NALAIYA THIRAN - IBM PROJECT REPORT

(19EC406T - Professional Readiness for Innovation, Employability and Entrepreneurship)

ON

SMART WASTE MANAGEMENT SYSTEM FOR METROPOLITAN CITIES

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in partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

VELAMMAL ENGINEERING COLLEGE, CHENNAI-66.

(An Autonomous Institution, Affiliated to Anna University, Chennai)

2022-2023

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BONAFIDE CERTIFICATE

Certified that this NALAIYA THIRAN–IBM PROJECT REPORT **"SMART WASTE MANAGEMENT SYSTEM FOR METROPOLITAN CITIES"** is the Bonafide work of "NEKHA.L (113219041074),NIVETHA.M(113219041076),PADMA.S(113219041078),SARMILA.S (113219041100) and SNEHA.S (113219041111)" carried out in "PROFESSIONAL READINESS FOR INNOVATION, EMPLOYABILITY AND ENTREPRENEURSHIP (NALAIYA THIRAN-IBM PROJECT)**"** during the Academic Year 2022-2023.

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ABSTRACT

One issue that most cities and municipalities are dealing with currently, is the degradation of environmental cleanliness with reference to waste management. This is a result of improper garbage collection management. Dumping garbage onto the streets and in public areas is a common synopsis found in all developing countries and this mainly ends up affecting the environment and creating several unhygienic conditions. To avoid improper garbage management and to create a hygienic environment, the concept of automation is used in waste management system. Any city being referred to as a "smart city" is because of its orderly and tidy surroundings. But currently, many issues including those related to smart grids, smart environments, and smart living are faced. Today, cities and metropolitan areas' top priority is proper garbage management. Traditional waste management techniques are too simplistic to create an effective and reliable waste management. The ideology put forward includes hardware and software technologies i.e. connecting Wi-Fi system to the normal dustbin in order to provide free internet facilities to the user for a particular period of time. The technology awards the user for keeping the surrounding clean and thus work hand in hand for the proper waste management in a locality. The smart bin uses multiple technologies - firstly the technology for measuring the amount of trash dumped and secondly the movement of the waste and lastly sending necessary signals and connecting the user to the Wi-Fi system. The proposed system will function on client server model, a cause that will assure clean environment, good health, and pollution free society.

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CHAPTER 1
INTRODUCTION

1.1 Project Overview

Smart waste management is an innovative approach to handling and collecting waste. Based on IoT (Internet of Things) technology, smart waste management provides data on waste generation patterns and behaviour. Our Smart waste management solution uses sensors placed in garbage bins to measurefill levels and notifies city collection services when bins are ready to be emptied. There areload and ultrasonic sensors placed to continuously monitor the bins. This data is sent to thecloud (via a microcontroller that is connected to Wi-Fi) where it is stored after which it is processed further. When the levels exceed a certain limit, a notification is sent to the garbage collector via a web application.

Over time, historical data collected by sensors can be used to identify fill patterns, optimize driver routes and schedules, and reduce operational costs. The cost of these sensors is steadily decreasing, making IoT waste bins more feasible to implement and more attractive.

1.2 Purpose

Around 2.1 billion tons of municipal solid waste is generated annually around the globe. Population growth and rapid urbanization lead to a huge increase in waste generation, so the traditional methods of waste collection have become inefficient and costly. This system cannot measure the fullness levels of containers, and as a result, half- full containers can be emptied, and in contrast, pre-filled ones need to wait until the next collection period comes. Moreover, since drivers collect empty bins, predefined collectionroutes of the system cause waste of time, an Increase in fuel consumption and excessive use of resources .

CHAPTER 2

LITERATURE SURVEY

2.1 EXISTING PROBLEMS

[1] Shivam Jagtap, Aditya Gandhi, Raviraj Bochare, "Waste Management Improvement in Cities using IoT", International Conference on Power Electronics & IoT Applications in Renewable Energy and its Control (PARC) 2020

Garbage collection is one of the most critical problems faced by Municipal Corporation. While implementing the waste management in cities the biggest challenge is the management of waste in cost optimal way with high performance. The current process of collecting the waste, separating it and transporting the containers everyday which is a complicated process. This paper deals with the concept of waste management and the smart system for waste management with higher benefits to the society. The proposed system for waste management will use various sensors for sensing the type of waste and separate the waste in different categories and actuator to inform the management to collect the waste container. This system will save money and time compared to the already available process of waste management and also improves the society cleanliness. Management and disposal of waste is a challenge in today's world. The dumping of garbage wastes at open landfill sites is the common method of disposal. The disposal method of dumping in open land sites has an adverse effect on the environment. Due to dumping of waste in such an open environment it affects the health of human beings and also life of plants & animals

[2]Mohit Badve, Apoorva Chaudhari, Palak Davda,"Garbage Collection System using IoT for Smart City", Fourth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)2020.

In today's world, one of the major environmental problems is the collection, management and disposal of the garbage. The current process of garbage collection does not consider real-time garbage level in dustbins while generating routes for garbage trucks. Collecting garbage in an unordered way leads to overfilling of bins, rotting garbage smell, more fuelconsumption of trucks and hence has adverse effects on the environment. Moreover, the capacity of garbage trucks is not utilized. With the development of smart cities around theglobe, there is an increasing need for IoT based technological solutions for solid waste management which will help in promoting a clean and sustainable environment. The proposed system gathers the real-time garbage level of every bin with the help of ultrasonic sensors. This data is then used to generate dynamic routes for garbage trucks while considering several factors like capacity of trucks and bins, the distance between bins, and the level of garbage.

[3] P. Leninpugalhanthi,G. Bharanidaran, T. Bahiradhan,"Enhanced Smart Waste Management System With Incinerator Compartment", 7th International Conference on Advanced Computing and Communication Systems (ICACCS) 2021.

As of now we are in the 21s century, where we find many technologies ruling the world, and the Internet of Things is one among them which can be defined as an intelligent node that was interconnected in a global infrastructure which helps to implement the connectivity of anything from anywhere at anytime and transferring of data over wireless network. Human growth becomes liable to overwhelming and stopping difficulties which have been putting its existence in danger. As the human population increases, and the lack of knowledge about the waste management system, increase the risk of pollution to the environment. The enormous measure of

waste products is additionally a major danger to the environment. Disposing the Waste like wet, dry or biodegradable and non-biodegradable which are getting dumped together are being the big deal in India right now. There was a large amount of plastics and other wastes were produced every year which are not currently carried out in any recycling plants. In order to provide a solution for these wastes and managing the wastes, we proposed a "Enhanced Smart waste management system with Incinerator compartment", Where the wastes which may be located in either city.

[4] Jacob John, Mariam Sunil Varkey, Riya Sanjay Podder,"Smart Prediction and Monitoring of Waste Disposal System Using IoT and Cloud for IoT Based Smart Cities", Wireless Personal Communications: An International Journal, Volume 122, Issue 1, Jan 2022.

One of the prominent applications of Internet of Things (IoT) in this digital era is the development of smart cities. In IoT based smart cities, the smart objects (devices) are connected with each other via internet as a backbone. The sensed data by the smart objects are transmitted to the sink for further processing using multi hop communication. The smart cities use the analyzed data to improve their infrastructure, public utilities and they enhance their services by using the IoT technology for the betterment of livelihood of the common people. For IoT based smart cities, waste collection is a prominent issue for municipalities that aim to achieve a clean environment. With a boom in population in urban areas, an increasing amount of waste is generated public bins begin to overflow for a long period before the process of cleaning starts, which is resulting in an accumulation of bacteria causing bad odors and spreading of diseases. In order to overcome this issue, in this paper an IoT based smart predication and monitoring of waste disposal system is proposed which utilizes of-the-shelf components that can be mounted to a bin of any size and measure fill levels. An Arduino microcontroller is employed in the proposed model to interface the infrared (IR), ultraviolet (UV) and etc.

2.2PROBLEM STATEMENT AND DEFINITION

With increasing populations, changing policy requirements, new sustainability and recycling goals and improved technology departments, municipalities across the globe arejoining the “smart cities” movement to become more efficient in managing solid waste.

The improvement of the urban waste collection service and, in general, the achievement of a more efficient management of the waste, is one of the main challenges that the cities face, especially due to the population growth. Thus, smart waste management is a key factor of smart cities.

Problem Statement:

Design a smart waste collection system that allows citizens to segregate the various typesof solid waste they want to dispose and the municipal authorities to efficiently collect the same. The system should be mobile app (Android) based. The system should have two interfaces:

Citizen: Citizen should have an option to schedule a waste pickup request, at a particular date and time at his chosen location (via map or geolocation). The pickup request can be no less than 24 hours in advance.

Citizen should mention the amount of waste for disposal, choose what categories of waste are present for disposal as well as optionally snap a picture of the waste.

Citizen should be able to see all upcoming waste pickup requests, as well as past pickup request history.

Garbage collector: Garbage collector should be shown a list of all pickups to be made that day, along with a most efficient route for all pickups. Please note that start and stop point for each truck is from a central depot with fixed location. There should be GPS based navigation for the garbage collector from one point to another. For each pickup request, garbage collector is shown the following:

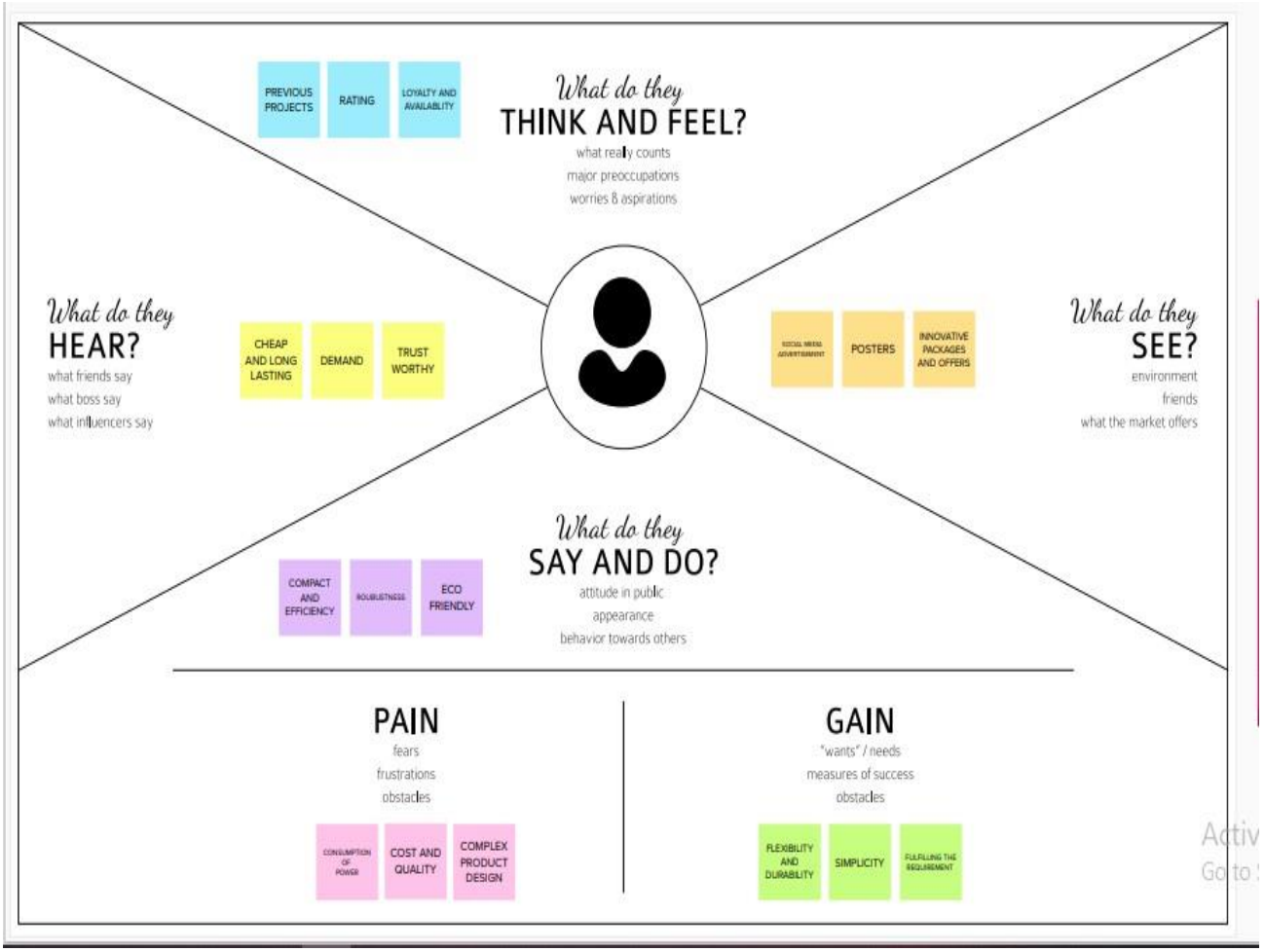
Citizen name & location (address & map) Garbage amount Garbage category Garbage photo, if available Make a web interface for both citizen & garbage collector. Implement a hybrid mobile app (Android/iOS). Make an admin web interface where we can see all garbage trucks, citizens, collection requests (past & upcoming) etc.

Implement a waste classification helper for citizen which suggests what waste category it is after the citizen takes a photo of the waste. It can suggest multiple categories as well.

CHAPTER 3

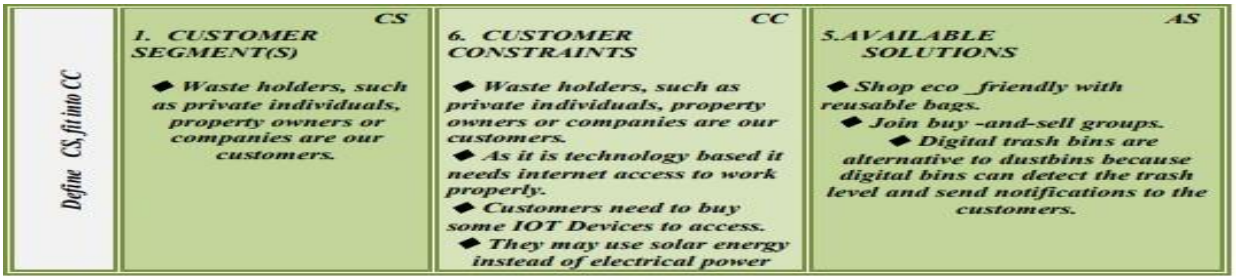
IDEATION AND PROPOSED SOLUTION

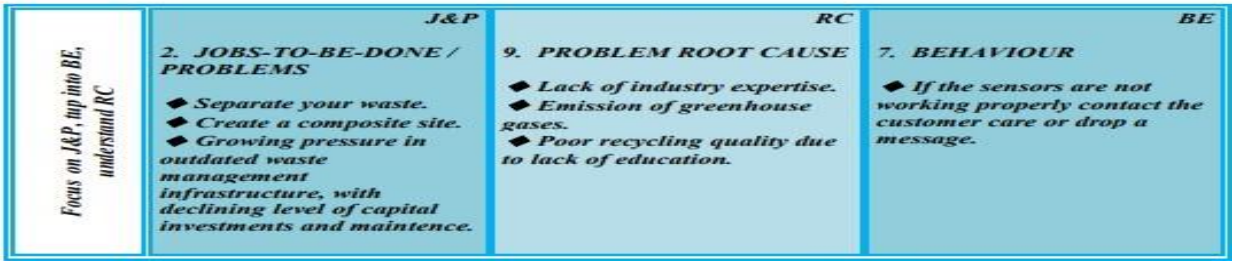
3.1 EMPATHY MAP CANVAS

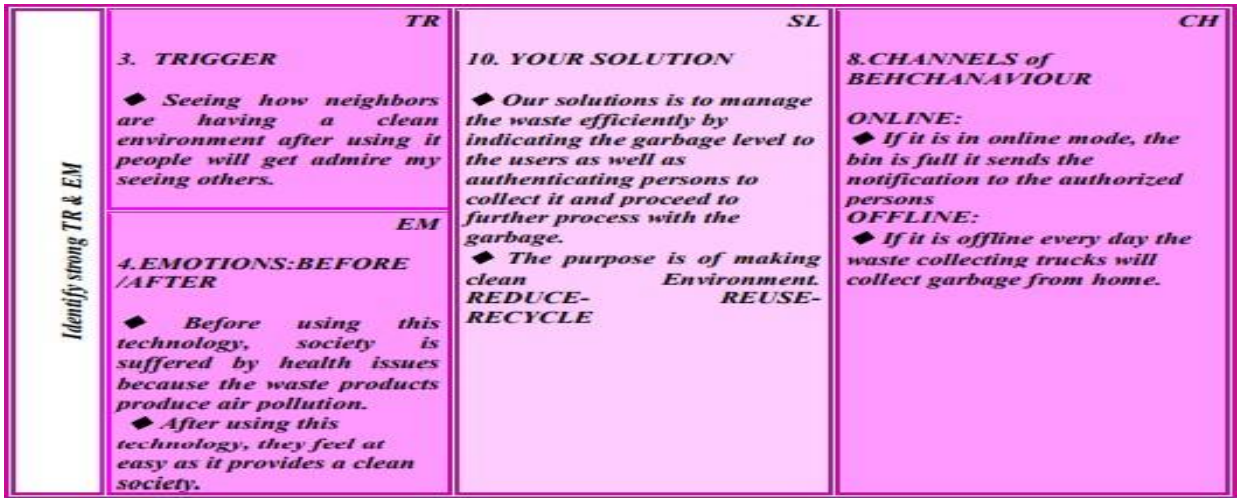


3.2 IDEATION AND BRAIN STORMING

INDIVIDUAL IDEAS







TEAM IDEAS

Garbage Truck Weighing Mechanisms

Like waste level sensors, weighing mechanisms installed in garbage trucks can help predict fill levels and reduce collection trips. They do this by measuring and storing the weight of waste containers, then using the data to predict fill levels over time.

Cities can use this technology to more accurately predict how often they need to send their trucks out and reduce annual collection costs.

E-Waste Kiosks

Electronic waste that is improperly disposed of can be harmful to both humans and the environment. Fortunately, many companies and organizations have started e-waste recycling programs that will accept and even reimburse you for old electronic devices. Eco ATM, a smart recycling company, took this idea one step further by creating a line of e-waste recycling kiosks that allow you to exchange your electronics for cash on the spot. While they won't always offer cash for devices that are broken or destroyed, they accept phones, tablets and MP3 players in any condition and ensure that they are recycled properly.

Self-Driving Trucks

It's still in the development phase, but autonomous waste pickup is close to being implemented. As known, Volvo has been working on this technology for many years with Uber for a self-driving pickup truck. This system targets a truck maneuvering itself while the operator gets out to collect the garbage. Gear changing, steering, and speed are also optimized for low fuel consumption and emissions. "Our self-driving refuse truck is leading the way in this field globally, and one of several exciting autonomous innovations we are working with right now" explains Lars Stenqvist, Chief Technology Officer, Volvo Group. Additionally, Stenqvist states this new technology provides benefits for a reduction in the risk of occupational injuries.

3.3 PROPOSED SOLUTION

S.NO	PARAMETER	DESCRIPTION
1.	Problem statement (Problem to be solved)	In this technology, Sensors require power for various operations. Energy is consumed in data collection, data method, data communication. Wireless sensor networks once deployed should be in a position to work with none human intervention. It should be in a position to manage the network and analyse it for its Configuration, adaptation, maintenance and repair by itself. Quality of service is the level of service provided by the sensor networks to its users. WSN are being used in various real time and vital applications, so it is mandatory for the network to offer sensible QoS.Requires a lot of maintenance price. The bins are clean only if it's totally stuffed.

2.	Idea/Solution description	Even if knowledge Confidentiality and Data Integrity is assured, there is a desire to make sure the freshness of every message. To solve this problem another time-related counter, can be other into the packet to make sure knowledge freshness. A sensor network designed to find faults can would like correct location data in order to pin purpose the placement of a fault. Providing awareness of the presence of sensor nodes and knowledge acquisition is notably vital.
3.	Novelty/ Uniqueness	Novelty/ Uniqueness A wireless sensor network is a collection of large number of sensor nodes and at least one base station. The sensor node is an autonomous small device that consists of mainly four units that are sensing, processing, communication and power supply. These sensors are used to collect the information from the environment and pass it on to base station. A base station provides a

		connection to the wired world where the collected data is processed, analysed and presented to useful applications. Thus by embedding processing and communication within the physical world, Wireless Sensor Network (WSN) can be used as a tool to bridge real and virtual environment
4	social Impact/ customer satisfaction	A large proportion of recyclable components Le. paper, plastics, metal, etc. is collected by rag pickers from the garbage bins, from roadside or in streets marker paces, et in metropolitan cities, thus supplying raw material to the flourishing recycling units About 0.75 million tons of plastics wastes are recycled every year in India in the business is very lucrative and can fetch anything between Rs 3 to Rs 15 per kg at each stage of the transfer. In smaller cities and towns about 14-20% of the total garbage comes of recyclable terms (TERI, 1998) This excludes the plastics and paper retained in the households

		to be sold. The plastic recycling industry in India is valued at 25 rupees at pre- granulation stage and 39 billion rupees at the post-granulation stage
5.	Business Model (Revenue Model)	Residential Customers, comprising residential homeowners and renters to which the Company provides services such as curbside pickup, dumpster collection, and portable storage. Industrial Customers, comprising various industrial entities, including construction firms, manufacturers, healthcare providers, and foodservice businesses, to which the Company provides specialist waste management services
6.	Scalability of the Solution	IoT based projects are already designed while keeping future demands in mind and in a rising economy like India where the concept of smart cities is new the demand for our project will keep on increasing. This project here is a model of the large-scale application which spans pan India in different smart cities. The implementation of this project has

		been divided into various phases. Starting from the metropolitan cities and moving towards the concept of smart cities.

3.4 PROBLEM SOLUTION FIT

CHAPTER 4
REQUIREMENT ANALYSIS

4.1 Functional Requirements

FR No.	Functional Requirement (Epic)	Sub Requirement (Story / Sub-Task)
FR-1	Detailed bin inventory.	All monitored bins and stands can be seen on the map, and you can visit them at any time via the Street View feature from Google. Bins or stands are visible on the map as green, orange or red circles. You can see bin details in the Dashboard-capacity, waste type, last measurement,GPS location and collection schedule or pick recognition.
FR-2	Real time bin monitoring.	The Dashboard displays real-time data on fill-levels of bins monitored by smart sensors. In addition to the percentage of fill-level, based on the historical data, the tool predicts when the bin will become full, one of the functionalities that are not included even in the best waste management software. Sensors recognize picks as well, so you can check when the bin was last collected. With real-time data and predictions, you can eliminate the overflowing bins and stop collecting half-empty ones.

FR-3	Expensive bins.	We help you identify bins that drive up your collection costs. The tool calculates a rating for each bin in terms of collection costs. The tool considers the average distance deposit bin discharge in the area. The tool assigns bin a rating (1-10) and calculates distance from deposit bin discharge.
FR-4	Adjust bin distribution.	Ensure the most optimal distribution of bins. Identify areas with either dense or sparse bin distribution. Make sure all trash types are represented within a stand. Based on the historical data, you can adjust bin capacity or location where necessary condition occurs.
FR-5	Eliminate inefficient picks.	Eliminate the collection of half-empty bins. The sensors recognize picks. By using real-time data on fill-levels and pick recognition, we can show you how full the bins you collect are. 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.

4.2 Non-functional Requirements:

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 user's product usability can indeed help designers better understand users' potential needs in waste management, behavior and experience.
NFR-2	**Security**	• Use 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 router education 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.

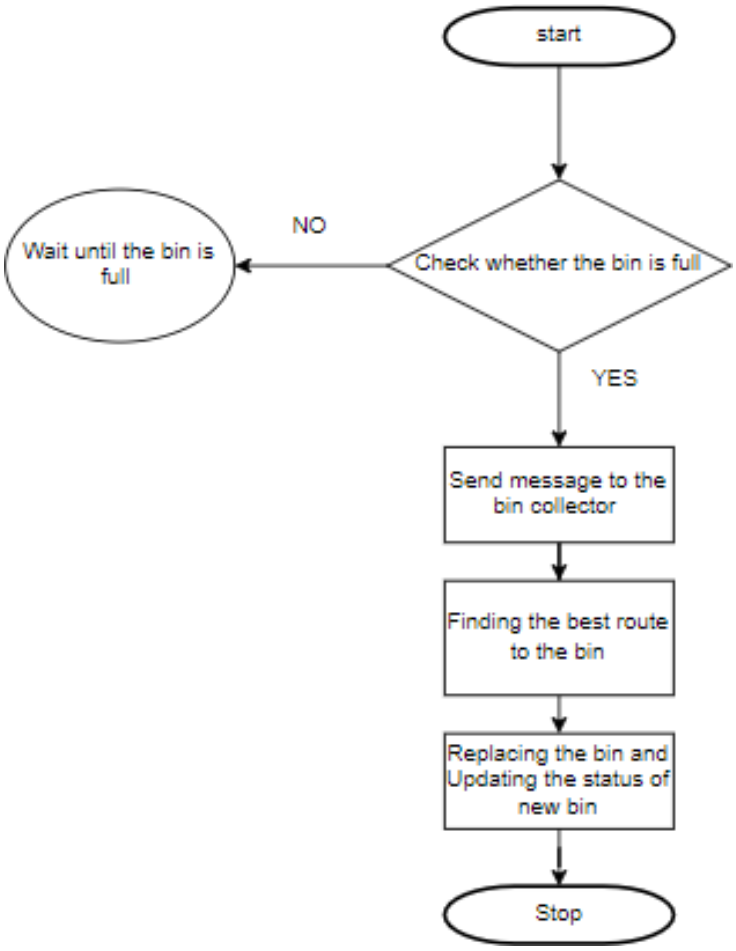
NFR-6	**Scalability**	Using smart waste bins reduce the number of bins inside town, cities because we able to monitor it

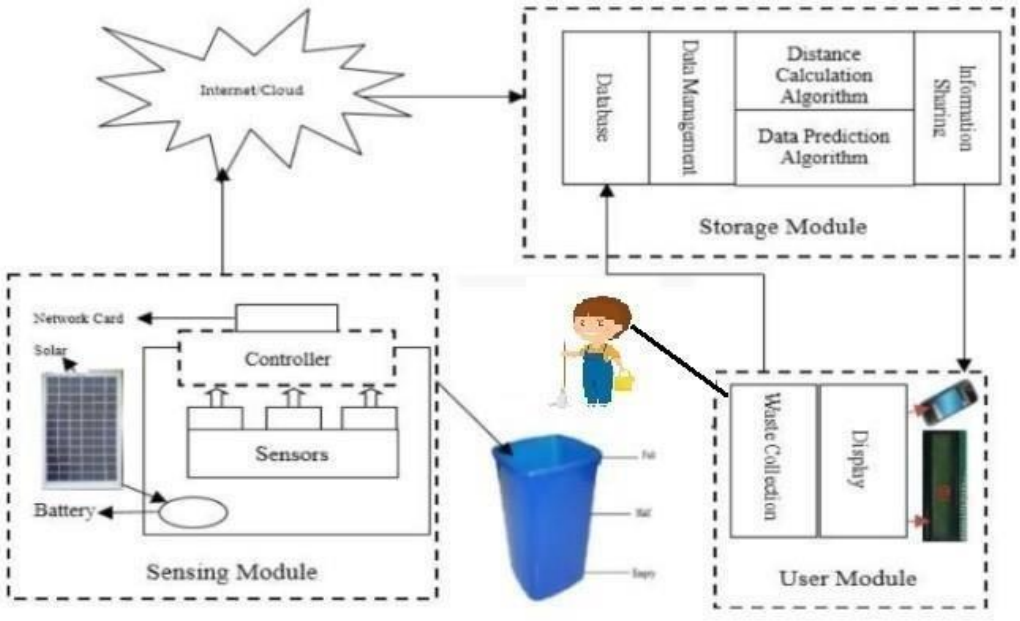
CHAPTER 5

PROJECT DESIGN

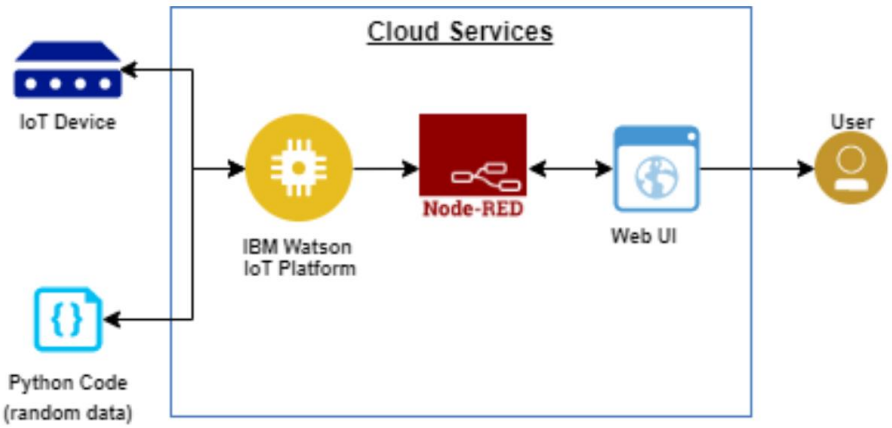
5.1 Data Flow Diagram:

A Data Flow Diagram (DFD) is a traditional visual representation of the information flows within a system. A neat and clear DFD can depict the right amount of the system requirement graphically. It shows how data enters and leaves the system, what changes the information, and where data is stored.





5.2 Solution and Technical Architecture



5.3 User Stories

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria
Customer (Mobile user)	Login	USN-1	Can access his or her account to access site with the given credentials.	Admin can access the account / dashboard
Admin	Admin	USN-2	Monitor the user/customer and other participants in the process of garbage disposal/collection.	Authorized User
Garbage Collector	Login	USN – 3	Updates the status of the garbage bins once visited.	Registered by admin and authorized
Truck Driver	Login	USN-4	As user, they are directed to the work assigned to them in site and take the given route.	Admin can register and route can be dynamically re-routed
Organization Head	Login	USN-5	Has the privilege to monitor over the sectors and customers under their control and division.	Admin verified and authorized user from the organization

CHAPTER 6

PROJECT PLANNING AND SCHEDULING

6.1 Sprint Schedule, and Estimation

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Login	USN-1	As a administrator, I need to give user id and passcode for every workers over there municipality	10	High	Sarmila S
Sprint-1	Login	USN-2	As a Co-Admin, I'll control the waste level by monitoring them via real time web portal. Once the filling happens, I'll notify trash truck with location of bin with bin ID	10	High	Nekha L
Sprint-2	Dashboard	USN-3	As a Truck Driver, I'll follow Co-Admin's Instruction to reach the filling bin in short roots and save time.	20	Low	Nivetha M
Sprint-3	Dashboard	USN-4	As a Local Garbage Collector,I'II gather	20	Medium	Padma S

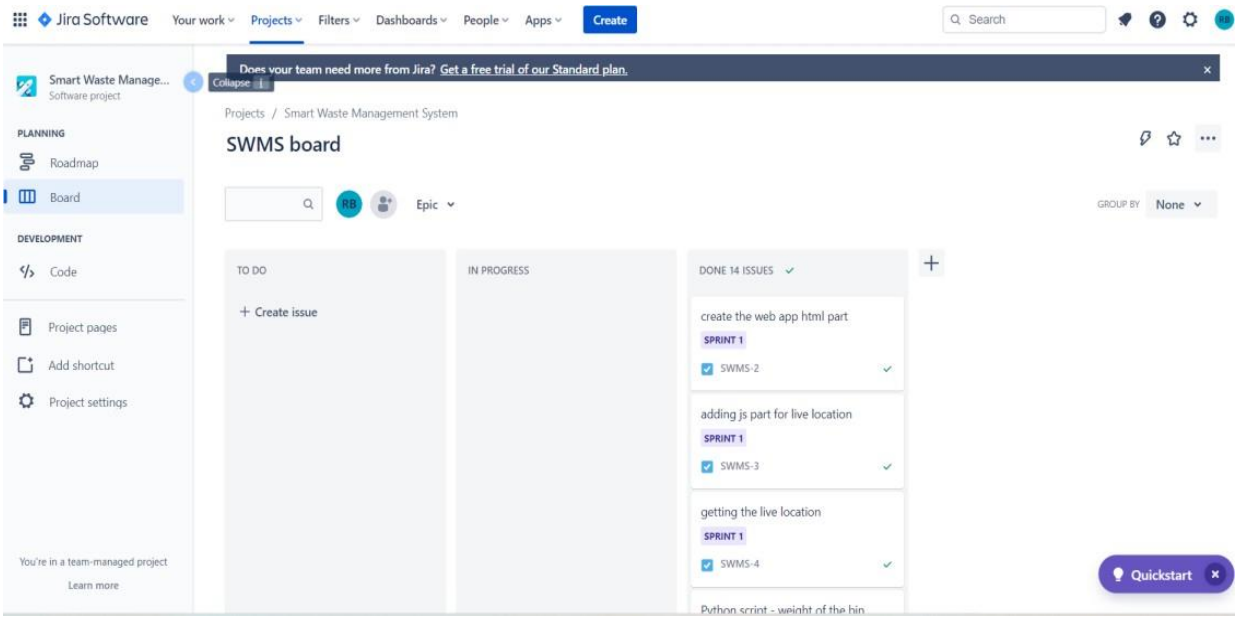
			all the waste from the garbage, load it onto a garbage truck, and deliver it to Landfills			
Sprint-4	Dashboard	USN-5	As a Municipality officer, I'll make sure everything is proceeding as planned and without any problems	20	High	Sneha S

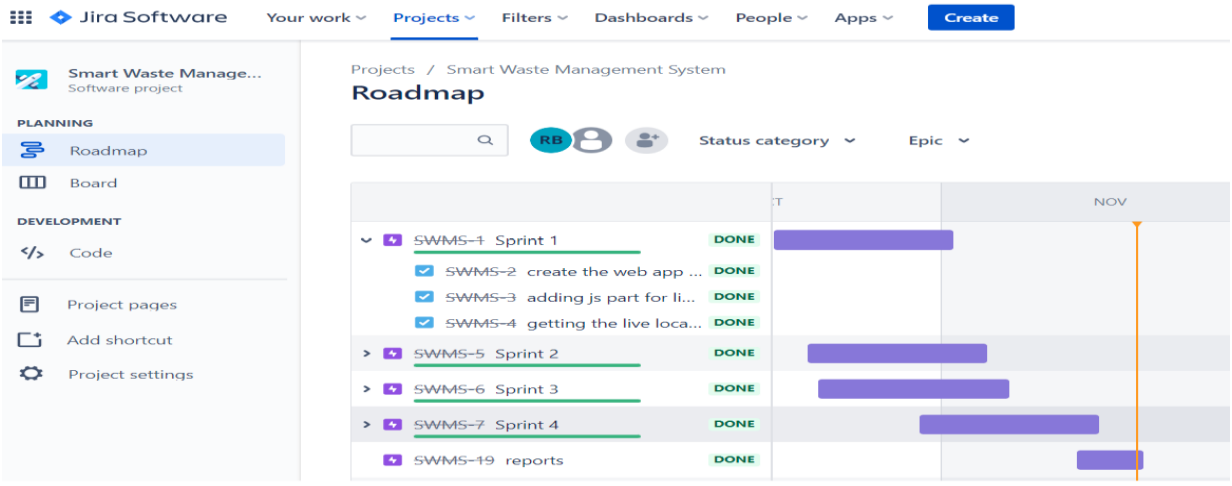
Use the below template to create product backlog and sprint schedule

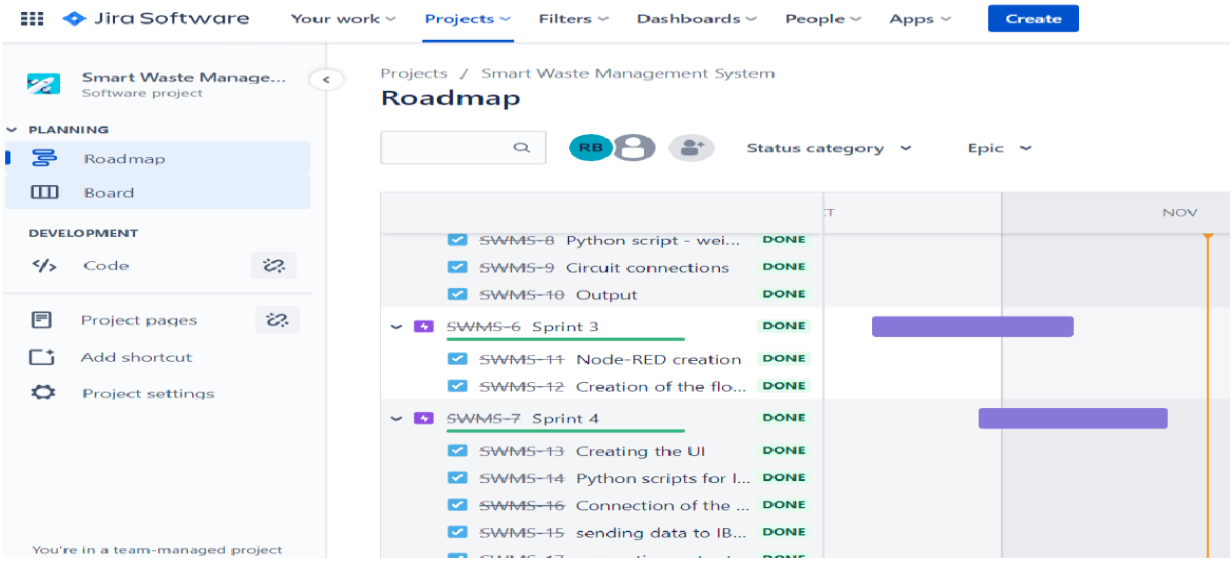
6.2Sprint Delivery Schedule:

Sprint	Total Story Points	Duration	Sprint Start Date	Sprint End Date (Planned)	Story Points Completed (as on Planned End Date)	Sprint Release Date (Actual)
Sprint-1	35	10 Days	22 Oct 2022	31 Oct 2022	35	31 Oct 2022
Sprint-2	20	6 Days	31 Oct 2022	05 Nov 2022	20	05 Nov 2022
Sprint-3	20	6 Days	07 Nov 2022	12 Nov 2022	20	12 Nov 2022
Sprint-4	15	6 Days	14 Nov 2022	19 Nov 2022	20	19 Nov 2022

6.3 Reports from JIRA:



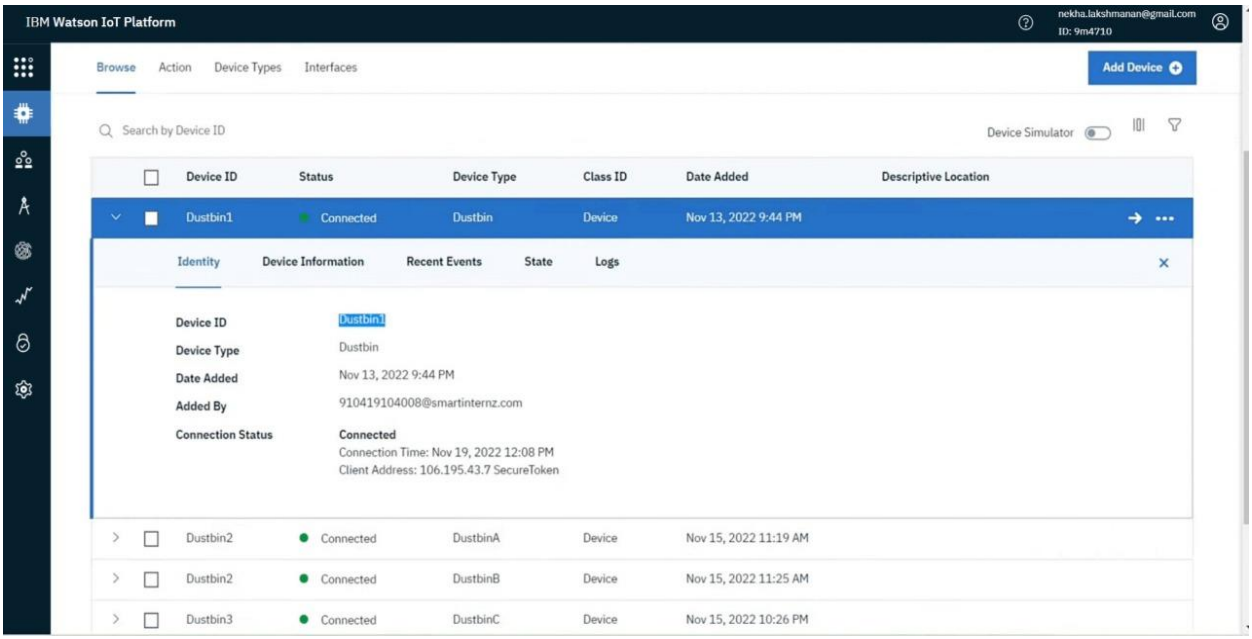




CHAPTER 7
CODING & SOLUTIONING

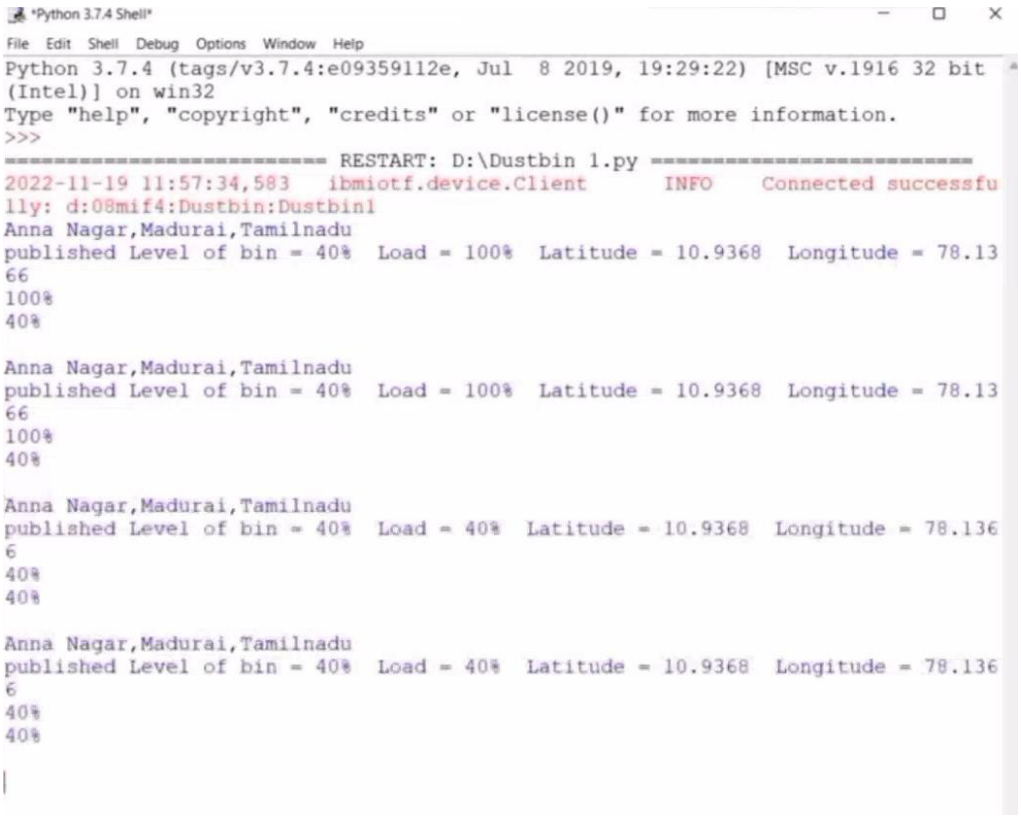
7.1 Configuration of the IBM Watson IOT Platform

In the IBM Watson IOT Platform, we have created four dustbins. These four dustbins are successfully connected to the IBM Watson cloud.



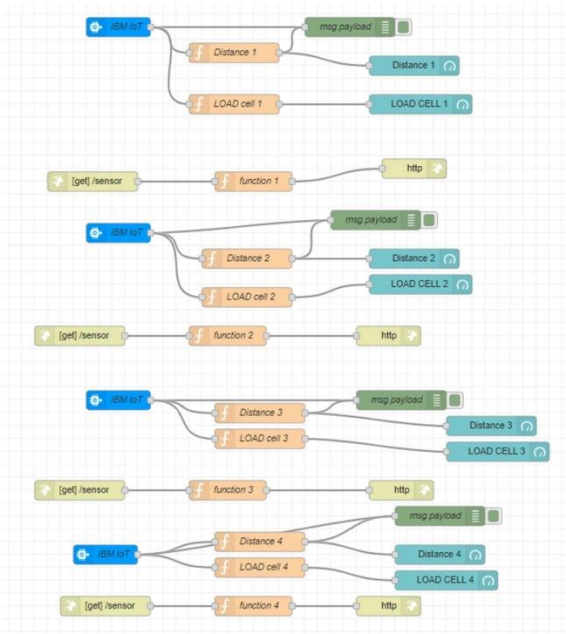
Development of the Python Script

Publishing the data to the IBM Watson Platform by developing the python script. In this python code we constantly entered the longitude and latitude values. This code is composed of organization ID, type ID, device ID and authentication token for connecting to IBM IOT platform. We have used a while loop. in this while loop we gave some random values for the bin level latitude and longitude. We also used if else, to know whether the bin level is full or not.



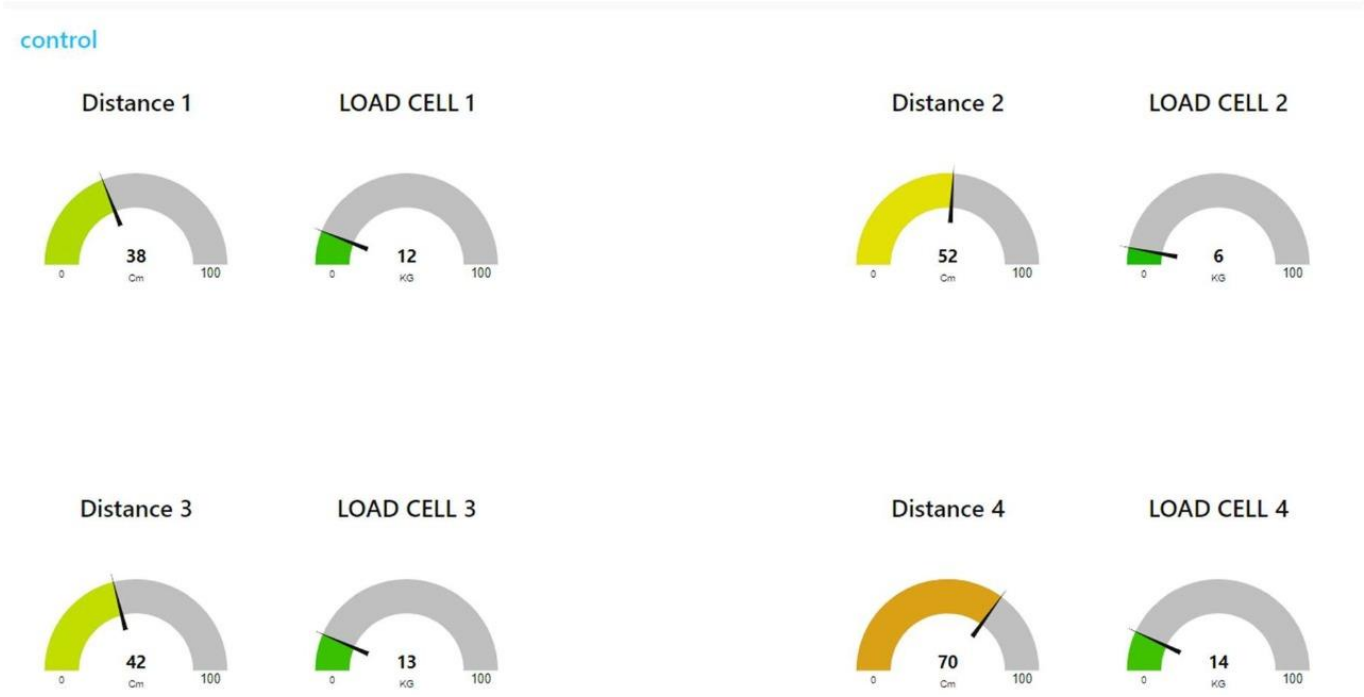
7.2 Creation of the Node Red Service

In Node Red, we have pinned the IBM IOT, to transfer the data to cards. These are the building blocks we have fixed. We fixed 4 IBM IOT's according to our dustbins.



7.3 Creation of the Website Dashboard

We have created the website dashboard. In the dashboard, we can see the real data for the python script. These values are randomly shifting from the data in the python script.



CHAPTER 8
TESTING

8.1 Test cases:

A test case has components that describe input, action and an expected response, in order to determine if a feature of an application is working correctly. A test case is a set of instructions on “HOW” to validate a particular test objective/target, which when followed will tell us if the expected behavior of the system is satisfied or not. Characteristics of a good test case:

- Accurate: Exacts the purpose.
- Economical: No unnecessary steps or words.
- Traceable: Capable of being traced to requirements.
- Repeatable: Can be used to perform the test over and over.
- Reusable: Can be reused if necessary.

8.2 User Acceptance testing

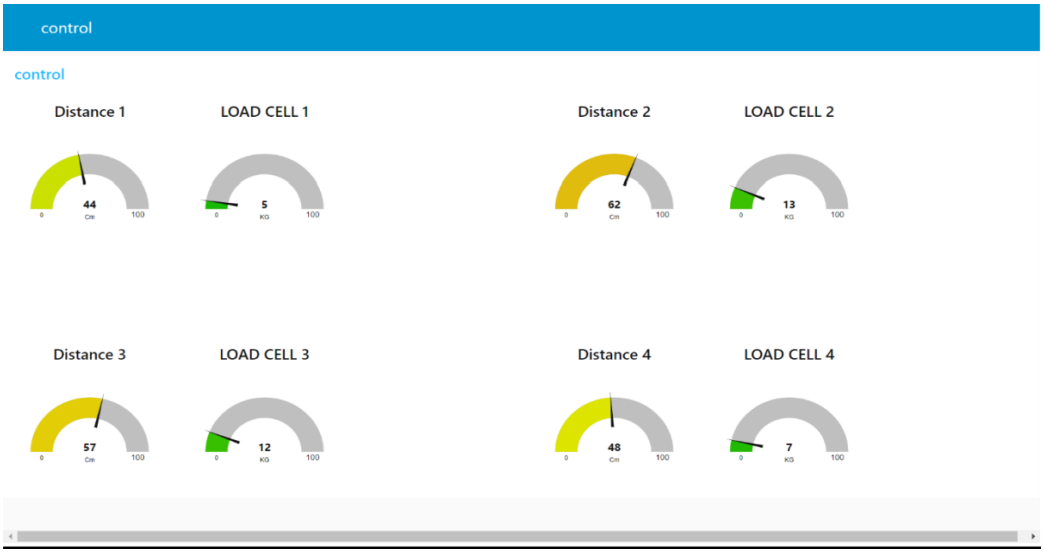
Acceptance testing - is the final phase of product testing prior to public launch. A level of the software testing process where a system is tested for acceptability. The purpose of this test is to evaluate the system’s compliance with the business requirements and assess whether it is acceptable for delivery.

Test case no.	Sensor/Stage	Input	Expected output	Obtained output	Status
1.	Ultrasonic	Garbage level in bin i)Null ii)Full iii)Range in %	Correct level or distance	As expected	Pass
2.	ESP – 32	Microcontroller to process the input data	To collect the data from sensor	As expected	Pass
3.	Load cell	To measure mechanical force	Calculate the force due to the bin weight	As expected	Pass
4.	Gauge	To display the tares	Display the level for collection	As expected	Pass
5.	HX710	Weight of the bin(in kg)	Measure the weight	As expected	Pass

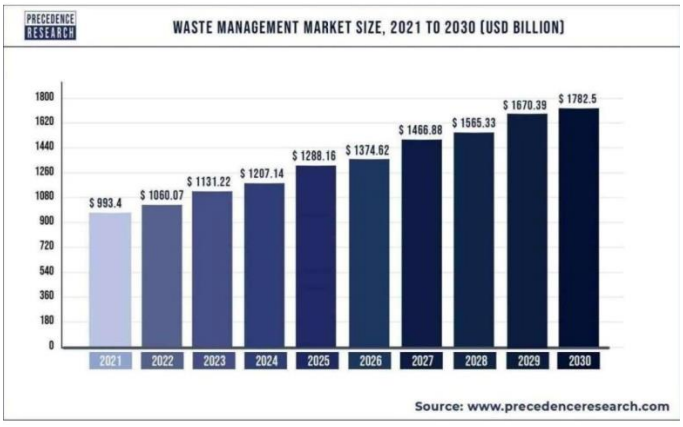
CHAPTER 9

RESULTS

Sample output:



9.1 Performance Metrics



CHAPTER 10
ADVANTAGES AND DISADVANTAGES

10.1 Advantages:

- Intelligent compaction of waste by monitoring fill level in real-time using sensors.
- It keeps our surroundings clean and keeps free from bad odour.
- Reduces manpower requirement to handle the garbage collection
- Emphasizes of healthy environment and keep the cities cleaner and more beautiful.
- It reduces infrastructure, operating and maintenance costs by upto 30%.
- Increases recycling rate of waste.

10.2 Disadvantages:

- Initial large-scale implementation takes cost.
- System requires more number waste bins for separate waste collection.
- Wireless technologies used should have proper connections as they have shorter range and lower data speed
- Training programs should be provided to people involving in theecosystem of smart waste management.
- Sensors may encounter damage so it should be kept under protectiveambience to prevent the damage.
- Replacement of sensors require knowledgeable people and thus acknowledgement of malfunction of sensor.

CHAPTER 11
CONCLUSION

Improper disposal and improper maintenance of domestic waste create issues in public health and environment pollution thus this paper attempts to provide practical solution towards managing the waste collaborating it with the use of IOT. by using the smart waste management system, we can manage waste properly we are also able to sort the Bio-degradable and non-Biodegradable waste properly which reduces the pollution in the environment. Various waste management initiatives taken for human well-being and to improve the TWM practices were broadly discussed in this chapter. The parameters that influence the technology and economic aspects of waste management were also discussed clearly. Different types of barriers in TWM, such as economic hitches, political issues, legislative disputes, informative and managerial as well as solutions and success factors for implementing an effective management of toxic organic waste within a globular context, were also discussed giving some real examples. The effect of urbanization on the environmental degradation and economic growth was also discussed. The proposed system will help to overcome all the serious issues related to waste and keep the environment clean.

CHAPTER 12
FUTURE WORK

Based on the real-time and historical data collected and stored in the cloud waste collection schedules and routes can be optimized. Predictive analytics could be used to make decisions ahead of time and offers insight into waste bin locations. Graph theory optimization algorithms can be used to manage waste collection strategies dynamically and efficiently. Every day, the workers can receive the newly calculated routes in their navigation devices. The system can be designed to learn from experience and to make decisions not only on the daily waste level status but also on future state forecast, traffic congestion, balanced cost-efficiency functions, and other affecting factors that a priori humans cannot foresee.

Garbage collectors could access the application on their mobile phone/tablets using the internet. Real-time GPS assistance can be used to direct them to the pre-decided route. As they go collecting the garbage from the containers, the management is also aware of the progress as the vehicle, as well as the garbage containers, are traced in real-time. The management staff gets their own personalized administration panel over a computer/tablet which gives thema bird eye view over the entire operations.

An alternative solution using image processing and camera as a passive sensor could be used. But, the cost of those image processing cameras is higher as compared to the ultrasonic sensors, which leads to high solution implementation cost.

CHAPTER 13
APPENDIX

Web Application to get the Live location:

index.html:

```
<!DOCTYPE html>
<html>

<head>
  <link rel="stylesheet" href="https://cdn.jsdelivr.net/npm/bootstrap@4.3.1/dist/css/bootstrap.min.css"
    integrity="sha384-
    ggOyR0iXCbMQv3Xipma34MD+dH/1fQ784/j6cY/iJTQUOhcWr7x9JvoRxT2MZw1T" cross
    origin="anonymous">
    <meta charset="utf-8">
    <meta name="viewport" content="width=device-width">
    <title>Smart Waste Management System</title>
    <link rel="icon" type="image/x-icon" href="/imgs/DUMPSTER.png">
    <link href="style.css" rel="stylesheet" type="text/css" />
    <script src="https://www.gstatic.com/firebasejs/9.14.0/firebase-app.js"></script>
    <script src="https://www.gstatic.com/firebasejs/9.14.0/firebase-analytics.js"></script>
    <script src="https://www.gstatic.com/firebasejs/9.14.0/firebase-database.js"></script>

    <script>
      var firebaseConfig =
      {
            apiKey: "AIzaSyCcZk7b1CLOGviwUpthRDLotrmFX0MFuTs",
        authDomain: "swms-3840.firebaseapp.com",
        projectId: "swms-3840",
        storageBucket: "swms-3840.appspot.com",
        messagingSenderId: "479902726304",
        appId: "1:479902726304:web:3d822880d1275ee57a71c5",
        measurementId: "G-MHP4N77MTP"
      };
      firebase.initializeApp(firebaseConfig)
```

```
    </script>
    <script defer src="db.js"></script>
</head>

<body style="background-color:#1F1B24;">
    <script src="maps.js"></script>
    <div id="map_container">
      <h1 id="live_location_heading" >LIVE LOCATION</h1>
      <div id="map"></div>
      <div id="alert_msg">ALERT MESSAGE!</div>
    </div>
    </div>
    <center>
      <a href="https://goo.gl/maps/G9XET5mzSw1ynHQ18" type="button" class="btn btn-dark">
        DUMPSTER
      </a>
    </center>
    <script
      src="https://maps.googleapis.com/maps/api/js?key=AIzaSyBBLyWj-
    3FWtCbCXGW3ysEiI2fDfrv2v0Q&callback=myMap"></script></div>
</body>
</html>
```

db.js:

```
const cap_status = document.getElementById("cap_status");
const alert_msg = document.getElementById("alert_msg");

var ref = firebase.database().ref();

ref.on(
  "value",
  function (snapshot) {
    snapshot.forEach(function (childSnapshot) {
      var value = childSnapshot.val();

      const alert_msg_val = value.alert;
      const cap_status_val = value.distance_status;
```

```
      alert_msg.innerHTML = `${alert_msg_val}`;
    });
  },
  function (error) {
    console.log("Error: " + error.code);
  }
);
```

maps.js:

```
const database = firebase.database();

function myMap() {
  var ref1 = firebase.database().ref();

  ref1.on(
    "value",
    function (snapshot) {
      snapshot.forEach(function (childSnapshot) {
        var value = childSnapshot.val();
        const latitude = value.latitude;
        const longitude = value.longitude;

        var latlong = { lat: latitude, lng: longitude };
        var mapProp = {
          center: new google.maps.LatLng(latlong),
          zoom: 10,
        };
        var map = new google.maps.Map(document.getElementById("map"), mapProp);
        var marker = new google.maps.Marker({ position: latlong });
        marker.setMap(map);
      });
    },
    function (error) {
      console.log("Error: " + error.code);
    }
  );
}
```

Code to evaluate the level of the garbage in bin:

bin1.py:

```
import requests
import json
import ibmiotf.application
import ibmiotf.device
import time
import random
import sys

# watson device details
organization = "73ffyv"
devicType =  "BIN1"
deviceId = "BIN1ID"
authMethod= "token"
authToken= "123456789"

#generate random values for randomo variables (temperature&humidity)
def myCommandCallback(cmd):
    global a
    print("command recieved is:%s" %cmd.data['command'])
    control=cmd.data['command']
    print(control)

try:
    deviceOptions={"org": organization, "type": devicType,"id": deviceId,"auth-method":authMethod,"auth-
token":authToken}
    deviceCli = ibmiotf.device.Client(deviceOptions)
except Exception as e:
    print("Exception while connecting device %s" %str(e))
    sys.exit()
```

```
#connect and send a datapoint "temp" with value integer value into the cloud as a type of event for every 10 seconds
deviceCli.connect()

while True:
    distance= random.randint(10,70)
    loadcell= random.randint(5,15)
    data= {'dist':distance,'load':loadcell}


    if loadcell < 13 and loadcell > 15:
        load = "90 %"
    elif loadcell < 8 and loadcell > 12:
        load = "60 %"
    elif loadcell < 4 and loadcell > 7:
        load = "40 %"
    else:
        load = "0 %"


    if distance < 15:
        dist = 'Risk warning:' 'Garbage level is high, collection time :) 90 %'
    elif distance < 40 and distance >16:
        dist = 'Risk warning:' 'garbage is above 60%'
    elif distance < 60 and distance > 41:
        dist = 'Risk warning:' '40 %'
    else:
        dist = 'Risk warning:' '17 %'


    if load == "90 %" or distance == "90 %":
        warn  = 'alert :' ' Garbage level is high, collection time :)'
    elif load == "60 %" or distance == "60 %":
        warn = 'alert :' 'garbage is above 60%'
    else :
```

```
        warn = 'alert :' 'Levels are low, collection not needed '

    def myOnPublishCallback(lat=11.035081,long=77.014616):
        print("Peelamedu, Coimbatore")
        print("published distance = %s " %distance,"loadcell:%s " %loadcell,"lon = %s " %long,"lat = %s"
%lat)
        print(load)
        print(dist)
        print(warn)

    time.sleep(10)
    success=deviceCli.publishEvent ("IoTSensor","json",warn,qos=0,on_publish= myOnPublishCallback)
    success=deviceCli.publishEvent ("IoTSensor","json",data,qos=0,on_publish= myOnPublishCallback)

    if not success:
        print("not connected to ibmiot")

    time.sleep(30)
    deviceCli.commandCallback=myCommandCallback

#disconnect the device
deviceCli.disconnect()
```

bin2.py:

```
import requests
import json
import ibmiotf.application
import ibmiotf.device
import time
import random
import sys

# watson device details
organization = "73ffyv"
devicType =  "BIN2"
deviceId = "BIN2ID"
authMethod= "token"
```

```
authToken= "123456789"

#generate random values for randomo variables (temperature&humidity)
def myCommandCallback(cmd):
    global a
    print("command recieved is:%s" %cmd.data['command'])
    control=cmd.data['command']
    print(control)



try:
    deviceOptions={"org": organization, "type": devicType,"id": deviceId,"auth-method":authMethod,"auth-
token":authToken}
    deviceCli = ibmiotf.device.Client(deviceOptions)
except Exception as e:
    print("Exception while connecting device %s" %str(e))
    sys.exit()

#connect and send a datapoint "temp" with value integer value into the cloud as a type of event for every 10
seconds
deviceCli.connect()

while True:
    distance= random.randint(10,70)
    loadcell= random.randint(5,15)
    data= {'dist':distance,'load':loadcell}


    if loadcell < 13 and loadcell > 15:
        load = "90 %"
    elif loadcell < 8 and loadcell > 12:
        load = "60 %"
    elif loadcell < 4 and loadcell > 7:
        load = "40 %"
    else:
        load = "0 %"


    if distance < 15:
        dist = 'Risk warning:' 'Garbage level is high, collection time :) 90 %'
    elif distance < 40 and distance >16:
        dist = 'Risk warning:' 'garbage is above 60%'
    elif distance < 60 and distance > 41:
        dist = 'Risk warning:' '40 %'
```

```
    else:
        dist = 'Risk warning:' '17 %'


    if load == "90 %" or distance == "90 %":
        warn  = 'alert :' ' Garbage level is high, collection time :)'
    elif load == "60 %" or distance == "60 %":
        warn = 'alert :' 'garbage is above 60%'
    else :
        warn = 'alert :' 'Levels are low, collection not needed '

    def myOnPublishCallback(lat=11.068774,long=77.092978):
       print("PSG iTech, Coimbatore")
       print("published distance = %s " %distance,"loadcell:%s " %loadcell,"lon = %s " %long,"lat = %s"
     %lat)
       print(load)
       print(dist)
       print(warn)

    time.sleep(10)
    success=deviceCli.publishEvent ("IoTSensor","json",warn,qos=0,on_publish= myOnPublishCallback)
    success=deviceCli.publishEvent ("IoTSensor","json",data,qos=0,on_publish= myOnPublishCallback)

    if not success:
       print("not connected to ibmiot")

    time.sleep(30)
    deviceCli.commandCallback=myCommandCallback

#disconnect the device
deviceCli.disconnect()
```

bin3.py:

```
import requests
import json
import ibmiotf.application
import ibmiotf.device
import time
import random
import sys


# watson device details
```

```
organization = "73ffyv"
devicType =  "BIN3"
deviceId = "BIN3ID"
authMethod= "token"
authToken= "123456789"

#generate random values for randomo variables (temperature&humidity)
def myCommandCallback(cmd):
    global a
    print("command recieved is:%s" %cmd.data['command'])
    control=cmd.data['command']
    print(control)

try:
    deviceOptions={"org": organization, "type": devicType,"id": deviceId,"auth-
method":authMethod,"auth-token":authToken}
    deviceCli = ibmiotf.device.Client(deviceOptions)
except Exception as e:
    print("Exception while connecting device %s" %str(e))
    sys.exit()

#connect and send a datapoint "temp" with value integer value into the cloud as a type of event for
every 10 seconds
deviceCli.connect()

while True:
    distance= random.randint(10,70)
    loadcell= random.randint(5,15)
    data= {'dist':distance,'load':loadcell}



    if loadcell < 13 and loadcell > 15:
        load = "90 %"
    elif loadcell < 8 and loadcell > 12:
          load = "60 %"
```

```
    elif loadcell < 4 and loadcell > 7:
        load = "40 %"
    else:
        load = "0 %"


    if distance < 15:
        dist = 'Risk warning:' 'Garbage level is high, collection time :) 90 %'
    elif distance < 40 and distance >16:
        dist = 'Risk warning:' 'garbage is above 60%'
    elif distance < 60 and distance > 41:
        dist = 'Risk warning:' '40 %'
    else:
        dist = 'Risk warning:' '17 %'


    if load == "90 %" or distance == "90 %":
        warn  = 'alert :' ' Garbage level is high, collection time :)'
    elif load == "60 %" or distance == "60 %":
        warn = 'alert :' 'garbage is above 60%'
    else :
        warn = 'alert :' 'Levels are low, collection not needed '

    def myOnPublishCallback(lat=11.007403,long=76.963439):
       print("Kattoor, Coimbatore")
       print("published distance = %s " %distance,"loadcell:%s " %loadcell,"lon = %s " %long,"lat =
%s" %lat)
       print(load)
       print(dist)
       print(warn)

    time.sleep(10)
    success=deviceCli.publishEvent ("IoTSensor","json",warn,qos=0,on_publish=
myOnPublishCallback)
```

```
    success=deviceCli.publishEvent ("IoTSensor","json",data,qos=0,on_publish=
myOnPublishCallback)

    if not success:
        print("not connected to ibmiot")

    time.sleep(30)
    deviceCli.commandCallback=myCommandCallback

#disconnect the device
deviceCli.disconnect()
```

Measuring the weight of the garbage bin:

main.py:

```
from hx711 import HX711
hx = HX711(5,4,64)
print(1)
while True:
    hx.tare()
    read = hx.read()
    #average=hx.read_average()
    value=hx.read_average()
    print(value,"#")
```

hx711.py:

```
from machine import Pin, enable_irq, disable_irq, idle

class HX711:
    def __init__(self, dout, pd_sck, gain=128):

        self.pSCK = Pin(pd_sck , mode=Pin.OUT)
        self.pOUT = Pin(dout, mode=Pin.IN, pull=Pin.PULL_DOWN)
        self.pSCK.value(False)
```

```
        self.GAIN = 0
        self.OFFSET = 0
        self.SCALE = 1

        self.time_constant = 0.1
        self.filtered = 0

        self.set_gain(gain);

    def set_gain(self, gain):
        if gain is 128:
self.GAIN = 1
        elif gain is 64:
            self.GAIN = 3
        elif gain is 32:
            self.GAIN = 2

        self.read()
        self.filtered = self.read()
        print('Gain & initial value set')

    def is_ready(self):
        return self.pOUT() == 0

    def read(self):
        # wait for the device being ready
        while self.pOUT() == 1:
            idle()

        # shift in data, and gain & channel info
        result = 0
        for j in range(24 + self.GAIN):
            state = disable_irq()
            self.pSCK(True)
```

```
            self.pSCK(False)
            enable_irq(state)
            result = (result << 1) | self.pOUT()

        # shift back the extra bits
        result >>= self.GAIN

        # check sign
        if result > 0x7fffff:
            result -= 0x1000000

        return result
    def read_average(self, times=3):
        s = 0
        for i in range(times):
            s += self.read()
        ss=(s/times)/210
        return '%.1f' %(ss)

    def read_lowpass(self):
        self.filtered += self.time_constant * (self.read() - self.filtered)
        return self.filtered

    def get_value(self, times=3):
        return self.read_average(times) - self.OFFSET

    def get_units(self, times=3):
        return self.get_value(times) / self.SCALE

    def tare(self, times=15):
        s = self.read_average(times)
        self.set_offset(s)

    def set_scale(self, scale):
        self.SCALE = scale
```

```
def set_offset(self, offset):
    self.OFFSET = offset

def set_time_constant(self, time_constant = None):
    if time_constant is None:
        return self.time_constant
    elif 0 < time_constant < 1.0:
        self.time_constant = time_constant
def power_down(self):
    self.pSCK.value(False)
    self.pSCK.value(True)

def power_up(self):
    self.pSCK.value(False)
```

Project Links:

Smart Waste Management Demo Link

Github Link

CHAPTER 14
REFERENCES

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[6] Rasha Elhassan; Mahmoud Ali Ahmed; Randa AbdAlhalem ,"Smart Waste Management System for Crowded area : Makkah and Holy Sites as a Model", 4th MEC International Conference on Big Data and Smart City (ICBDSC) 2019.

[7] Shaunak Varudandi,Raj Mehta, Jahnavi Mahetalia, Harshwardhan Parmar,Krishna Samdani"A Smart Waste Management and Segregation System that Uses Internet of Things, Machine Learning and Android Application", 6th International Conference for Convergence in Technology (I2CT) 2021.

[8] Dung D. Vu, Georges Kaddoum,"A waste city management system for smart cities applications", Advances in Wireless and Optical Communications (RTUWO) 2017.