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Project report

Smart City waste Management System with connected trashcans

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1.Introduction

1.1 Project Overview :

The project aims to develop and implement a smart city waste management system that leverages IoT technology and connected trash cans to optimize waste collection processes and enhance overall efficiency in waste management. The system utilizes sensors embedded in trash cans to monitor fill levels, temperature, and other relevant data in real-time. This data is collected, aggregated, and analysed to generate insights and enable intelligent decision-making for waste collection and disposal.

The smart city waste management system offers several key features and functionalities. It provides waste management personnel with a web-based application that allows them to monitor and control the status of trash cans, schedule waste collection routes, and generate reports on collection activities and efficiency.

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1.2 Purpose :

The proposed solution addresses various challenges faced by traditional waste management systems, such as inefficient collection routes, overflowing trash cans, and inconsistent waste disposal. By leveraging IoT technology and real-time data analysis, the system aims to improve waste collection efficiency, reduce operational costs, minimize environmental impact, and enhance the overall cleanliness.

Overall, the smart city waste management system with trash cans aims to transform traditional waste management practices into a data-driven and efficient process, contributing to a cleaner and more sustainable environment in the smart city.

2. IDEATION & PROPOSED SOLUTION

2.1 Problem Statement Definition:

The current waste management system in cities faces numerous challenges and inefficiencies, leading to detrimental environmental and public health impacts. Traditional trash cans are limited in their capabilities to handle the increasing volume of waste generated in urban areas. Therefore, there is a pressing need for a smart city waste management system that incorporates intelligent trash cans to address the following problems:

1. Inefficient waste collection
2. Inaccurate waste monitoring
3. Ineffective recycling practices
4. Environmental and health hazards
5. Lack of public engagement

Example:

1.Inefficient waste collection: The existing waste collection process lacks optimization, often resulting in irregular and inadequate pickups. This leads to overflowing trash cans, littering, and unsanitary conditions, negatively impacting the aesthetics and cleanliness of the city.

2. Inaccurate waste monitoring: The absence of real-time monitoring mechanisms makes it difficult to gather accurate data on waste generation patterns and fill levels of trash cans. This results in inefficient resource allocation and planning, leading to wasted time and resources.

3.Ineffective recycling practices: Limited awareness and lack of infrastructure for recycling lead to a significant portion of recyclable materials ending up in landfills. The absence of an integrated system for waste segregation and recycling discourages sustainable practices and hampers efforts towards a circular economy.

4. Environmental and health hazards: Poor waste management practices contribute to pollution, greenhouse gas emissions, and the spread of diseases. The absence of smart technology and advanced waste disposal techniques aggravates these hazards, posing risks to both the environment and public health.

5. Lack of public engagement: There is a disconnect between citizens and waste management authorities, resulting in a lack of awareness, apathy, and non-compliance with waste management regulations. The absence of interactive systems and citizen involvement prevents the realization of a comprehensive and sustainable waste management strategy.

2.2 Empathy Map Canvas:

- **What does the user Think and Feel?**
  - There must be a better way to optimize waste collection routes.
  - It would be great to have real-time data on trash can fill levels.
  - How can we improve waste segregation practices?

- **What does the user See?**
  - Overflowing trash cans and littered streets.
  - Inefficient waste collection and disposal processes.
  - Environmental and health hazards caused by improper waste management.

- **What does the user Hear?**
  - Complaints from residents about irregular waste collection.
  - Calls for better waste segregation practices.
  - Suggestions for improving waste management through technology.

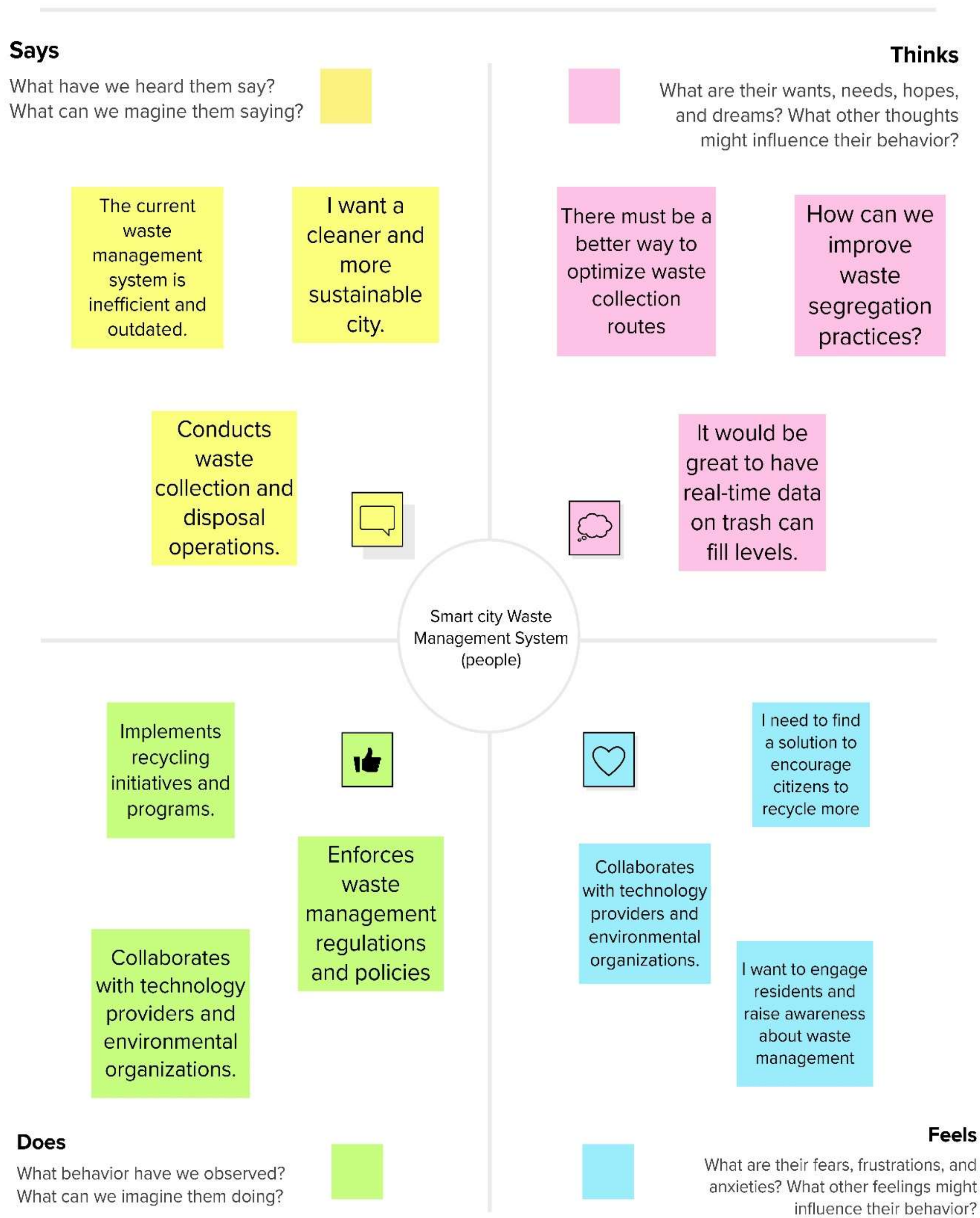
- **What does the user Say and Do?**
  - The current waste management system is inefficient and outdated.
  - I want a cleaner and more sustainable city.
  - Conducts waste collection and disposal operations.

- **What does the user Pain?**
  - Inefficient waste collection routes and schedules.
  - Lack of real-time data on trash can fill levels.

- **What does the user Pain?**
  - Optimized waste collection routes and schedules.

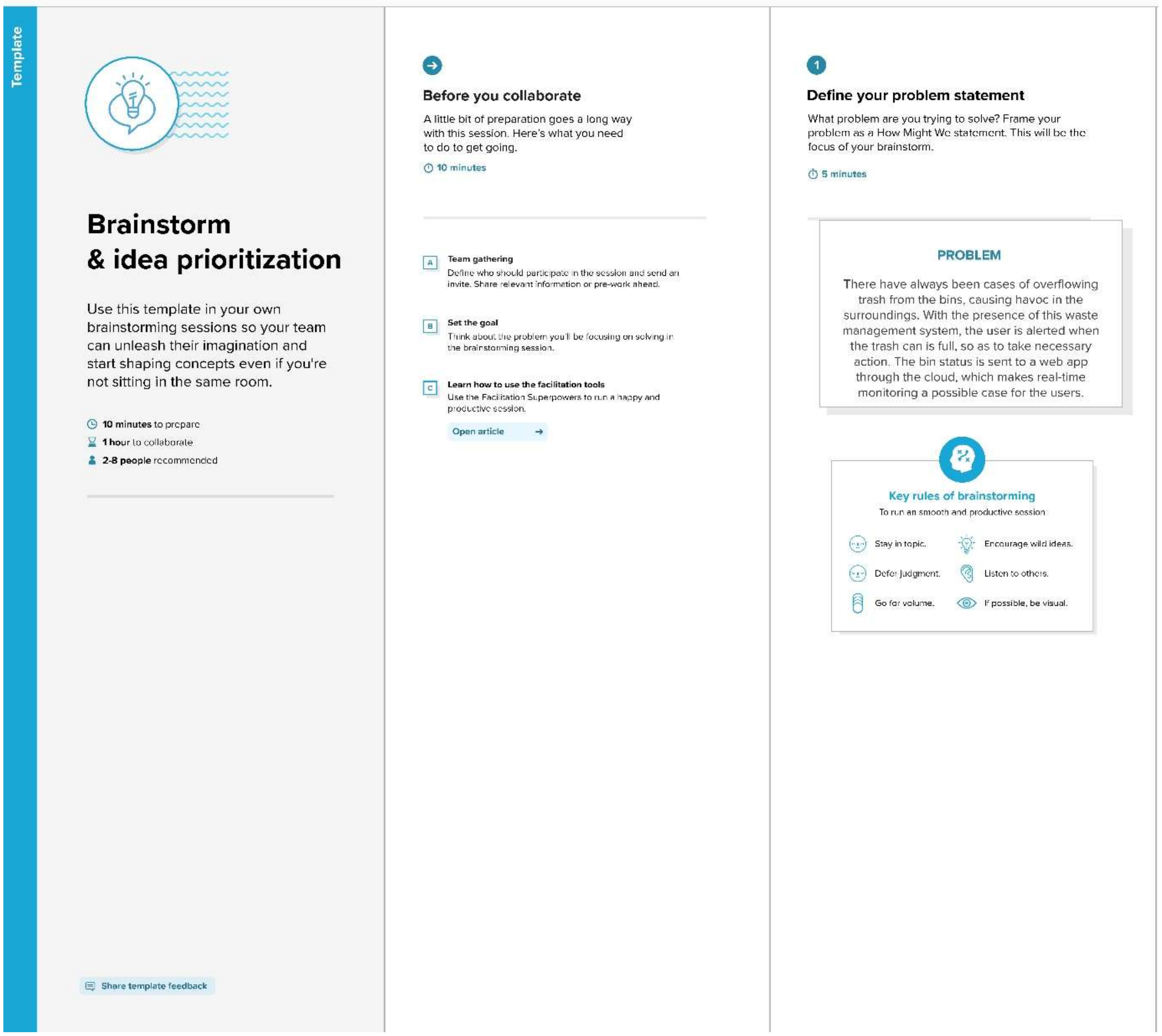
➢ Real-time monitoring of trash can fill levels.

<u>Example:</u> Smart City waste Management System with connected trashcans

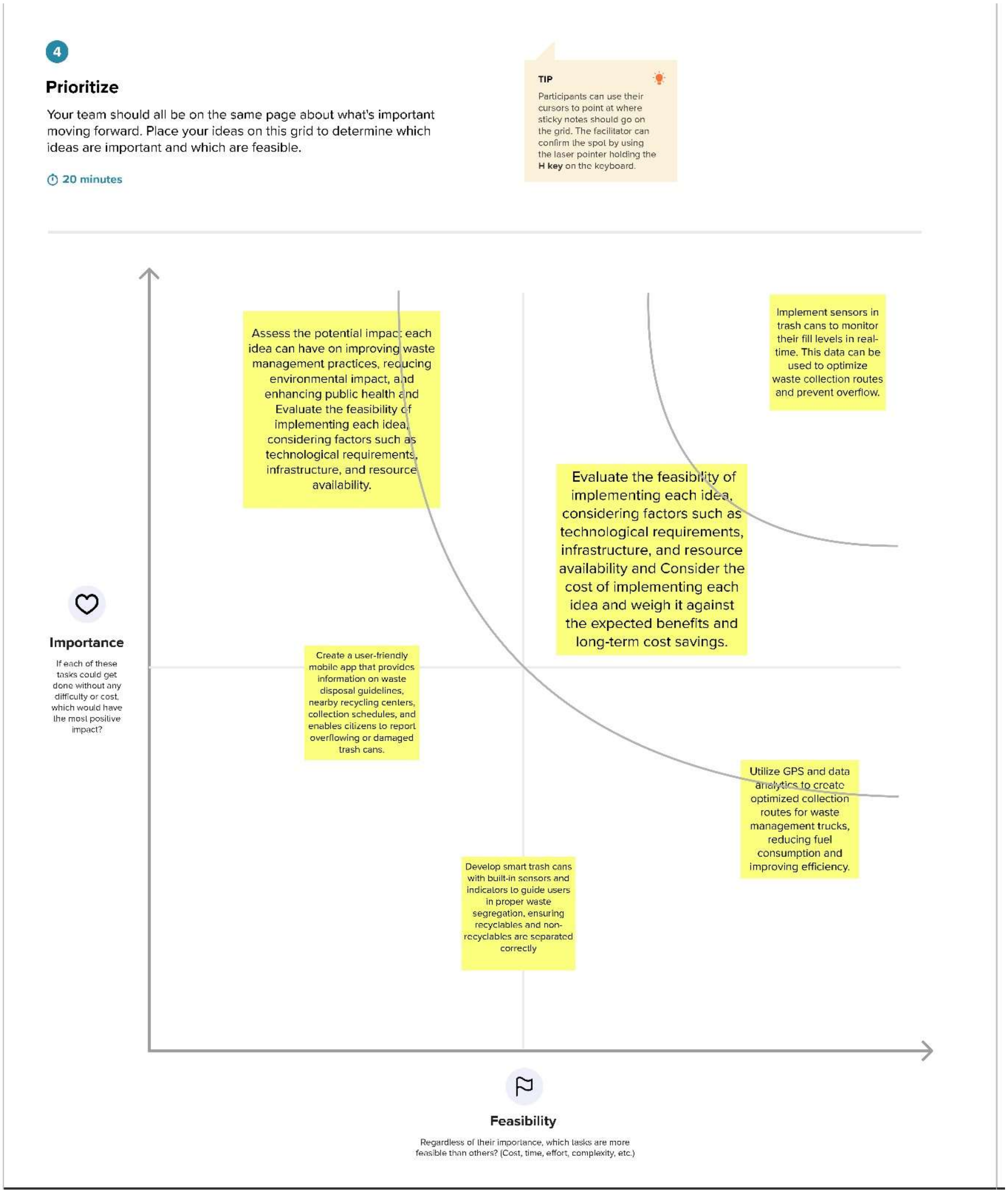


2.3 Ideation & Brainstorming:

Step-1: Team Gathering, Collaboration and Select the Problem Statement



Step-3: Idea Prioritization



2.4 Proposed Solution:

S.No:	Parameter	Description
1.	Problem Statement (Problem to be solved)	The current waste management system in cities is inefficient, leading to overflowing trash cans, irregular waste collection, inadequate recycling practices, and environmental hazards. There is a need for a smart city waste management system that addresses these challenges and improves overall waste management processes.
2.	Idea / Solution description	There have always been cases of overflowing trash from the bins, causing havoc in the surroundings. With the presence of this waste management system, the user is alerted when the trash can is full, so as to take necessary action. The bin status is sent to a web app through the cloud, which makes real-time monitoring a possible case for the users.
3.	Novelty / Uniqueness	Our system stands out due to its integration of various smart technologies. The real-time monitoring of trash can fill

		levels, intelligent waste segregation, and data-driven decision-making distinguish it from conventional waste management systems.
4.	Social Impact / Customer Satisfaction	The smart city waste management system brings several social benefits. It improves the cleanliness and aesthetics of the city by preventing overflowing trash cans and littered streets. Efficient waste collection reduces environmental and health hazards, leading to a safer and healthier living environment. Citizens gain access to user-friendly tools, information, and recycling facilities, increasing convenience and promoting sustainable practices.
5.	Business Model (Revenue Model)	• Sale/Lease of intelligent trash cans and related sensors to waste management authorities. • Subscription fees for waste management analytics and optimization services. • Advertising and sponsorship opportunities within the mobile

		application and public awareness campaigns. • Grants and funding from government bodies and environmental organizations supporting smart city initiatives.
6.	Scalability of the Solution	The smart city waste management system is designed to be scalable. It can be implemented in various cities, adapting to local waste management regulations and infrastructure. The modular design allows for easy integration with existing waste management systems, ensuring scalability and minimizing disruption. With proper customization and deployment, the solution can be replicated and expanded to address waste management challenges in different regions, thereby maximizing its impact.

3. REQUIREMENT ANALYSIS

3.1 Functional Requirements:

Following are the functional requirements of the proposed solution.

FR No.	Functional Requirement (Epic)	Sub Requirement (Story / Sub-Task)
FR-1	Real-time monitoring	The system should provide real-time monitoring of trash can fill levels using sensors to enable efficient waste collection.
FR-2	Waste segregation guidance	The solution should include intelligent trash cans with indicators or instructions to guide users in proper waste segregation.
FR-3	Optimized waste collection routes	The system should optimize waste collection routes based on real-time data, minimizing travel time and fuel consumption.
FR-4	Web application	A user-friendly mobile application should be developed to provide waste disposal guidelines, recycling center locations, collection schedules, and reporting functionalities.

FR-5	Data analytics	The solution should employ data analytics to analyze waste generation patterns, monitor performance, and make data-driven decisions for waste management strategies.
FR-6	Reporting and issue resolution	The web application should allow residents to report issues such as overflowing trash cans or damaged containers, enabling quick resolution by waste management authorities.

3.2 Non-functional Requirements:

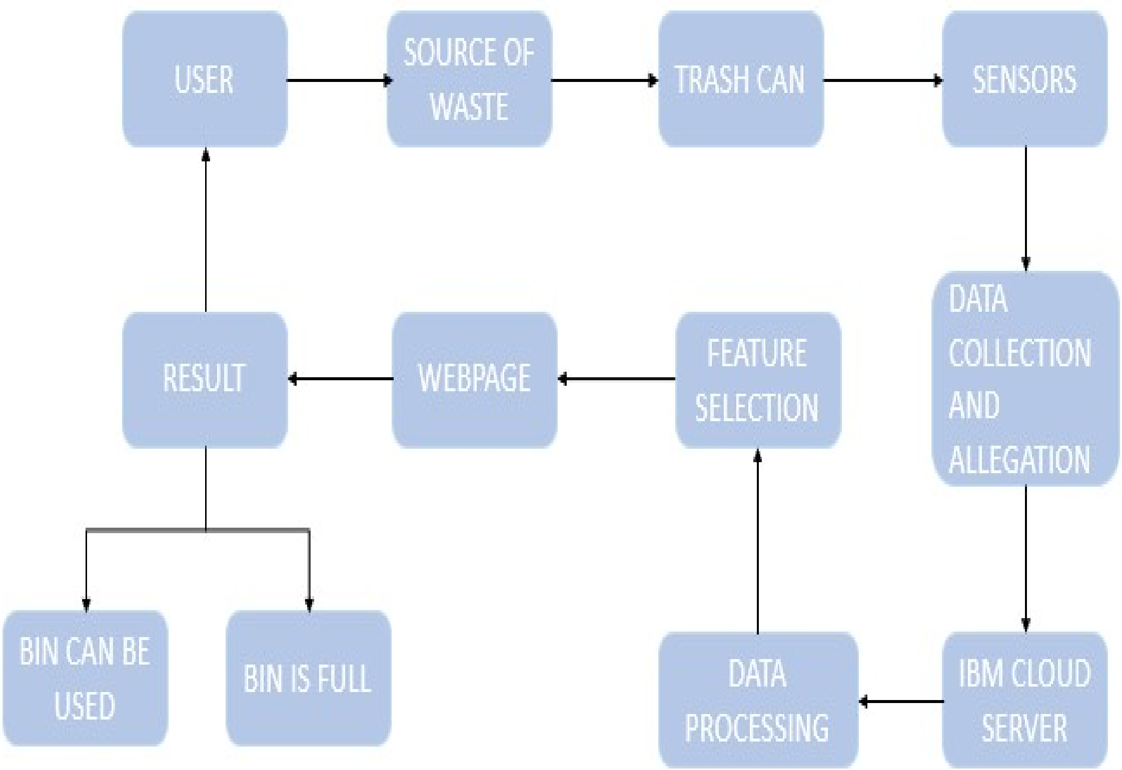
Following are the non-functional requirements of the proposed solution.

FR No.	**Non-Functional Requirement**	**Description**
NFR -1	**Usability**	The user interfaces, including the mobile application and web portal, should be user-friendly and easy to navigate, requiring minimal training for users. The system should be accessible to users with disabilities, complying with accessibility standards and guidelines.
NFR -2	**Security**	Robust security measures should be implemented to protect user data,

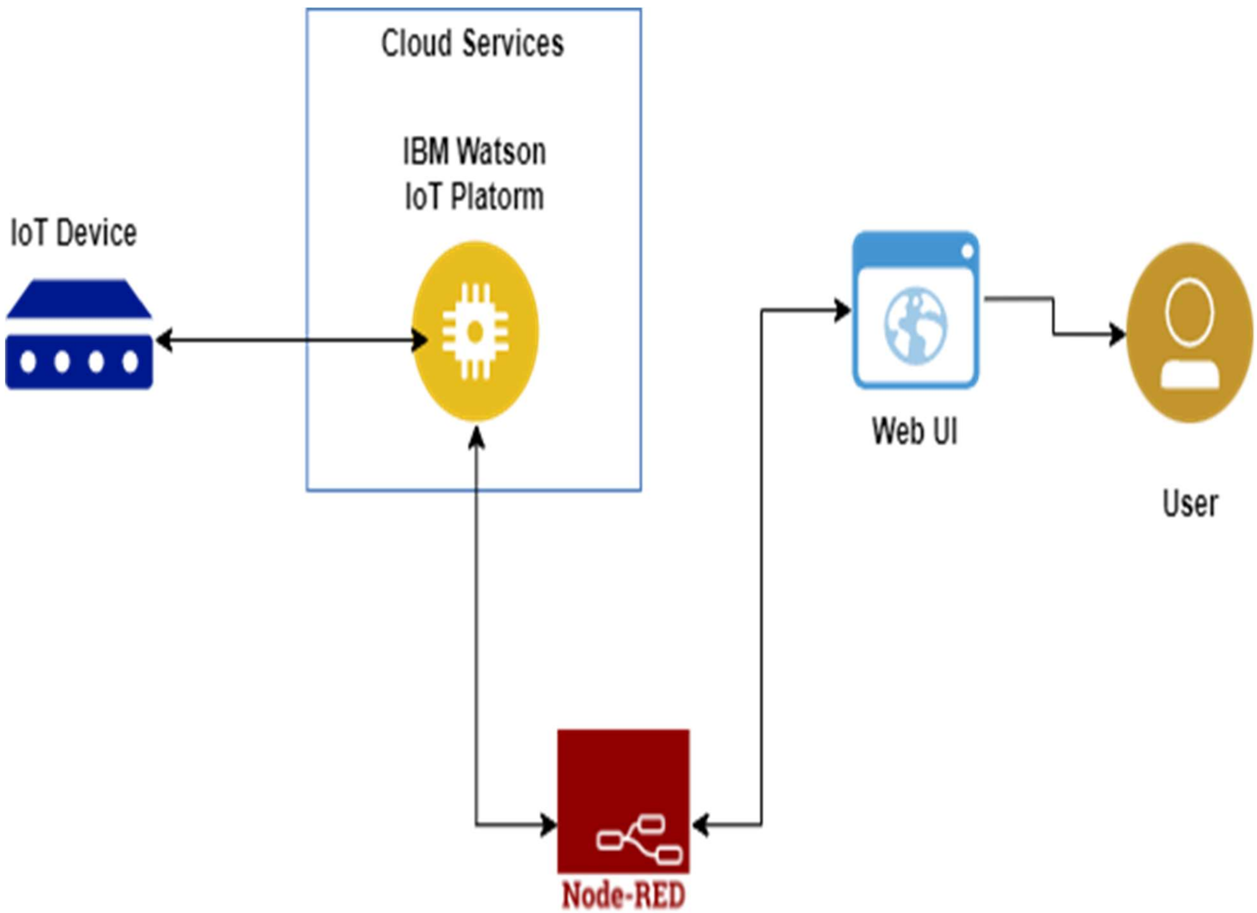
		ensuring privacy and preventing unauthorized access.
NFR -3	**Reliability**	The solution should be reliable, ensuring uninterrupted monitoring, accurate data collection, and timely waste collection.
NFR -4	**Performance**	The system should provide real-time or near-real-time responses to user actions, ensuring a smooth and responsive user experience. The system should be designed and optimized for fast and efficient data processing, ensuring timely delivery of information and reducing latency.
NFR -5	**Availability**	Implement redundant systems and failover mechanisms to ensure high availability and minimize service disruptions. Provide round-the-clock technical support to address any issues or incidents promptly and ensure continuous system availability.
NFR -6	**Scalability**	The system should be scalable to accommodate varying city sizes and future growth, supporting an increasing number of trash cans and users.

4. PROJECT DESIGN

4.1 Data Flow Diagrams:



4.2 Solution & Technical Architecture:



4.3 User Stories:

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Team Member
				The reports can be filtered by date range, location, or specific trash cans.		
Waste Management Personnel	Integration with City Services	USN-5	As a waste management personnel, I want to integrate the waste management system with the city's billing system.	The system provides the necessary data (e.g., number of collections, fill levels) to the billing system for accurate waste billing. The integration is secure and maintains data privacy.	High	VEDANAYAGAM L
Waste Management Personnel		USN-6	As a waste management personnel, I want to share waste management data with other city departments (e.g., environmental department, urban planning).	The system allows the waste management personnel to generate reports and export data for sharing with other departments. The data sharing process is secure and complies with data protection regulations.	Medium	SHARUKESHAN R

5. CODING & SOLUTIONING

5.1 Feature 1:

```
#include <WiFi.h>//library for wifi
#include <PubSubClient.h>//library for MQtt
#include "Ultrasonic.h"
Ultrasonic ultrasonic(2, 4);
float distance;


void callback(char* subscribetopic, byte* payload, unsigned int payloadLength);

//-------credentials of IBM Accounts------

#define ORG "z0daqf"//IBM ORGANITION ID
#define DEVICE_TYPE "abcd"//Device type mentioned in ibm watson IOT Platform
#define DEVICE_ID "1234" //Device ID mentioned in ibm watson IOT Platform
#define TOKEN "12345678"     //Token
String data3;
//float h, t;


//-------- Customise the above values --------
char server[] = ORG ".messaging.internetofthings.ibmcloud.com";// Server Name
char publishTopic[] = "iot-2/evt/Data/fmt/json";// topic name and type of event
perform and format in which data to be send
char subscribetopic[] = "iot-2/cmd/test/fmt/String";// cmd  REPRESENT command
type AND COMMAND IS TEST OF FORMAT STRING
char authMethod[] = "use-token-auth";// authentication method
char token[] = TOKEN;
char clientId[] = "d:" ORG ":" DEVICE_TYPE ":" DEVICE_ID;//client id




//-----------------------------------------
WiFiClient wifiClient; // creating the instance for wificlient
```

```
PubSubClient client(server, 1883, callback ,wifiClient); //calling the predefined
client id by passing parameter like server id,portand wificredential
void setup()// configureing the ESP32
{
  Serial.begin(115200);


  delay(10);
  Serial.println();
  wificonnect();
  mqttconnect();
}

void loop()// Recursive Function
{

  distance = ultrasonic.read(CM);

  Serial.print("Distance in CM: ");
  Serial.println(distance);
  delay(1000);

  PublishData(distance);
  delay(1000);
  if (!client.loop()) {
    mqttconnect();
  }
}



/*.....................................retrieving to
Cloud...............................*/

void PublishData(float distance) {
  mqttconnect();//function call for connecting to ibm
  /*
     creating the String in in form JSon to update the data to ibm cloud
  */
  String payload = "{\"distance\":";
  payload += distance;

  payload += "}";
```

```
  Serial.print("Sending payload: ");
  Serial.println(payload);


  if (client.publish(publishTopic, (char*) payload.c_str())) {
    Serial.println("Publish ok");// if it sucessfully upload data on the cloud
then it will print publish ok in Serial monitor or else it will print publish
failed
  } else {
    Serial.println("Publish failed");
  }

}
void mqttconnect() {
  if (!client.connected()) {
    Serial.print("Reconnecting client to ");
    Serial.println(server);
    while (!!!client.connect(clientId, authMethod, token)) {
      Serial.print(".");
      delay(500);
    }

     initManagedDevice();
     Serial.println();
  }
}
void wificonnect() //function defination for wificonnect
{
  Serial.println();
  Serial.print("Connecting to ");

  WiFi.begin("Wokwi-GUEST", "", 6);//passing the wifi credentials to establish
the connection
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
  Serial.println("WiFi connected");
  Serial.println("IP address: ");
  Serial.println(WiFi.localIP());
}

void initManagedDevice() {
  if (client.subscribe(subscribetopic)) {
```

```
    Serial.println((subscribetopic));
    Serial.println("subscribe to cmd OK");
  } else {
    Serial.println("subscribe to cmd FAILED");
  }
}

void callback(char* subscribetopic, byte* payload, unsigned int payloadLength)
{

  Serial.print("callback invoked for topic: ");
  Serial.println(subscribetopic);

  for (int i = 0; i < payloadLength; i++) {
    //Serial.print((char)payload[i]);
    data3 += (char)payload[i];
  }

  Serial.println("data: "+ data3);

data3="";


}
```

5.1 Feature 1:

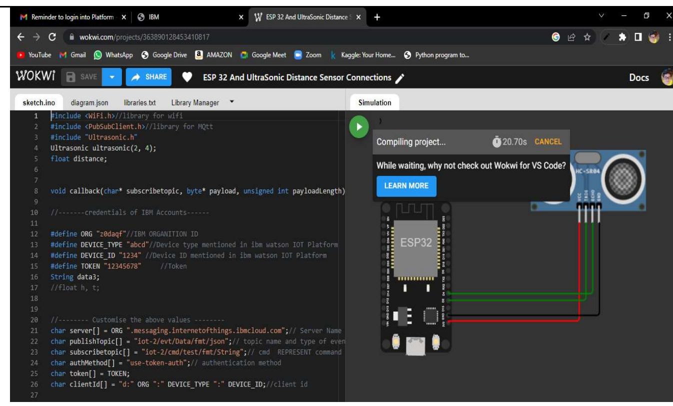
Trash Can Monitoring: Each trash can is equipped with sensors to detect the fill level of the bin in real-time. This data can be used to optimize collection routes and schedules, ensuring that waste is collected only when necessary, reducing unnecessary pickups, and optimizing resource allocation.

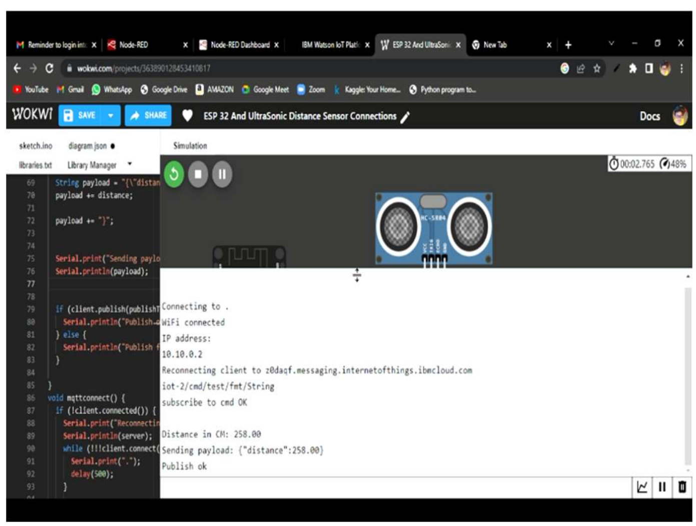
5.2 Feature 2:

Fill Level Notifications: The smart system sends notifications to waste management personnel when the trash cans reach a certain fill level threshold. This feature helps them plan collection routes effectively and ensures timely waste disposal, minimizing overflow and littering.

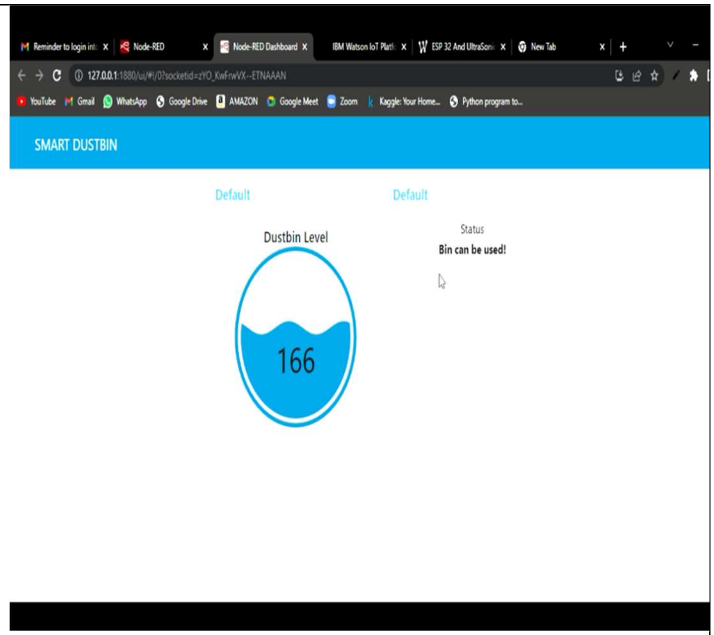
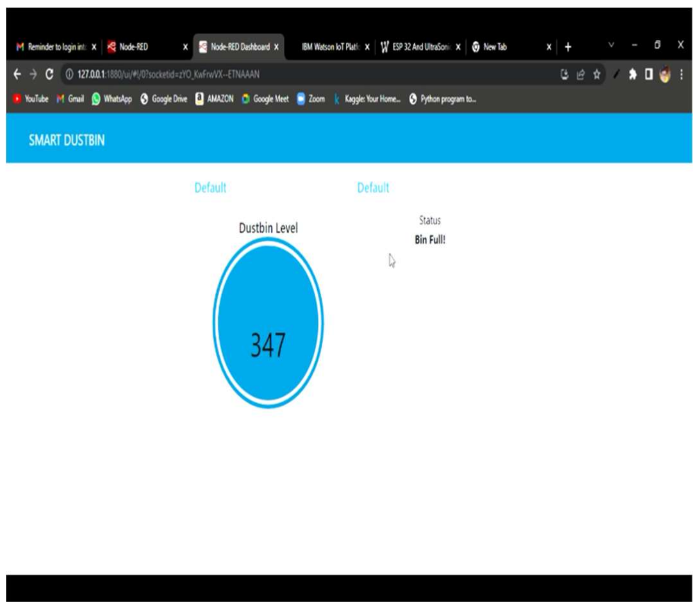
6. RESULTS

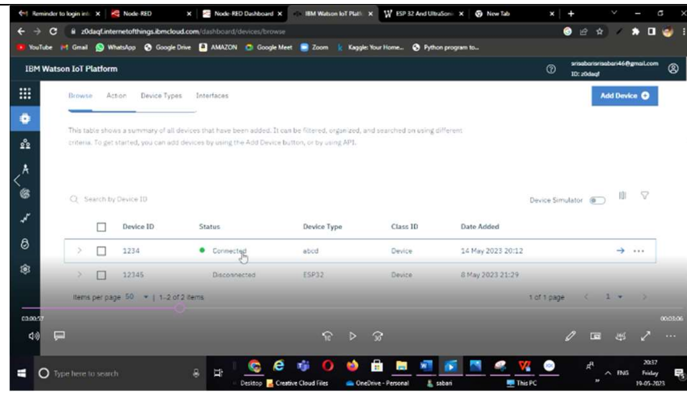
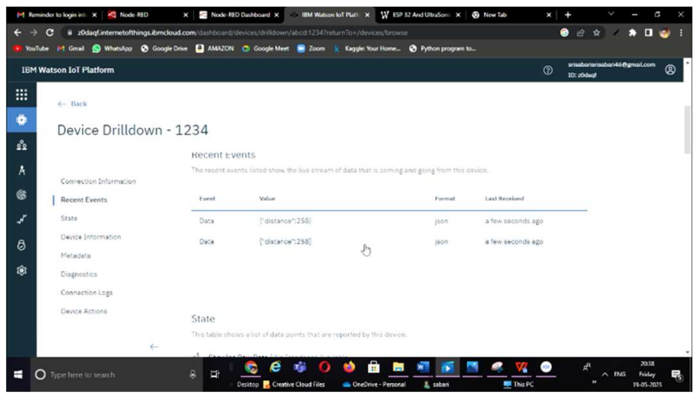
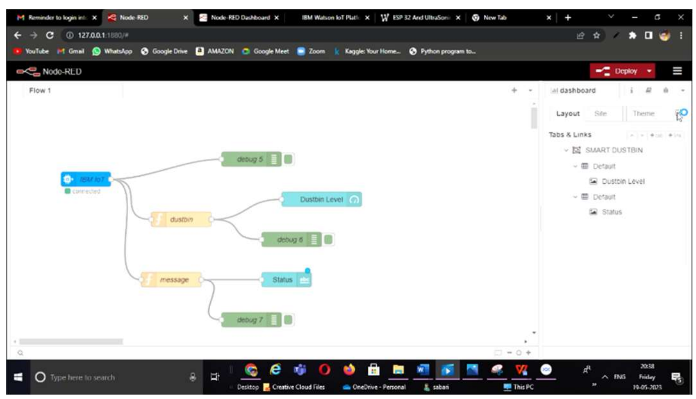
6.1 Performance Metrics:

<table>
<tr><th>Parameter</th><th>Values</th><th>Screenshot</th></tr>
<tr><td rowspan="2">Metrics</td><td>Wokwi Execution time</td><td>


</td></tr>
<tr><td>Wokwi Output</td><td>


</td></tr>
</table>

	Output	
	Output	

	IBM Watson cloud Node red	  

7. ADVANTAGES & DISADVANTAGES

Advantages:

Efficient Resource Management: Real-time monitoring of trash can fill levels allows for optimized waste collection routes and schedules, leading to more efficient resource allocation and cost savings.

Improved Service Quality: Timely collection of waste prevents overflowing bins, reduces littering, and enhances the cleanliness and appearance of the city, improving the overall quality of service for residents.

Environmental Sustainability: Smart waste management systems promote proper waste segregation and recycling, leading to reduced landfill usage, increased recycling rates, and a positive environmental impact.

Disadvantages:

Initial Investment Cost: Implementing a smart waste management system requires an initial investment in infrastructure, technology, and equipment. This can be a significant upfront cost for cities or municipalities.

Maintenance and Upkeep: Smart waste management systems involve the use of sensors, GPS devices, and other technology, which may require regular maintenance and upkeep. This can add to the operational costs and require skilled personnel for maintenance tasks.

Technological Dependencies: Smart systems rely on technology such as sensors and communication networks. Any disruptions in these systems, such as power outages or network failures, can impact the functionality of the waste management system.

8.Conclusion

In conclusion, a smart city waste management system with trash cans offers numerous advantages for efficient and sustainable waste disposal. The system's real-time monitoring of fill levels enables optimized collection routes and resource allocation, leading to cost savings and improved service quality. By promoting proper waste segregation and recycling, the system contributes to environmental sustainability and reduced landfill usage. Additionally, the optimized collection routes help minimize carbon emissions, reducing the city's carbon footprint and creating a greener environment. Data-driven decision making and insights derived from the system's data facilitate continuous improvement and informed planning for waste management strategies. While there may be initial investment costs, maintenance requirements, and privacy considerations, these can be effectively managed with proper planning, user education, and addressing equity and accessibility concerns. Overall, a smart city waste management system with trash cans is a valuable investment that enhances operational efficiency, environmental sustainability, and the overall quality of life for residents in a smart city context.in segments of the population.

9. FUTURE SCOPE

As the Internet of Things (IoT) continues to evolve, there will be opportunities to integrate more sensors and devices into the waste management system. This could include smart bins with advanced sensors for detecting specific types of waste, temperature sensors for identifying potential hazardous materials, or even AI-powered cameras for identifying illegal dumping activities. The integration of big data analytics can further enhance the system's predictive capabilities, allowing for better waste management planning and decision-making. he smart waste management system can collaborate with advanced waste treatment facilities and recycling centers. This collaboration can leverage technologies such as anaerobic digestion, composting, and advanced recycling techniques to further reduce waste generation and maximize resource recovery. Integration with these facilities can facilitate a closed-loop system where waste is effectively converted into valuable resources.

Overall, the future scope of a smart city waste management system project is promising, with potential advancements in IoT, AI, waste treatment technologies, citizen engagement, and integration with other smart city initiatives.

10.Appendix

In this appendix, we provide additional information and supporting materials related to the implementation of a smart city waste management system with trash cans.

System Architecture: A visual representation of the system's architecture, including the integration of sensors, communication networks, data processing, and user interfaces.

Data Flow Diagram: A diagram illustrating the flow of data within the smart waste management system, showcasing how data is collected from trash cans, processed, and used for decision-making and reporting.

Sensor Specifications: Detailed specifications of the sensors used in the trash cans, including the type of sensors, their accuracy, range, and power requirements.

Communication Protocols: Information about the communication protocols used to transmit data from the trash cans to the central system, ensuring secure and reliable data transfer.

User Interface Design: Screenshots or wireframes of the user interfaces, such as mobile applications or web portals, displaying the features and functionalities available to residents, waste management personnel, and administrators.