage can reduce the corruption among the municipal management system as the smart dustbin sends a real-time email [19]. Other than that, the other project mentioned that it would reduce the time of using the garbage truck at one time [20].

As such, technology is much needed in helping the disposal of garbage appropriately. However, by contributing to this development, author is able to educate the people and also offers an efficient way of disposing the garbage appropriately and saving the environment better. The next section will discuss on the methodology used in the development of this study.

3. Methodology

The methodology used in this study is the Agile methodology [21] as it requires less documentation, and this method made this project design and development quicker for the author to finish this project in a short span of time. Throughout the project's life cycle, the Agile approach enables continuous iteration of development and testing. There are five stages to producing a project using Agile methodology: brainstorming, design, development, quality assurance, and deployment.

3.1 Brainstorming

Brainstorming is a technique for producing ideas on the spur of the moment by delving into one's imagination. The goal is to generate as many ideas as possible while simultaneously capturing them. After all of the suggestions have been considered, each weighs the merits and downsides [22]. In this phase. The author has decided the hardware and software needed for the development of this Smart Dustbin. On top of that, the author conducted a survey to collect information and feedback from the public.

Total of 28 respondents participated in this survey that was randomly generated to the residents around Taman Paya Redan, Kluang. Based on the feedback received, in **Figure 2** shows that 82.1% agrees on the fact that the garbage bin is full and dirty in the residential area. This shows that the garbage is not being disposed accordingly at proper time once its full rather left it to be overloaded.

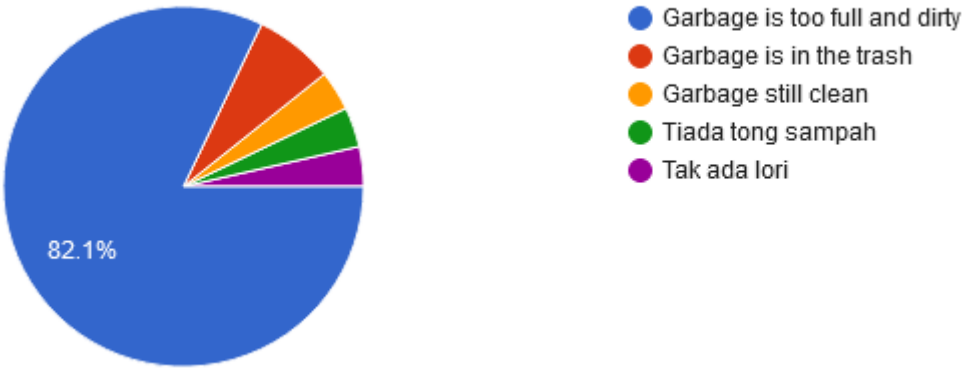

Figure 2: Garbage Bin Condition

The collected responds clearly show that the garbage disposal needed immediate attention as the uncollected garbage and full dustbin could lead to hygiene issues and also indicate a lot of health issues as well to the people in surrounding area. As such, idea of technology-imposed garbage bin has been designed and developed as the section follows describes.

3.2 Design

This design consists of Radio Frequency Identification (RFID) card, ultrasonic sensor, servo motor, and NodeMCU. In this project, two ultrasonic sensors were put inside and outside of the bin. The external ultrasonic use to sense the hand when the user is throwing rubbish, and it will automatically open the lid with the help of a servo motor, while the ultrasonic inside the bin is used to estimate the level of the trash and give notification to the garbage collector when it full. The bin monitoring must be done for the bin prototype by the programmer itself, while the actual bin must be monitored by the SWM company. **Figure 3** shows the flowchart from when the bin is empty until the waste collection is done. **Figure 4** shows the prototype image of an E-Bin that consists of an ultrasonic sensor inside and outside the dustbin, RFID tag, LCD and NodeMCU. While **Figure 5** shows the circuit diagram of the prototype.

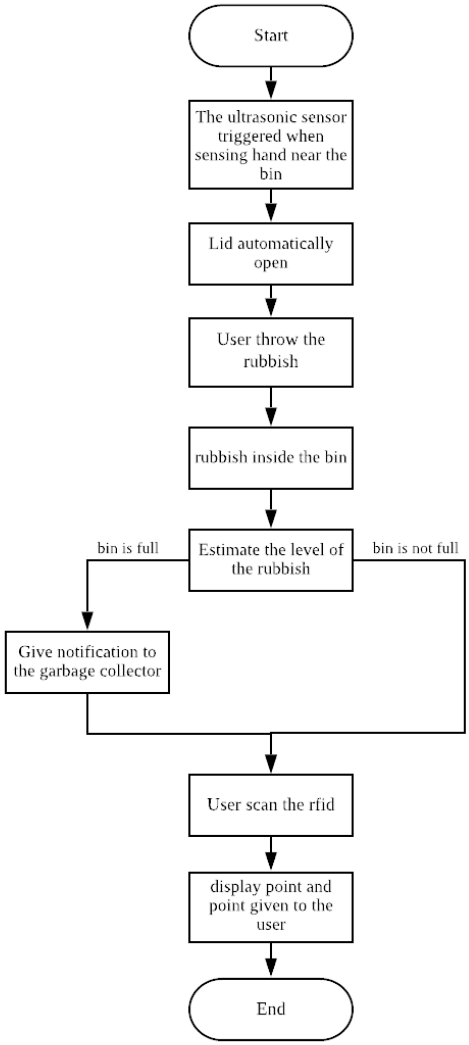

Figure 3: The Flowchart of the E-bin

Figure 4: Exterior Design of the E-Bin

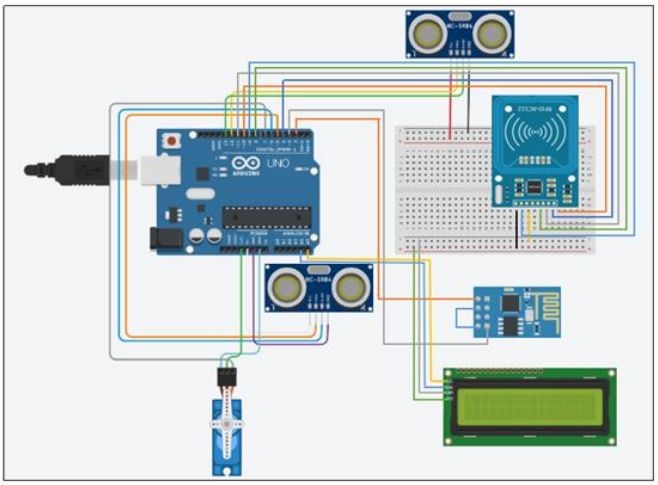

Figure 5: Circuit Diagram

3.3 Development

Throughout this phase, everything that will be needed to complete the project is organized. All the hardware and software needed is prepared such as Arduino Uno board, RFID, ultrasonic sensor, Blynk and LCD. In order to meet all of the objectives, the developer began connecting all of the components and compiling code in the Arduino IDE. **Figure 6** below show the code to activate the lid opening for the dustbin when someone is trying to throw garbage into the bin

```
int distance = 0;

long readUltrasonicDistance(int triggerPin, int echoPin)
{
  pinMode(triggerPin, OUTPUT);  // Clear the trigger
  digitalWrite(triggerPin, LOW);
  delayMicroseconds(2);
  // Sets the trigger pin to HIGH state for 10 microseconds
  digitalWrite(triggerPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(triggerPin, LOW);
  pinMode(echoPin, INPUT);
  // Reads the echo pin, and returns the sound wave travel time in microseconds
  return pulseIn(echoPin, HIGH);
}

void setup()
{
  Serial.begin(9600);

  pinMode(9, OUTPUT);
}

void loop()
{
  distance = 0.01723 * readUltrasonicDistance(3, 2);
  Serial.println(distance);
  //delay(10); // Wait for 40 millisecond(s)
  if (distance < 120) {
    digitalWrite(9, HIGH);
  } else {
    digitalWrite(9, LOW);
  }
}
```

Figure 6: Code for automatic lid opening

3.4 Quality Assurance

Software quality assurance (QA) is a sequence of tasks to prevent defects and ensure that the techniques, methods, approaches, and processes designed for a specific application must be

implemented correctly [23]. In this phase, all components and code have been identified to ensure that it is appropriate for the project and provide the right response. Through iteration testing, bugs and shortcomings of the project have been identified. All problems that occur in the test are fixed with the most accurate solution. Eventually, the performance of this project has improved.

3.4 Deployment

The deployment phase is where the product manufacturing team ensures the product is appropriate for the user's work environment [24]. During this phase, the project requires final assurance before it can be implemented. After that, the project will be tested on the targeted users. We can collect the exact data and fix the problems or errors from the feedback received through this test. After that, the project can be modified accordingly. Finally, a final assessment is carried out to analyses and report the results.

4. Project Development

E-Bin is then completed by wiring all the electrical components, created a product of smart dustbin and generated the code for the entire project. The components include Arduino, breadboard, ultrasonic sensor, nodemcu, RFID card and LCD. The platform used within E-Bin is Blynk Application.

4.1 Hardware

The hardware used on E-Bin is Arduino Uno, ultrasonic sensor, LCD, RFID, NodeMCU ESP8266 and breadboard. The E-Bin was completed by wired all the hardware and created a prototype of the dustbin model. **Table 1** shows the function of each of the hardware used in E-Bin. All the functions specified in the table are run successfully according to that function. All the functions shown are working perfectly when the E-Bin is turned on.

Table 1: Electronic components and it function

Electronic components	Function
Arduino Uno	To execute the code on Arduino IDE and interact with sensor’s input and output
Ultrasonic sensors	To estimate the level of the garbage in the bin and to activate lid opening mechanism when someone is trying to throw garbage into the bin
LCD	To display point after user scan the RFID
RFID	To get point when throw out the garbage
Nodemcu ESP8266	To connect Wi-Fi to receive notification via Blynk when the dustbin is full
Servo Motor	To open the lid of the bin
Breadboard	To connect the other components to the Arduino Uno board

Figure 7 shows the hardware used in the project such as Arduino Uno, Ultrasonic sensors, LCD, RFID, NodeMCU ESP8266 and Breadboard. All hardware has been installed using a wire that connects between the Arduino UNO and the breadboard.

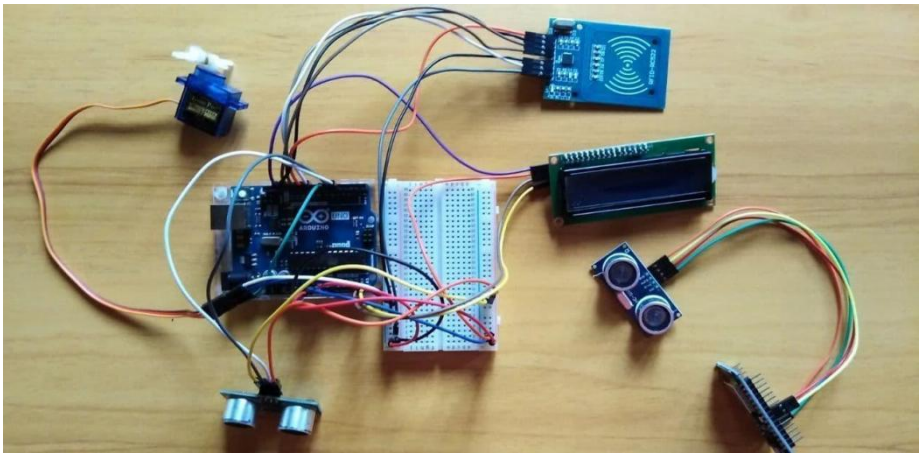

Figure 7: Hardware use in project

4.2 Software

The software used to upload the code is Arduino Integrated Development Environment (IDE). The code is written and uploaded to Arduino IDE via the USB cable. There are a lot of libraries included in this project such as Servo.h, SPI.h, MFRC522.h, Wire.h, LiquidCrystal_I2C.h, ESP8266WiFi.h and BlynkSimpleEsp8266.h. The sensor code will detect the distance of the rubbish inside the dustbin. The calculation of distance is when the sensor detects the distance of the garbage, the code will determine whether the garbage reaches a level of distance less than or equal to 10.00 cm. If the garbage has reached a level of 10.00 cm and below, a notification will be received via Blynk. The Blynk will show the notification message such as "THE DUSTBIN IS FULL! CLEAN THE TRASH". Next, the code of the external sensor will detect things in front of the sensor.

The formula calculation of distance is (Time x SpeedOfSound) / 2. The dustbin lid will be opened once the sensor detected the distance declared and RFID card coded to read the unique Identification (UID) of the card. Once the user who flash their ID card, points will be recorded upon throwing the garbage into the dustbin. The point will appear in LCD to indicate the number of points that the user has accumulated. Therefore, the function of LCD is to show the points collected by the user so that the user can know how many points have been collected.

4.3 Blynk

Blynk is an IoT platform for E-Bin for mobile phone notifications. In this project, the author used NodeMCU ESP8266 Wi-Fi Receiver to allow the connection between the Arduino UNO board and Blynk application. Therefore, a notification will be received when the sensor detects the rubbish that has been full in the dustbin.

Figure 8 shows the notification via Blynk which will be received by the garbage carrier. The garbage carrier will pick up the garbage upon receipt of the notification.

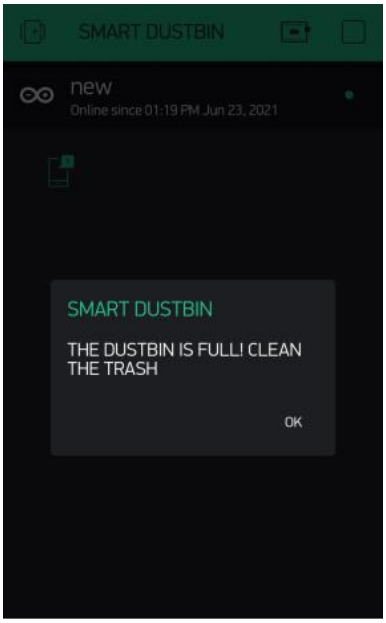

Figure 8: Notification give warning to clean the trash to SWM local town council

4.4 E-Bin Model

The prototype of E-Bin is built with a medium size of dustbin and hardware components to develop the function of smart dustbin. The ultrasonic sensor used to detect the author's hand and the other ultrasonic inside the dustbin was used to detect the level of garbage and gives notification if the smart dustbin is full and all components are connected by wire to breadboard and Arduino UNO.

Figure 9 shows the developed E-Bin prototype. The ultrasonic sensors will be inside and outside the dustbin. Arduino Uno and breadboard are placed in the dustbin. The LCD and RFID are placed outside the dustbin. The LCD and RFID should be placed outside because the user will scan the RFID card and the LCD will display the point after the user scans the card.

Figure 9: E-Bin Prototype

The E-Bin has been developed and the next section discuses on the results obtained from the usage of this smart dustbin.

5. Result and Discussion

Analysis and evaluation survey was conducted by the author to his family because the author could not bring the E-Bin to public survey because of the pandemic situation. The below **Table 2** shows the results regarding the E-Bin evaluation test based on the 4 respondents answered.

Table 2: Analysis Question

Questions	Answers
What is your opinion on this E-Bin?	3 out of 4 respondents agree with the development of e-Bin Smart Dustbin and prefer the e-Bin to use at school, public and shops. Meanwhile, only 1 respondent does not agree because the Malaysian were not exposed to IoT Smart Dustbin.
What are the advantages/ disadvantages of this E-Bin?	Respondent 1 opinion about the e-Bin is the e-Bin size is small and needs to be upgraded. Respondent 2 said that the e-Bin will not last longer if some chemical waste was thrown in the e-Bin. Respondents 3 and 4 said that e-Bin is very good to implement in public because of the card point reward.
What improvements need to be made when using the E-Bin?	Respondents 1 said that e-Bin must have a plan to always ensure the e-Bin's functionality. Respondent 2 said that there is nothing to improve. Respondent 3 suggests that the e-Bin can sense the chemical waste and gives warning before the public throws the chemical inside the e-Bin to avoid malfunction. Respondent 4 suggests the e-Bin has manual instruction before use, especially the redeem card point.

The overall respondents concluded that the E-Bin is appropriately developed and very useful in proper garbage disposal among the residents and garbage collectors as well. By using this smart dustbin, is it to efficiently able to dispose the garbage and allow the authorities to properly dispose on time leaving a smarter and clean environment for everyone.

6. Conclusion

The main hurdle that the SWM agencies unable to solve is that they fails to do the immediate collection work action of waste when the municipal bin was in full or overloaded condition. With the invention of bin full capacity notification, this problem was successfully handled. The full capacity condition bin has now immediately been collected within an hour of the notification received and replaced with a new bin or cleaned and emptied bin. Besides, this invention encouraging users to dispose of the garbage appropriately by giving reward points to user's every time users throw out the rubbish using E-Bin. With this invention, all downtown and residential areas with this smart bin are always cleaned and beautiful. Future improvements that may be made to the project to make it more effective and beneficial to the public and its target audience are implementing GPS technology to help the garbage collector locate and collect garbage. Other than that, implement manual instructions to facilitate the user and add a sensor to sense chemical waste to warn before throwing the chemical waste into the dustbin.

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