SMART WASTE MANAGEMENT SYSTEM FOR METROPOLITAN CITIES

DOMAIN – INTERNET OF THINGS (IoT)

PROJECT REPORT

SUBMITTED BY

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CONTENT

1. INTRODUCTION

The Internet of Things is nothing but the applications performing with the help of internet access. IoT Communication over the internet has grown from user - user interaction to device – device interactions these days. The IoT concepts were proposed years back but still it's in the initial stage of commercial deployment. The home automation industry and transportation industries are seeing rapid growth with IoT. The basic project idea is to design a smart waste detection system which would automatically notify the officials about the current status of various garbage bins in the city, would have real time monitoring capabilities, which would be remotely controlled using IoT techniques. This paper introduces you to the use of IoT in one such area, that is, Garbage detection in smart ways using IoT and see how this can also be a major part of developing a city into a smart city.

1.1. Project Overview

A big challenge in the urban cities is that of waste management as there is a rapid growth in the rate of urbanisation and thus there is a need for sustainable urban development plans. As the concept of smart cities is very much trending these days and the smart cities cannot be complete without a smart waste management system. There needs to be a system that gives prior information of the filling of the bin that alerts the municipality so that they can clean the bin on time and safeguard the environment. To avoid all such situations we intend to propose a solution for this problem "Smart Garbage Bin", which will alarm and inform the authorised person when the garbage bin is about to fill. Then a message will be sent to the authorised person to collect the garbage from the particular area. The authorised person will send the message from his web application to the garbage collectors by sending a SMS. This system maintains a dry waste and a wet waste separately. This will help to reduce the overflow of the garbage bin and thus keep the environment clean.

1.2.Purpose

This project helps the citizens to make their surroundings and environment clean , pollution free and lead a healthy life throughout. It avoids the possibility of garbage overflow, unhygienic environment, air-borne and waterborne disease , etc...

2. LITERATURE SURVEY

2.1 EXISTING PROBLEM

India is the second most populated country in the world and it is still facing hindrances to its development on waste management. It is believed that 10 million tons of waste is produced just by the metropolitan cities in India. In this work, a way to classify the waste and find the category of it is proposed with a well-defined and labelled data set of images consisting of categories (plastic, paper, cardboard, metals) using Convolutional Neural Network (CNN). Images are categorised based on their properties by the help of a self-learning neural network. The designed classifier learns from the image data provided for training purposes. As the population is growing, the garbage is also increasing. This huge unmanaged accumulation of garbage is

polluting the environment, spoiling the beauty of the area and also leading to health hazards. In this era of Internet, IOT (Internet of Things) can be used effectively to manage this solid waste. Waste has always been a serious problem, not only to the environment but also to the economic and social aspect. Solid waste management models are created to solve waste problems in different aspects and areas. Many models were made to tackle waste problems in cities or metropolitan areas. Yet, there are no specific solid waste management models that are made specifically for villages that undergo a transition to a city and it is affecting both the natural and social environment in the area. In this literature survey, we have collected the major problems that are being faced due to improper garbage management systems

PROPOSED SYSTEM:

In this proposed system there will be no issues repeated that of the previous system. In this system the bin is designed in such a way that when the waste level reaches the threshold limit it automatically closes the bin and intimates the alert to the admin. The bins are provided with low cost embedded device which helps in tracking the level of the garbage bins and a unique ID will be provided for every dustbin in the city .These details can be accessed by the concerned authorities from their place with the help of internet and an immediate action can be made to clean the bin. The admin can monitor the level of the bin and can trace the location where it exists.

Advantages:

- Real time information on the fill level of the dustbin.
- Deployment of dustbin based on the actual needs.
- Cost Reduction and resource optimization.
- Improves Environment Quality.

2.2. REFERENCES:

1. Ikuo Ihara; Nagaoka University of Technology; Ultrasonic Sensing: Fundamentals and Its applications to Non-destructive Evaluation.
2. Arduino, “Available at http://www.arduino.cc,” 2010.
3. M. Batty, “Smart Cities, Big Data,” Environment and Planning B: Planning and Design 2012, vol. 39, pp. 191– 93.
4. Xu Li, Student Member, IEEE, Performance Evaluation of Vehicle-Based Mobile Sensor Networks for Traffic Monitoring.

5. Yusuf Abdullahi Badamasi, The Working Principle Of An Arduino, Electronics, Computer and Computation (ICECCO), 2014 11th International Conference on 29 Sept.-1 Oct. 2014.

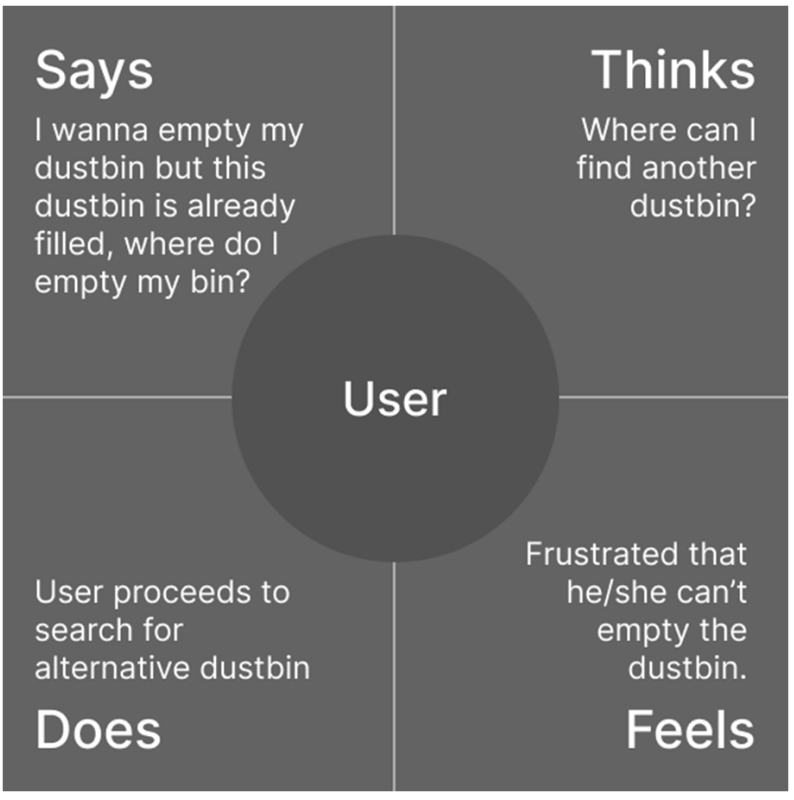
2.3. Problem Statement

The waste management system provided earlier is not very reliable, efficient, cost effective and does not have any advanced processing features like automatic close of bin and alert intimations system .The following is a well articulated problem statement that allows you to find the ideal solution for the challenges faced.

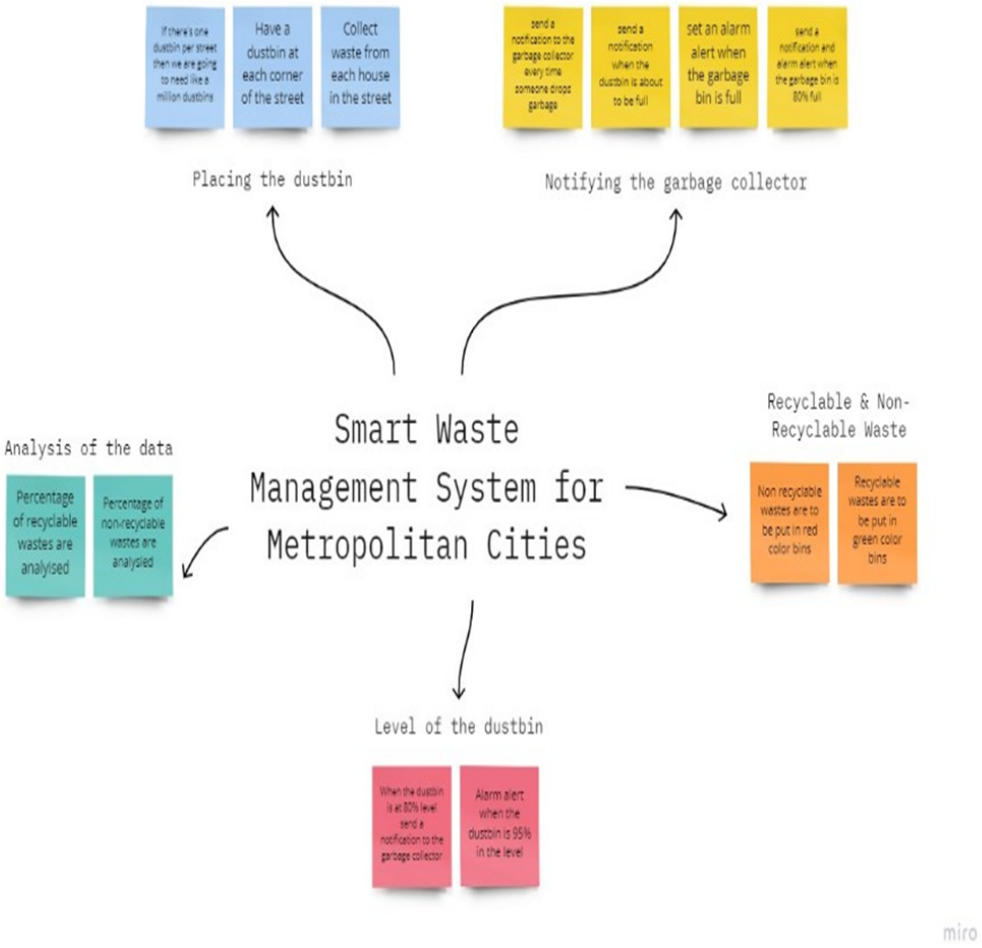
Problem statement	I am (user)	I'm trying to	But	Because	Which makes me feel
PS-1	Colony resident member	Put the waste into the waste bin	Bin is already in the state of overflow	Bin is not cleared by the corporation cleaners	So disgusting to see the spoiled area that stays as a major reason for many air-borne disease
PS-2	Street walker	Throw the waste into the bin	There is no waste bin at all	Bin is not provided for the area	The main reason to make the unclean and unhygienic

3. IDEATION & PROPOSED SOLUTION

3.1. EMPATHY MAP CANVAS



3.2. Ideation and Brainstorming



3.3. PROPOSED SOLUTION

Project team shall fill the following information in proposed solution template.

S.No.	Parameter	Description
1.	Problem Statement (Problem to be solved)	The process in current city setting solves the waste problem partially while it creates other problems like • Some trash bins are overfilled while others are under-filled by the trash collection time, • Overfilled trash bins create unhygienic problems, • All collected trash is combined which complicates sorting for recycling the waste.
2.	Idea / Solution description	A sensor attached to the trash bin that measures fill level and a communication system that transfers this data to Cloud. Data is processed in the Cloud.
3.	Novelty / Uniqueness	The trash is sorted as recyclable and non-recyclable before it is put in the trashcan by the person. The recyclable wastes are processed and recycled.
4.	Social Impact / Customer Satisfaction	Since there are sensors to intimate the municipality once the trashcan is full. There would be no hygienic problem. Since the trashcan will not be full when the user puts the trash there would be no confusion to search for a different trashcan.
5.	Business Model (Revenue Model)	There are sensors for making the process easier for the user, so it would be useful to have a smart trashcan at an affordable rate.
6.	Scalability of the Solution	There would be trucks to collect the trash. If we optimize the routes for the trucks, it would save fuel and reduce traffic.

3.4. PROBLEM SOLUTION FIT

4 . REQUIREMENT ANALYSIS

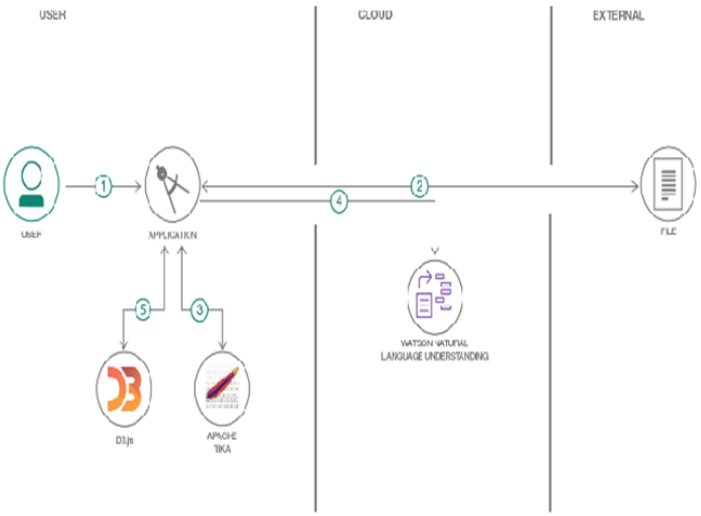
Following are the non-functional requirements of the proposed solution.

FR No.	Non-Functional Requirement	Description
NFR-1	**Usability**	IoT device verifies that usability is a special and important perspective to analyze user requirements, which can further improve the design quality. In the design process with user experience as the core, the analysis of users' product usability can indeed help designers better understand users' potential needs in waste management, behavior and experience.
NFR-2	**Security**	Use a reusable bottles Use reusable grocery bags Purchase wisely and recycle Avoid single use food and drink containers.
NFR-3	**Reliability**	Smart waste management is also about creating better working conditions for waste collectors and drivers. Instead of driving the same collection routes and servicing empty bins, waste collectors will spend their time more efficiently, taking care of bins that need servicing.
NFR-4	**Performance**	The Smart Sensors use ultrasound technology to measure the fill levels (along with other data) in bins several times a day. Using a variety of IoT networks ((NB-IoT,GPRS), the sensors send the data to Sensoneo's Smart Waste Management Software System, a powerful cloud-based platform, for data-driven daily operations, available also as a waste management app. Customers are hence provided data-driven decision making, and optimization of waste collection routes, frequencies, and vehicle loads resulting in route reduction by at least 30%.
NFR-5	**Availability**	By developing & deploying resilient hardware and beautiful software we empower cities, businesses, and countries to manage waste smarter.
NFR-6	**Scalability**	Using smart waste bins reduce the number of bins

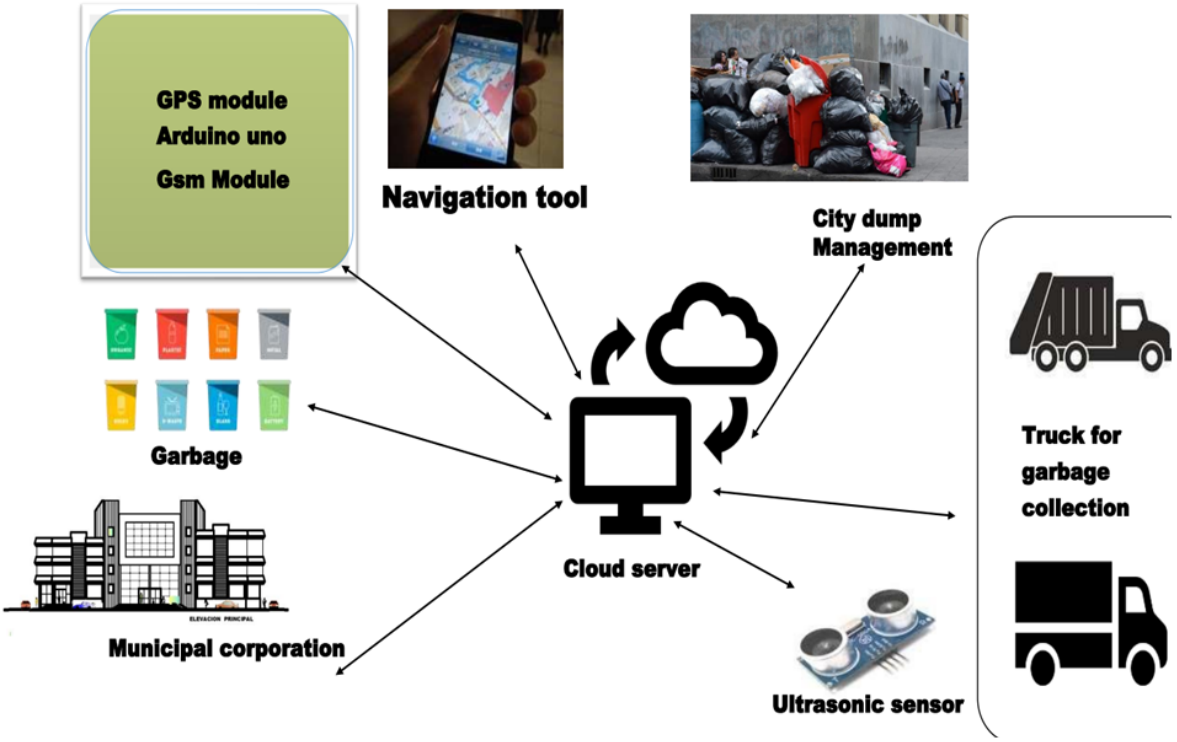
		. The report shows how full the bin was when picked. You immediately see any inefficient picks below 80% full.
FR-6	Plan waste collection routes.	. The tool semi-automates waste collection route planning. Based on current bin fill-levels and predictions of reaching full capacity, you are ready to respond and schedule waste collection. . You can compare planned vs. executed routes to identify any inconsistencies.

5. PROJECT DESIGN

5.1 . DATA FLOW DIAGRAM



5.2. SOLUTION ARCHITECTURE AND TECHNICAL ARCHITECTURE



5.3 USER STORIES

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
Customer (Mobile user / Web user)	Signup	USN-1	User can signup using their email and password and confirm the details.	I can access my account / dashboard	High	Sprint-1
		USN-2	A confirmation mail is sent to the user.	I can receive confirmation email & click confirm	High	Sprint-1
	Login	USN-3	User can login using login credentials	User can log on to the website	High	Sprint-1
	Dashboard	USN-4	User can specify the location and area to check the availability of bins.	User can access dashboard and search for bins in specified areas	High	Sprint-2
		USN-5	User can post the queries and grievances in the report section	Options are provided to solve user issues	Medium	Sprint-2

6. PROJECT PLANNING AND SCHEDULING

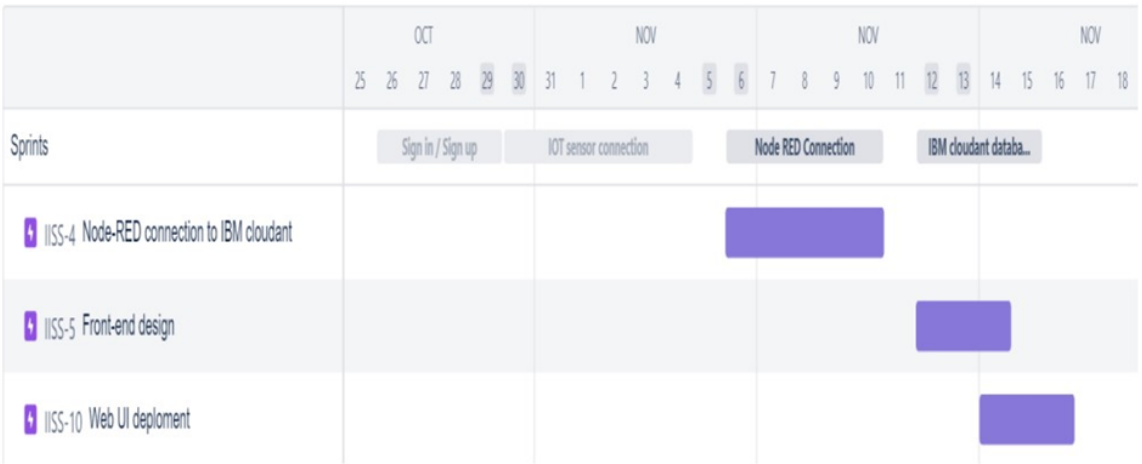
6.1 . SPRINT PLANNING AND ESTIMATION

TITLE	DESCRIPTION	DATE
Literature Survey & Information Gathering	Literature survey on the selected project & gathering information by referring the, technical papers,research publications etc.	24 SEPTEMBER 2022
Prepare Empathy Map	Prepare Empathy Map Canvas to capture the user Pains & Gains, Prepare list of problem statements	24 SEPTEMBER 2022
Ideation	List the by organizing the brainstorming session and prioritize the top 3 ideas based on the feasibility & importance.	24 SEPTEMBER 2022
Proposed Solution	Prepare the proposed solution document, which includes the novelty, feasibility of idea, business model, social impact, scalability of solution, etc.	24 SEPTEMBER 2022
Problem Solution Fit	Prepare problem - solution fit document.	02OCTOBER 2022

Solution Architecture	Prepare solution architecture document.	01 OCTOBER 2022
Customer Journey	Prepare the customer journey maps to understand the user interactions & experiences with the application.	15 OCTOBER 2022
Functional Requirement	Prepare the functiona requirement document.	8 OCTOBER 2022
Data Flow Diagrams	Draw the data flow diagrams and submit for review.	15 OCTOBER 2022
Technology Architecture	Preparethetechnology architecture diagram.	16 OCTOBER 2022
Prepare Milestone & Activity List	Prepare the milestones & activity list of the project.	22 OCTOBER 2022
Project Development - Delivery of Sprint-1, 2, 3 & 4	Develop & submit the developed code by testing it.	IN PROGRESS

6.3. JIRA REPORTS

ROADMAP



7. CODING AND SOLUTION

7.1 Wokwi code for Sensor transmission

```
#include<WiFi.h>// library for wifi
#include<PubSubClient.h>// library for MQTT
#include<LiquidCrystal_I2C.h>
#include<mjson.h>

LiquidCrystal_I2C lcd(0x27, 20, 4);


//---------------------- credentials of IBM Accounts
------------------------------
#define ORG "9gbe4w"// IBM organisation id
#define DEVICE_TYPE "SWMSMC"// Device type mentioned in ibmwatsoniot platform
#define DEVICE_ID "ibmproject"// Device ID mentioned in ibmwatsoniot platform
#define TOKEN "sUNA41tG6-Pq)0rk5X"// Token


//---------------------- customise above values ----------------------------------------------------
charserver[] = ORG ".messaging.internetofthings.ibmcloud.com";                  // server
name
charpublishTopic[] = "iot-2/evt/data/fmt/json";                                 // topic name and
type of event perform and format              in which data to be sendchar topic[] =
"iot-2/cmd/led/fmt/String";                         // cmd Represent type and command is
test format of stringscharauthMethod[] = "use-token-auth";                                      //
authentication methodchar token[] = TOKEN; charclientId[] = "d:" ORG ":" DEVICE_TYPE
":" DEVICE_ID;                  //Client id


//-------------------------------------------------------------------------------------------------------------------


WiFiClientwifiClient;   // creating instance for wificlient
PubSubClientclient(server, 1883, wifiClient);
#define TRIG_PIN 13floatdist; String data3;
boolSealBin = true; voidsetup()
{
Serial.begin(115200);   pinMode(LED_BUILTIN,
OUTPUT);
pinMode(TRIG_PIN, OUTPUT);
pinMode(ECHO_PIN, INPUT);
//pir pin
pinMode(34, INPUT);

ledpin pinMode(23, OUTPUT);   pinMode(2, OUTPUT);   pinMode(4, OUTPUT);   pinMode(15, OUTPUT);

lcd.init();   lcd.backlight();   lcd.setCursor(1, 0);   lcd.print("");   wifiConnect();   mqttConnect();}
floatreadcmCM()
{
```

```
digitalWrite(TRIG_PIN, LOW);
delayMicroseconds(2);   digitalWrite(TRIG_PIN,
HIGH);   delayMicroseconds(10);
digitalWrite(TRIG_PIN, LOW);   int duration =
pulseIn(ECHO_PIN, HIGH);   return duration *
0.034 / 2;
}
voidloop()
{
lcd.clear();
publishData();   delay(500);   if (!client.loop())
{
mqttConnect();                          // function
call to connect to IBM       }
}
/* ------------------------------retrieving to cloud----------------------------------------------------*/
voidwifiConnect()
{
Serial.print("Connecting to ");
Serial.print("Wifi");
WiFi.begin("Wokwi-GUEST", "", 6);
while(WiFi.status() != WL_CONNECTED)
{
delay(500);
Serial.print(".");
}
Serial.print("WiFi connected, IP address: ");
Serial.println(WiFi.localIP());
}
voidmqttConnect()
{
if (!client.connected())
{
Serial.print("Reconnecting MQTT client to "):
Serial.println(server);
while (!client.connect(clientId, authMethod,
token))
{
Serial.print(".");   delay(500);
}
initManagedDevice();
Serial.println
};
}
voidinitManagedDevice()
if(client.subscribe(topic))
{
Serial.println("IBM subscribe to cmd OK");
}
else
{
```

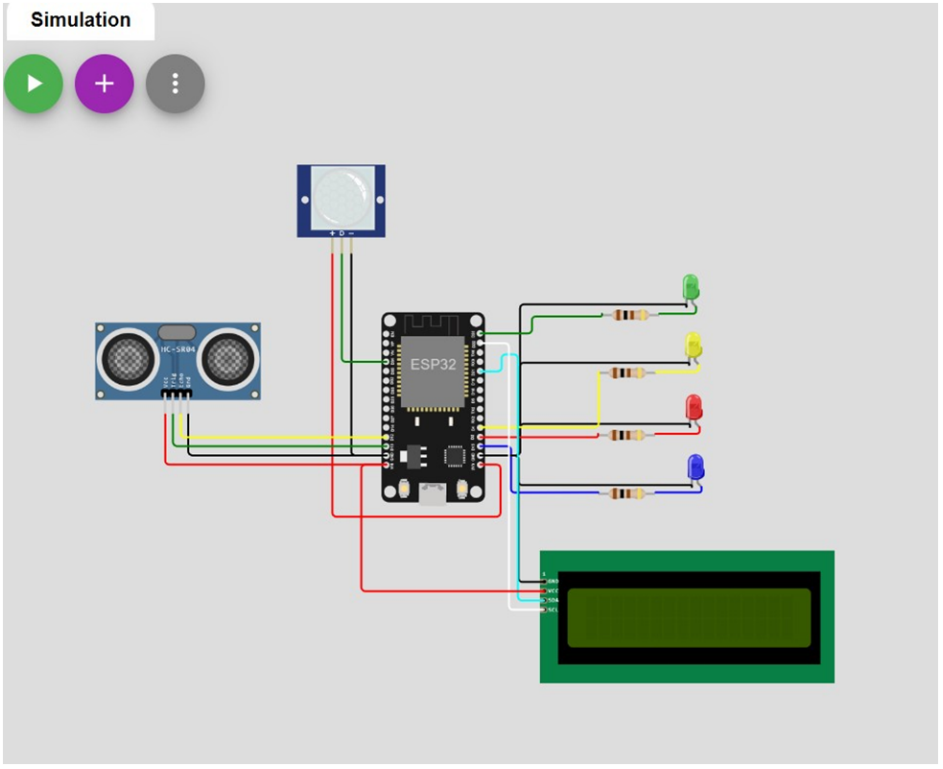
```
Serial.println("subscribe to cmd FAILED");
}
}
voidpublishData()
{
float cm = readcmCM();
if(digitalRead(34))                    //pir
motion detection
{
Serial.println("Motion Detected");
Serial.println("Lid Opened");
digitalWrite(15, HIGH);
if(digitalRead(34)== true)
 {
if(cm <= 100)                                  //Bin level detection
  {
digitalWrite(2, HIGH);
Serial.println("High Alert!!!,Trash bin is about to be full");
Serial.println("Lid Closed");   lcd.print("Full! Don't use");   delay(2000);     lcd.clear();
digitalWrite(4, LOW);        digitalWrite(23, LOW);
}
elseif(cm >100&& cm <180)
digitalWrite(4, HIGH);
Serial.println("Warning!!,Trash is about to
cross 50% of bin level");    digitalWrite(2, LOW)
digitalWrite(23, LOW);
}
elseif(cm >180)
{
digitalWrite(23, HIGH);
Serial.println("Bin is available");
digitalWrite(2,LOW);     digitalWrite(4, LOW);
}
delay(10000);
Serial.println("Lid Closed");
}
else
{
Serial.println("No motion detected");
digitalWrite(2, LOW);     digitalWrite(15, LOW);
digitalWrite(4, LOW);     digitalWrite(23, LOW);
 }
 }
Else
{
digitalWrite(15, LOW);
}
if(cm <= 100)
{
digitalWrite(21,HIGH);
```

```
String payload = "{\"High_Alert\":"; payload +=
cm; payload += " }";
Serial.print("\n");
Serial.print("Sending payload: ");
Serial.println(payload);


if (client.publish(publishTopic, (char*) payload.c_str()))          // if data is uploaded to
cloud successfully,prints publish ok else prints publish failed
{
Serial.println("Publish OK");
}
elseif(cm <= 180)
{
digitalWrite(22,HIGH);
String payload = "{\"Warning\":"; payload += cm ; payload
+= " }";
Serial.print("\n");
Serial.print("Sending payload: ");
Serial.println(payload);
if(client.publish(publishTopic, (char*) payload.c_str())) {
Serial.println("Publish OK");
}
else
{
Serial.println("Publish FAILED");
}elseif(cm >180)
{
digitalWrite(23,HIGH); String payload = "{";
payload += cm; payload += " }";
Serial.print("\n");
Serial.print("Sending payload: ");
Serial.println(payload);
if (client.publish(publishTopic, (char*) payload.c_str()))          // if data is uploaded to
cloud successfully,prints publish ok else prints publish failed
{
Serial.println("Publish OK");
}
 }
 float inches = (cm / 2.54);
//print on lcdlcd.setCursor(0,0);
lcd.print("Inches");   lcd.setCursor(4,0);
lcd.setCursor(12,0);   lcd.print("cm");
lcd.setCursor(1,1);   lcd.print(inches, 1);
lcd.setCursor(11,1);   lcd.print(cm, 1);
lcd.setCursor(14,1);   delay(1000);   lcd.clear();
}
//handles commands from user side
voidcallback(char* subscribetopic, byte*
payload, unsignedintpayloadLength)
{
```

```
Serial.print("callback invoked for topic: ");
Serial.println(subscribetopic);   for (inti = 0;
i<payloadLength; i++) {
data3 +=
(char)payload[i];
  }
Serial.println("data: "+ data3); constchar *s
=(char*) data3.c_str();   doublepincode = 0;
constchar *buf;   intlen;
if (mjson_find(s, strlen(s), "$.command",
&buf, &len))  // And print it
{
String command(buf,len);
if(command=="\"SealBin\"")
{
SealBin = true;
}
}
data3="";
}
```

7.2 . Sensor Connection Setup

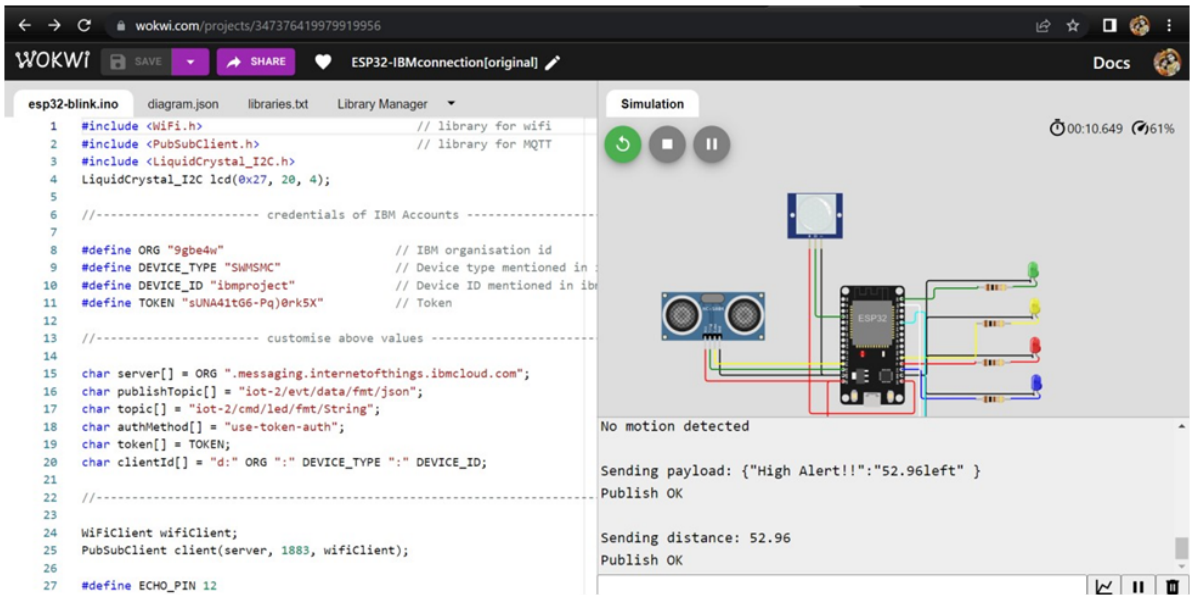


PHYSICAL COMPONENTS:

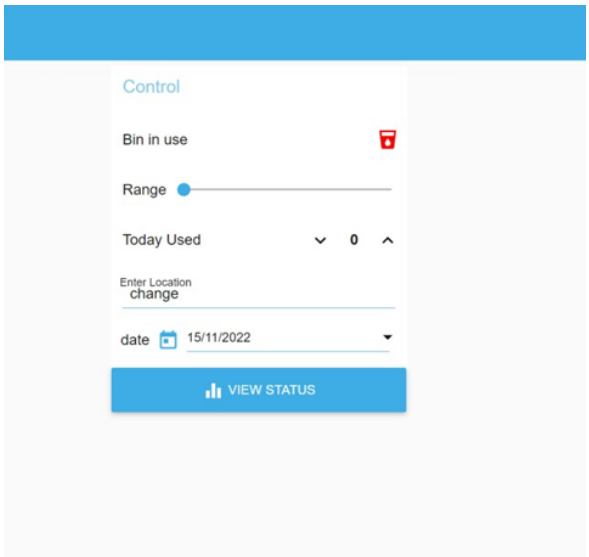
- PIR MOTION SENSOR
- ULTRASONIC DISTANCE SENSOR
- ESP32-ARDUINO MICROCONTROLLER

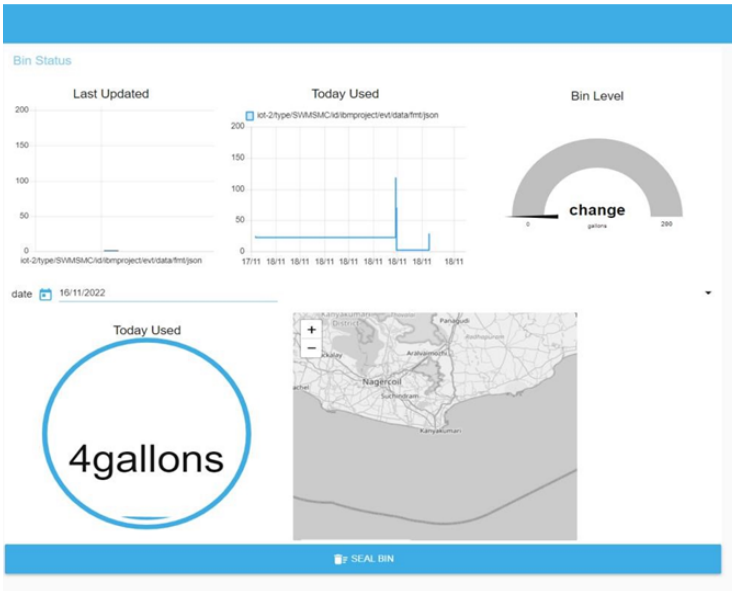
OUTPUT:

WOKWI SETUP



WEB UI





The admin gets notification when the bin detects motion and if the bin level crosses 50 percent it indicates warning and if it crosses 90 percent it gives a

High alert and closes the bin. If the admin wants to seal the bin the admin can command seal bin until it is accessed for cleaning.

Test Case:

Maximum Size of Bin : 200
Safe limit: below 100 cm
Minimum threshold limit of bin: 100 cm
Maximum threshold limit of bin: 180 cm

S.no	Bin Level (cm filled)	Bin Status	Location
1	45	Safe	Kanyakumari
2	78	Safe	Coimbatore
3	112	Warning	Trichy
4	169	Warning	Chennai
5	186	Warning	Ooty
6	193	High Alert	Tirunelveli
8	0	Safe	Chengalpattu
9	35	Safe	Madurai
10	101	Warning	Salem
11	132	Warning	Thanjavore
12	158	Warning	Vellore
13	93	High Alert	Erode
14	93	High Alert	Karur
15	93	High Alert	Cuddalore
16	30	Safe	Kumbakonam

USER ACCEPTANCE TESTING

1. Purpose of Document

The purpose of this document is to briefly explain the test coverage and open issues of the Smart Waste Management System project at the time of the release to User Acceptance Testing (UAT).

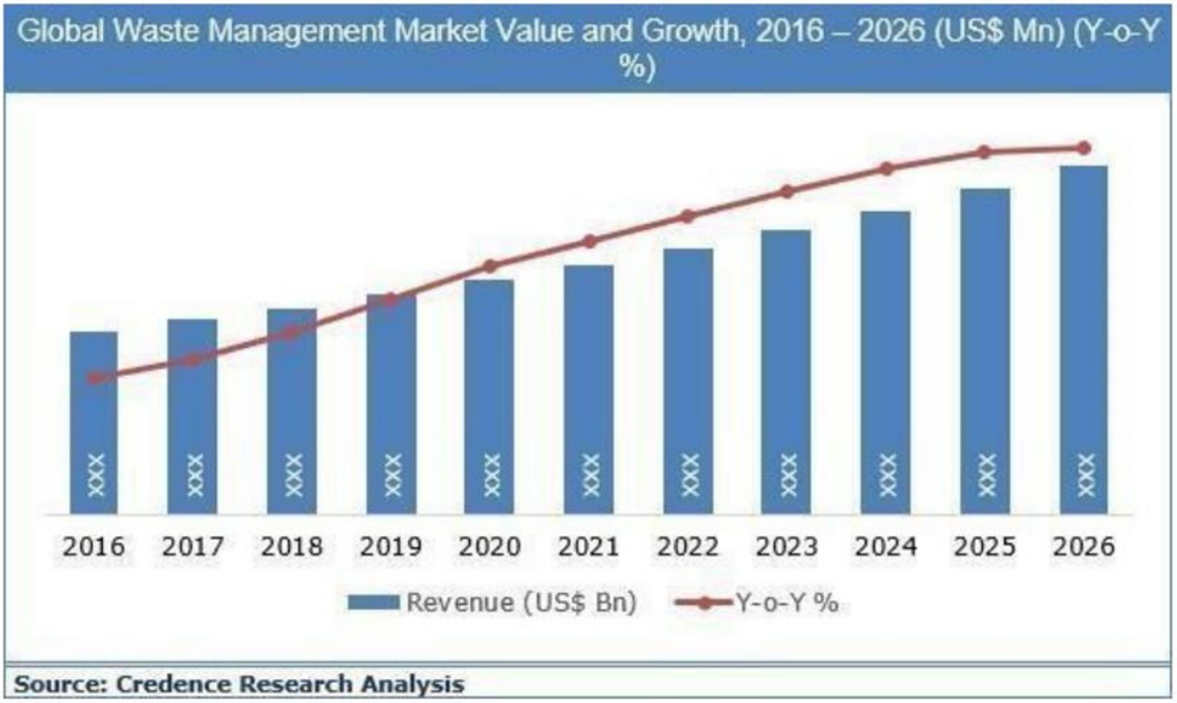
2. Defect Analysis

This report shows the number of resolved or closed bugs at each severity level, and how they were resolved.

Resolution	Severity 1	Severity 2	Severity 3	Severity 4	Subtotal
By Design	10	4	3	3	20
Duplicate	1	0	3	0	4
External	2	3	0	1	6
Fixed	11	2	4	20	37
Not Reproduced	0	0	1	0	1
Skipped	0	0	1	1	2
Won't Fix	0	5	2	1	8
Totals	24	14	13	26	78

9. RESULTS

9.1. Performance Metrics



10. ADVANTAGES AND DISADVANTAGES

10.1. ADVANTAGES

- Reduction in Collection Cost
- No Missed Pickups
- Reduced Overflows
- Waste Generation Analysis
- CO2 Emission Reduction

10.2 DISADVANTAGES

- The system requires a greater number of waste bins for separate waste collection as per population in the city.
- This results in high initial cost due to expensive smart dustbins compared to other methods. Sensor nodes used in the dustbins have limited memory size.

11. CONCLUSION :

A Smart Waste Management system that is more effective than the one in use now is achievable by using sensors to monitor the filling of bins. Our conception of a "smart waste management system" focuses on monitoring waste management, offering intelligent technology for waste systems, eliminating human intervention, minimising human time and effort, and producing a healthy and trash free environment. The suggested approach can be implemented in smart cities where residents have busy schedules that provide little time for garbage management. If desired, the bins might be put into place in a metropolis where a sizable container would be able to hold enough solid trash for a single unit. But these may price bit high

12. FUTURE SCOPE:

- There are several future works and improvements for the proposed system, including the following:
- Changes the system of user authentication and atomic lock of bins, which would aid in protecting the bin from damage or theft.

- The concept of green points would encourage the involvement of residents or end users, making the idea successful and aiding in the achievement of collaborative waste management efforts, thus fulfilling the idea of 'Swachh Bharath'.
- Having case study or data analytics on the type and time waste is collected on different days or seasons, making the bin level predictable and removing the reliance on electronic components, and fixing the coordinates.
- Improving the Server's and Android's graphical interfaces

13. APPENDIX

Esp32 - Microcontroller :
ESP32 is a series of low-cost, low-power system on a chip microcontrollers with integrated Wi-Fi and dual-mode Bluetooth.

- SRAM CPU: TensilicaXtensa LX6 microprocessor @ 160 or 240 MHz
- Power: 3.3 V DC
- Manufacturer: Espressif Systems

Sensors :

- PIR motion sensor:PIR sensors allow you to sense motion, almost always used to detect whether a human has moved in or out of the sensors range.
- Ultrasonic Distance Sensor : Ultrasonic Sensors measure the distance to the target by measuring the time between the emission and reception.

13.2 . GITHUB LINK

LINK :https://github.com/IBM-EPBL/IBM-Project-37496-1660310579