SMART CITY WASTE MANAGEMENT SYSTEM WITH CONNECTED TRASH CANS

A PROJECT REPORT

TEAM ID: NM2023TMID13925

Submitted by

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BONAFIDE CERTIFICATE

Certified that this project report **"SMART CITY WASTE MANAGEMENT SYSTEM WITH CONNECTED TRASH CANS"** is the bonafide work of **"SARATH KRISHNAN R (732520106034), DARMARAJ D (732520106005), THANIKACHALAM G (732520106328), VINOTHKUMAR S (732520106329)"** who carried out the project work under my supervision.

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INDEX

1. INTRODUCTION

1.1 PROJECT REVIEW:

As urban populations continue to grow rapidly, cities face mounting challenges in managing their waste efficiently. Traditional waste management methods often fall short in meeting the demands of a rapidly urbanizing world, leading to issues like overflowing trash bins, improper waste disposal, and inefficient collection processes. However, with the advent of smart technologies, cities are now turning to innovative solutions to tackle these waste management challenges.

One such solution is the implementation of smart city trash can systems. These systems leverage cutting-edge technologies to transform the way waste is handled, improving efficiency, reducing environmental impact, and enhancing the overall cleanliness of cities. By integrating smart features into traditional trash cans, municipalities can create a robust waste management infrastructure that aligns with the goals of sustainability, resource optimization, and enhanced quality of life.

1.2 PURPOSE

The purpose of a smart city waste management system using trash cans is to improve the efficiency and effectiveness of waste collection and disposal processes within a city. By incorporating smart technology into trash cans, cities can achieve the following objectives:

1. Optimization of waste collection: Smart trash cans can be equipped with sensors and monitoring devices that detect the fill level of the bins in real time. This data can be transmitted to a central management system, allowing waste collection teams to prioritize their routes based on the level of waste in each bin. This optimization reduces unnecessary trips to empty partially filled bins and ensures that bins are emptied at the right time, avoiding overflow and potential littering.

2. Cost reduction: Efficient waste collection translates into cost savings for the city. By using data-driven insights from smart trash cans, municipalities can streamline their waste management operations, reducing fuel consumption, labor hours, and maintenance costs associated with unnecessary or untimely bin collection. Additionally, smart systems can help identify bins that require urgent

attention, such as those with a malfunction or damage, reducing the overall maintenance expenses.

3. Environmental sustainability: Effective waste management contributes to environmental sustainability by minimizing the negative impact of waste on the environment. Smart trash cans can facilitate recycling efforts by including separate compartments for different types of waste, such as recyclables, organic waste, and general waste. This encourages citizens to properly sort their waste, making recycling and composting easier and more accessible. Furthermore, by optimizing waste collection routes, smart systems reduce greenhouse gas emissions associated with unnecessary vehicle trips.

4. Real-time monitoring and alerts: Smart trash cans can provide real-time monitoring and alerts, notifying waste management authorities when bins are nearing capacity or require maintenance. This proactive approach allows for timely intervention, preventing overflowing bins and reducing the likelihood of littering or unsightly conditions. Alerts can also help identify unusual waste patterns or illegal dumping, enabling authorities to take appropriate actions promptly.

5. Data-driven decision-making: By collecting and analyzing data from smart trash cans, city authorities can gain valuable insights into waste generation patterns, peak times, and overall waste management performance. This data can inform decision-making processes, allowing for better resource allocation, future planning, and policy development to improve waste management strategies.

Overall, the purpose of a smart city waste management system using trash cans is to enhance the efficiency, sustainability, and overall effectiveness of waste collection and disposal processes, leading to cleaner, greener, and more livable cities.

2. IDEATION & PROPOSED SOLUTION

2.1 PROBLEM STATEMENT DEFINITION

Designing and implementing a smart city waste management system using trash cans to address the following challenges:

1. Inefficient Waste Collection: The current waste management system lacks efficiency, leading to irregular waste collection and overflowing trash cans. This results in unsightly and unhygienic conditions in public spaces, posing health and environmental risks.

2. Resource Wastage: The existing waste management system often relies on scheduled pickups regardless of the actual fill level of trash cans. This inefficient process wastes valuable resources such as fuel and manpower by collecting halfempty bins or neglecting overflowing ones.

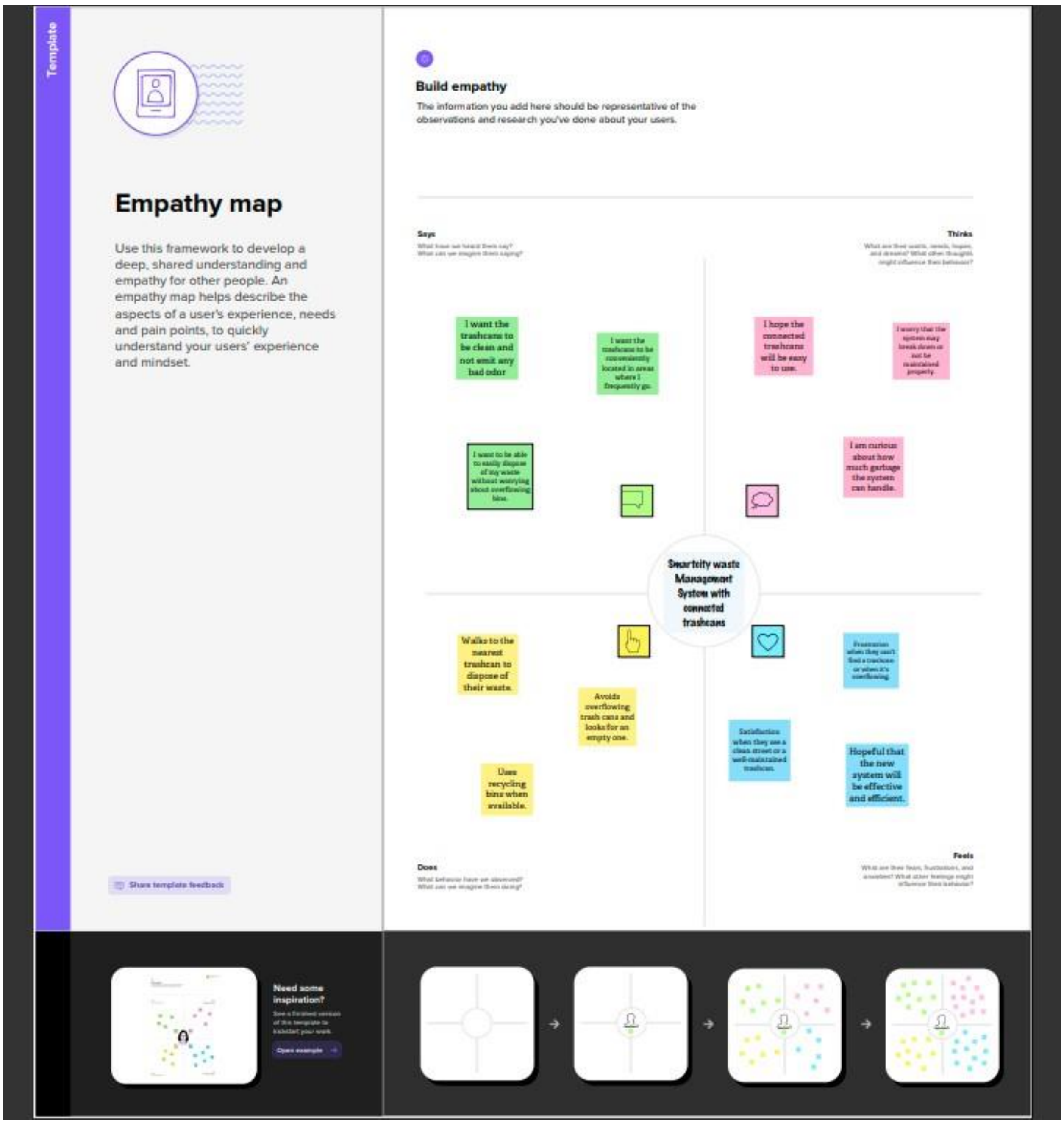
3. Lack of Real-time Monitoring: There is a lack of real-time monitoring of trash can fill levels, making it difficult for waste management authorities to optimize collection routes and schedules. This results in unnecessary trips and delays in waste collection, hampering the overall efficiency of the system.

4. Inadequate Data-driven Decision Making: The absence of accurate and up-todate data on waste generation patterns, collection frequencies, and routes makes it challenging for authorities to make informed decisions about resource allocation, route optimization, and future planning.

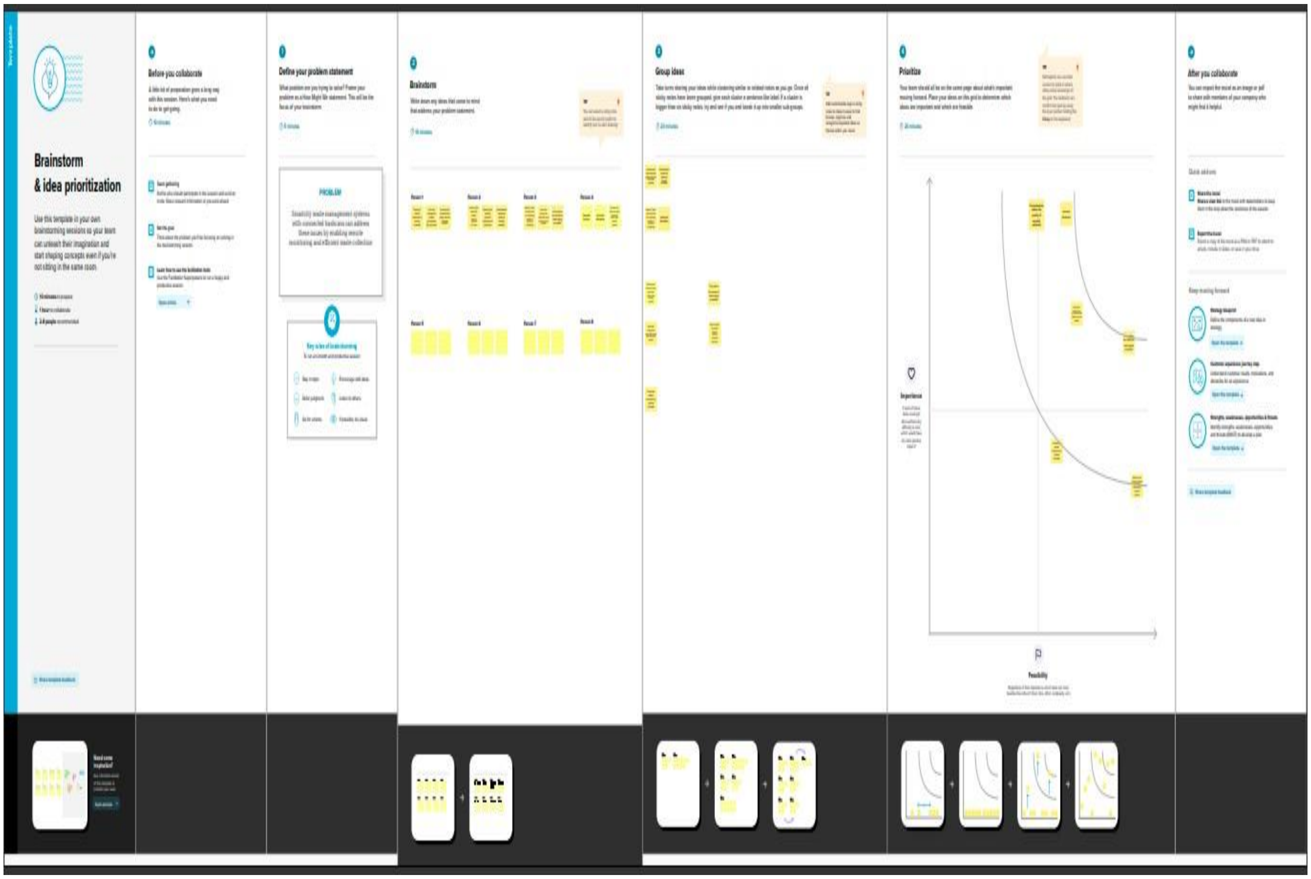
5. Limited Public Engagement: The current waste management system lacks public engagement, which hampers the overall effectiveness of waste reduction efforts. Citizens are unaware of their individual waste generation and lack incentives to reduce, recycle, or properly dispose of waste.

To address these challenges, a smart city waste management system utilizing trash cans can be developed. This system should incorporate real-time monitoring, data analytics, and citizen engagement to optimize waste collection routes, reduce resource wastage, and promote sustainable waste management practices.

2.2 EMPATHY MAP CANVAS:



2.3 IDEATION & BRAIN STORMING:



2.4 PROPOSED SOLUTION

A proposed solution for a smart city waste management system with connected trash cans involves integrating IoT (Internet of Things) technology, data analytics, and automation to improve waste collection efficiency and sustainability. Here are the key components and features of this system:

1. Smart Trash Cans: Replace traditional trash cans with smart trash cans equipped with various sensors and communication modules. These cans can monitor their fill levels, compaction ratios, and detect odors or hazardous materials.

2. IoT Connectivity: Connect all the smart trash cans to a centralized network using wireless technologies like Wi-Fi, Bluetooth, or LoRaWAN. This enables real-time data collection and communication between the trash cans and the waste management system.

3. Fill Level Monitoring: Utilize ultrasonic sensors or weight sensors inside the smart trash cans to measure the fill levels accurately. This data helps optimize waste collection routes, reducing unnecessary pickups and avoiding overflowing bins.

4. Predictive Analytics: Apply data analytics algorithms to predict future waste generation patterns based on historical data, seasonal variations, and other factors. This forecasting helps optimize waste collection schedules and resource allocation.

5. Route Optimization: Utilize advanced algorithms and machine learning techniques to optimize waste collection routes based on real-time data, traffic conditions, and predicted fill levels. This minimizes fuel consumption, reduces carbon emissions, and improves overall operational efficiency.

6. Intelligent Alerts and Notifications: Implement an alert system to notify waste collection teams when a trash can reaches its capacity or requires maintenance.

This proactive approach ensures timely pickups and prevents overflow or unsightly waste accumulation.

7. Smart City Dashboard: Develop a centralized dashboard that displays real-time data and insights about the waste management system. The dashboard can include information such as fill levels, collection schedules, route optimizations, and performance metrics to monitor and manage the system effectively.

8. Integration with Waste Processing Facilities: Connect the waste management system with recycling centers, composting facilities, and waste-to-energy plants. This integration facilitates efficient waste segregation, recycling, and disposal, promoting a circular economy and reducing environmental impact.

9. Public Engagement and Incentives: Implement citizen engagement initiatives, such as mobile apps or web portals, to encourage responsible waste disposal practices. Provide rewards or incentives for recycling or using the smart trash cans, fostering a sense of community participation in waste management efforts.

10. Data Security and Privacy: Implement robust security measures to protect the data transmitted by the smart trash cans and ensure the privacy of citizens. This includes encryption, authentication protocols, and adherence to data protection regulations.

By implementing a smart city waste management system with connected trash cans, cities can optimize waste collection operations, reduce costs, minimize environmental impact, and create cleaner and more sustainable urban environments.

3. REQUIREMENT ANALYSIS :

3.1 FUNCTIONAL REQUIREMENTS:

FR-NO	FUNCTIONAL REQUIREMENTS	SUB REQUIREMENT
FR-1	Real-time monitoring	The system should be capable of monitoring the fill level of the connected trash cans in realtime. This data should be available to waste management authorities to help them plan their collection routes and schedules.
FR-2	Automatic Notification	The system should send automatic notifications to the waste management authorities when the connected trash cans are almost full. This will enable the authorities to schedule collections before the trash cans overflow.
FR-3	Environmental Sensors	The system should be equipped with environmental sensors that can measure temperature, humidity, and air quality around the trash cans. This data can be used to analyse the impact of waste on the environment and to identify potential health hazards
FR-4	Mobile App Integration	The system should have a mobile app that residents can use to report overflowing trash cans or to request trash collection. This will help to improve communication between residents and waste management authorities.

3.2 NON-FUNCTIONAL REQUIREMENTS:

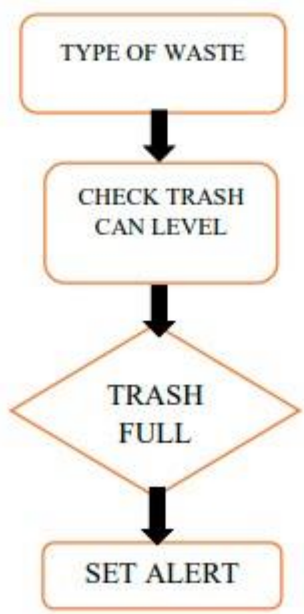
FR NO.	NON-FUNCTIONAL REQUIREMENT	DESCRIPTION
NFR-1	**Usability**	The system should be easy to use and intuitive for both city officials and citizens.
NFR-2	**Security**	The system should be secure to protect the data collected from the trash cans and prevent unauthorized access or tampering
NFR-3	**Reliability**	The system should be highly reliable to ensure that data is always available and the trash cans are functioning correctly
NFR-4	**Performance**	The system should be able to process and analyze the data collected from the trash cans in real-time to provide timely insights.
NFR-5	**Availability**	The system should be available 24/7 to ensure that the trash cans are always connected and functioning.
NFR-6	**Scalability**	The system should be able to handle an increasing amount of data as the number of connected trash cans and users grow.

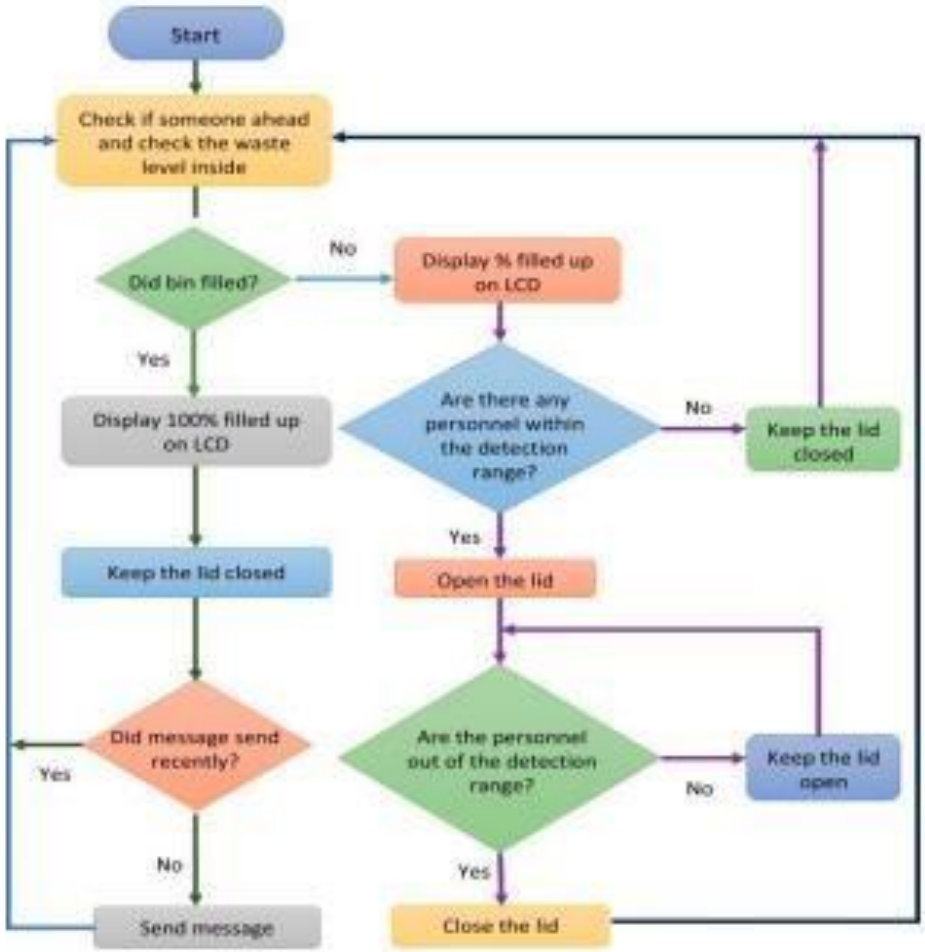
4. PROJECT DESIGN:

4.1 DATA FLOW DIAGRAMS

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.

EXAMPLE:(Simplified)




Start
Check if someone ahead and check the waste level inside
Did bin filled?
No
Display % filled up on LCD
Yes
Display 100% filled up on LCD
Are there any personnel within the detection range?
No
Keep the lid closed
Yes
Keep the lid closed
Open the lid
Did message send recently?
Yes
Are the personnel out of the detection range?
Keep the lid open
No
No
Yes
Send message
Close the lid

4.2 SOLUTION & TECHNICAL ARCHITECTURE :

A smart city waste management system with connected trash cans involves integrating various technologies and components to efficiently collect and manage waste. Here's a solution and technical architecture for such a system:

1. Connected Trash Cans:

   - Install IoT-enabled trash cans equipped with sensors to detect fill levels and communicate with a central management system.
   - The trash cans should have wireless connectivity capabilities such as Wi-Fi, LoRaWAN, or NB-IoT to transmit data.

2. Central Management System:

   - Develop a centralized software system to monitor and manage the connected trash cans.
   - Use cloud-based infrastructure to handle data storage, processing, and analysis.
   - Implement a user-friendly dashboard to visualize the data and enable administrators to make informed decisions.

3. Fill Level Monitoring:

   - Utilize ultrasonic or infrared sensors in the trash cans to measure the fill levels accurately.
   - The sensors should regularly send fill level data to the central management system.
   - Apply data analytics algorithms to predict when a trash can is reaching its capacity.

4. Route Optimization:

- Analyze the fill level data and historical patterns to optimize waste collection routes.
- Implement algorithms that determine the most efficient routes for waste collection trucks based on fill levels, traffic conditions, and other factors.
- Integrate with GPS systems on waste collection vehicles for real-time tracking and route guidance.

5. Smart Bin Allocation:

- Determine optimal locations for trash cans based on population density, foot traffic, and historical data.
- Use data analytics and machine learning algorithms to optimize the number and placement of trash cans in different areas.
- Adjust the distribution of trash cans based on changing needs and patterns.

6. Mobile Applications:

- Develop mobile apps for citizens to report issues such as overflowing trash cans or illegal dumping.
- Enable citizens to receive notifications about waste collection schedules, recycling initiatives, and other relevant information.
- Provide a feedback mechanism for citizens to interact with the waste management system.

7. Data Security and Privacy:

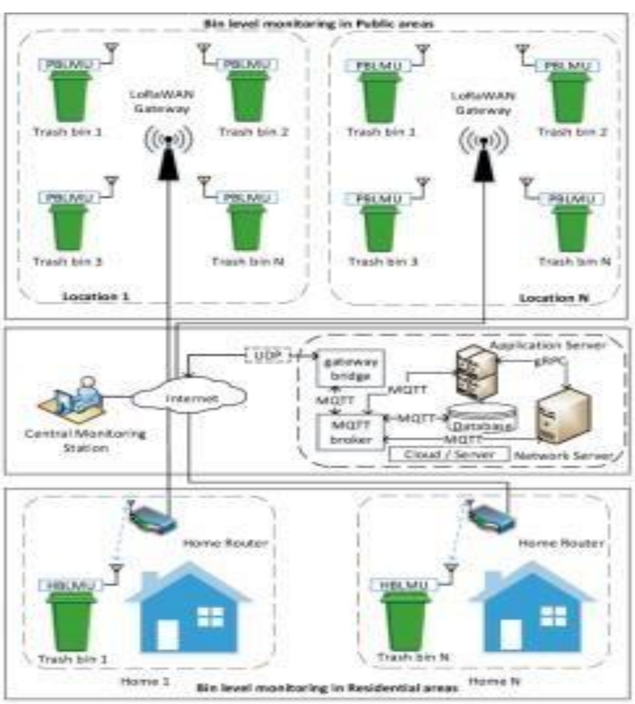
- Implement robust security measures to protect the data transmitted by the connected trash cans and stored in the central system.
- Use encryption techniques to secure data in transit and at rest.
- Ensure compliance with privacy regulations and obtain necessary consent for data collection and usage.

8. Integration with Waste Processing Facilities:

- Connect the waste management system with waste processing facilities to optimize the disposal and recycling process.
- Implement data exchange protocols to transmit information about waste composition, quantities, and recycling requirements.
- Enable automated communication between the waste management system and processing facilities for efficient waste handling.

By implementing this solution and technical architecture, a smart city waste management system with connected trash cans can improve waste collection efficiency, reduce costs, and enhance overall cleanliness and sustainability within the city.

Technical Architecture: The Deliverable shall include the architectural diagram as below and the information as per the table1 & table 2



Guidelines:

Use sensors and IoT technology to monitor trash can fill levels in real-time, so that waste collection can be scheduled based on actual needs, rather than fixed schedules.Implement a centralized waste management platform that can track and analyze data from con Use smart waste sorting technology to separate recyclables and organic waste from general waste, which can then be processed and reused.nected trash cans, allowing for more efficient routing and better decisionmaking. Encourage citizen participation by providing real-time feedback on their waste generation habits, and offering incentives for recycling and proper waste disposal. . Establish partnerships with local businesses and organizations to promote waste reduction and recycling initiatives, and to share data and resources to improve overall waste management efficiency.

Implementing a smart city waste management system with connected trash cans involves several key guidelines to ensure its effectiveness. Here are some guidelines to consider:

1. IoT-enabled Trash Cans: Equip trash cans with IoT (Internet of Things) technology to make them "smart" and connected. Each trash can should be equipped with sensors to monitor fill level, weight, and even odor. These sensors should be capable of transmitting data wirelessly to a central management system.

2. Real-time Monitoring: Implement a real-time monitoring system to track the fill levels of the connected trash cans. This allows waste management authorities to optimize collection routes, reduce unnecessary pickups, and prevent overflow situations. The data collected can also provide insights for planning and resource allocation.

3. Data Analytics and Predictive Modeling: Utilize data analytics and predictive modeling techniques to analyze the collected data. By studying historical patterns, you can predict future fill levels and optimize waste collection schedules. This helps in reducing operational costs and improving overall efficiency.

4. Efficient Routing and Collection: Leverage the collected data to optimize waste collection routes and schedules. By identifying trash cans that require immediate attention or are close to capacity, you can plan efficient routes and ensure timely

collections. This reduces fuel consumption, minimizes collection truck emissions, and improves the overall effectiveness of waste management.

5. Smart Alerts and Notifications: Implement an alert system to notify waste management personnel when a trash can is reaching its capacity or needs immediate attention (e.g., in case of odor or malfunction). Alerts can be sent through a mobile application, email, or other communication channels to ensure prompt action.

6. Public Engagement: Involve the public in the waste management process by providing them with information and feedback mechanisms. This can include smartphone apps or web portals that allow residents to report overflowing or damaged trash cans, schedule bulk pickups, or access educational resources on proper waste disposal practices. Engaging the public creates a sense of ownership and encourages responsible waste management behavior.

7. Sustainability and Recycling: Encourage waste separation and recycling by incorporating separate compartments within the connected trash cans. This facilitates the collection of recyclable materials and promotes sustainable waste management practices. Additionally, provide information to the public about recycling facilities, proper waste sorting techniques, and the environmental benefits of recycling.

8. Integration with Existing Systems: Ensure compatibility and integration with existing waste management systems, such as landfill management, recycling centers, and waste processing facilities. This facilitates seamless data sharing, resource optimization, and streamlines the entire waste management workflow.

9. Security and Privacy: Implement robust security measures to protect the collected data and the connected infrastructure from cyber threats. Additionally, comply with privacy regulations and ensure that personal data is handled securely and used only for the intended purpose.

10. Scalability and Future-proofing: Design the smart waste management system with scalability in mind to accommodate future expansion and increased data volumes. Choose flexible and adaptable technologies to future-proof the system against technological advancements and evolving waste management needs.

s.no	Component	Description	Technology
1.	User Interface	How user interacts with application e.g. Web UI, Mobile App, Chat bot etc.	HTML, CSS, JavaScript / Angular Js / React Js etc
2.	Application Logic-1	Logic for a process in the application	Java / Python
3.	Application Logic-2	Logic for a process in the application	IBM Watson STT service
4.	Application Logic-3	Logic for a process in the application	IBM Watson Assistant
5.	Database	Data Type, Configurations etc.	5. Database Data Type, Configurations etc. M
6.	Cloud Database	Database Service on Cloud	IBM DB2, IBM Cloudant etc.
7.	File Storage	File storage requirements	IBM Block Storage or Other Storage Service or Local File system
8.	External API-1	Purpose of External API used in the application	IBM Weather API, etc.
9.	External API-2	Purpose of External API used in the application	Aadhar API, etc.
10.	MQTT	MQTT could be used to communicate through protocol. .	Object Recognition Model, etc.
11.	Infrastructure (Server / Cloud)	Application Deployment on Local System / Cloud Local Server Configuration: Cloud Server Configuration :	Local, Cloud Foundry, Kubernetes, etc.

Table-2: Application Characteristics:

s.no	Characteristics	Description	Technology
1.	Open-Source Frameworks	List the open-source frameworks used	Technology of Open source framework
2.	Security Implementations	List all the security / access controls implemented, use of firewalls etc	e.g. SHA-256, Encryptions, IAM Controls, OWASP etc.
3.	Scalable Architecture	Justify the scalability of architecture (3 – tier, Microservices)	Technology used
4.	Availability	Justify the availability of application (e.g. use of load balancers, distributed servers etc.)	Technology used
5.	Performance	Design consideration for the performance of the application (number of requests per sec, use of Cache, use of CDN's) etc.	Technology used

4.3 USER STORIES

1. As a city resident, I want to receive real-time updates on the status of nearby trash cans, so I know which ones are full and which ones are available for use.

2. As a waste collection worker, I want to be notified when a trash can is reaching its capacity, so I can plan my route efficiently and empty the bins before they overflow.

3. As a city administrator, I want to monitor the overall waste generation patterns in different areas of the city, so I can allocate resources accordingly and optimize waste collection routes.

4. As a citizen concerned about the environment, I want to receive notifications and reminders about recycling initiatives and events happening in my area, so I can actively participate and contribute to sustainable waste management.

5. As a person with disabilities, I want the trash cans to be equipped with sensors that can detect my presence and automatically open the lid, making it easier for me to dispose of my waste.

6. As a tourist visiting the city, I want to easily locate nearby trash cans through a mobile application, ensuring that I can properly dispose of my waste and contribute to maintaining the cleanliness of the city.

7. As a sustainability advocate, I want the smart trash cans to have separate compartments for different types of waste (e.g., recyclables, organic waste), so I can easily sort and dispose of my waste correctly.

8. As a city official responsible for waste management planning, I want to access historical data and analytics on waste generation trends, so I can make informed decisions regarding infrastructure upgrades, waste reduction campaigns, and resource allocation.

9. As a local business owner, I want to be able to schedule waste pickups based on the fill levels of the trash cans near my establishment, ensuring that waste collection is efficient and minimizes disruptions to my business operations.

10. As a parent, I want the smart trash cans to be designed with child safety features, such as tamper-proof lids and sensors that prevent accidental entrapment, to ensure the well-being of my children while they dispose of waste.

These user stories highlight various perspectives and needs of different stakeholders in a smart city waste management system with connected trash cans. They can serve as a starting point for designing and developing such a system.

5.CODING & SOLUTIONING

5.1 FEATURE 1

1. IoT-enabled Trash Cans:

Install IoT devices (such as sensors) on the trash cans to detect the fill-level, temperature, and other relevant data.

Use wireless communication (e.g., Wi-Fi, LoRa, or cellular networks) to connect the trash cans to a central server or cloud platform.

CODE:

```
import time import
random import
requests


# Function to simulate trash can data def
simulate_trash_can():
   trash_level = random.uniform(0, 1)  # Simulating fill-level data (range: 0-1)
temperature = random.uniform(10, 40)  # Simulating temperature data (range:
10-40 degrees Celsius)     return
trash_level, temperature


# Function to send data to the server def
send_data(trash_level, temperature):
   api_endpoint = "http://your_server_endpoint/api/trashcan"  # Replace with your
server's API endpoint     data = {
      "trash_level": trash_level,
      "temperature": temperature
```

```
    }
    response = requests.post(api_endpoint, json=data)
if response.status_code == 200:         print("Data
sent successfully!")     else:
        print("Failed to send data.")

# Main program loop while
True:
    trash_level, temperature = simulate_trash_can()
send_data(trash_level, temperature)
    time.sleep(60)  # Sleep for 1 minute before sending the next data
```

5.2 FEATURE 2

2.Fill-Level Monitoring:

Implement algorithms to analyze the fill-level data and determine whether a trash can needs emptying.

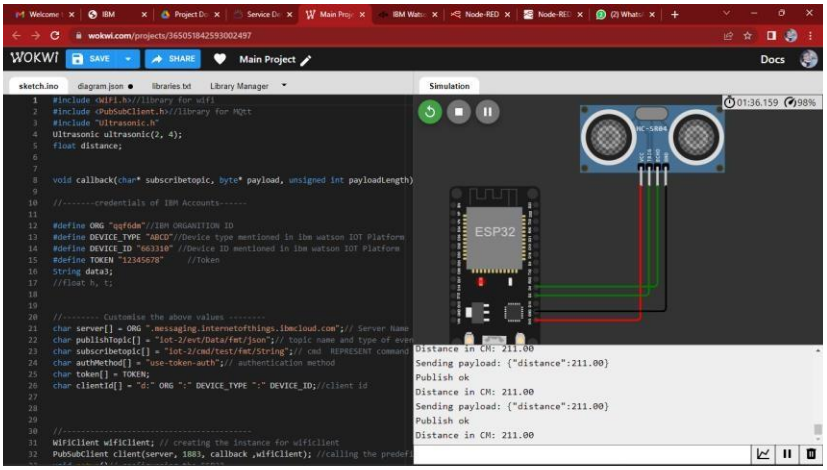
Notify the waste management team when a trash can reaches a certain threshold**.**

CODE:

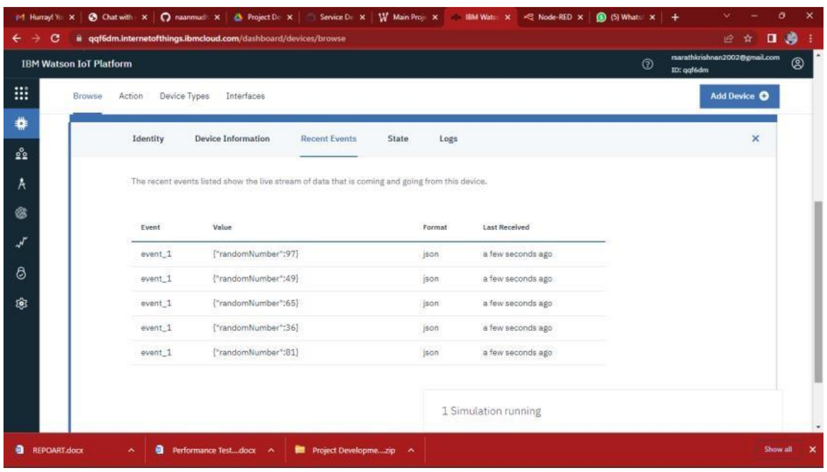
```
import random

# Simulating fill level data def
simulate_fill_level():
    # Generate a random fill level value between 0 and 100
fill_level = random.randint(0, 100)     return fill_level
```

```
# Function to check fill level and notify if it exceeds a threshold def
check_fill_level(trash_can_id, threshold):
    fill_level = simulate_fill_level()
if fill_level > threshold:
        notify_waste_management_team(trash_can_id, fill_level)

# Function to notify the waste management team def
notify_waste_management_team(trash_can_id, fill_level):
    message = f"Trash can {trash_can_id} is {fill_level}% full. Please empty it."
# Implement your notification mechanism here (e.g., sending an email or SMS)
print(message)


# Main function to monitor fill levels of connected trash cans def
monitor_fill_levels():
    trash_cans = ['Trash Can 1', 'Trash Can 2', 'Trash Can 3']  # Replace with actual
trash can IDs     threshold = 80  # Adjust the threshold as per your requirements

    for trash_can_id in trash_cans:
        check_fill_level(trash_can_id, threshold)

# Run the fill level monitoring function
monitor_fill_levels()
```

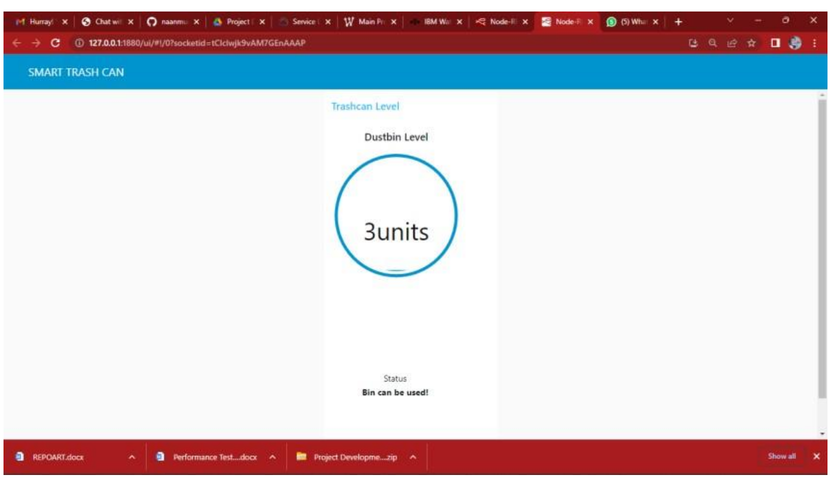
6. RESULTS:



WOKWI
SAVE
SHARE
Main Project
Docs
sketch.ino
diagram.json
libraries.txt
Library Manager
Simulation
ESP32
Distance in CM: 211.00
Sending payload: {"distance":211.00}
Publish ok
Distance in CM: 211.00
Sending payload: {"distance":211.00}
Publish ok
Distance in CM: 211.00



IBM Watson IoT Platform
Browse
Action
Device Types
Interfaces
Add Device
Identity
Device Information
Recent Events
State
Logs
The recent events listed show the live stream of data that is coming and going from this device.
Event
Value
Format
Last Received
event_1
{"randomNumber":97}
json
a few seconds ago
event_1
{"randomNumber":49}
json
a few seconds ago
event_1
{"randomNumber":65}
json
a few seconds ago
event_1
{"randomNumber":36}
json
a few seconds ago
event_1
{"randomNumber":81}
json
a few seconds ago
1 Simulation running



SMART TRASH CAN
Trashcan Level
Dustbin Level
3units
Status
Bin can be used!

6.1 PERFORMANCE METRICS:

Performance metrics for a smart city waste management system with connected trash cans can vary depending on the specific goals and objectives of the system. However, here are some common performance metrics that can be considered:

1. Fill Level Monitoring Accuracy: The accuracy of the system in determining the fill level of trash cans. This metric measures how well the system can accurately detect and report the fill levels of the connected trash cans.

2. Collection Efficiency: The efficiency of the waste collection process based on the data provided by the connected trash cans. This metric evaluates how effectively the system optimizes waste collection routes and schedules based on real-time fill level data, reducing unnecessary collection trips and optimizing resource allocation.

3. Collection Frequency Optimization: The system's ability to optimize the frequency of waste collection based on fill level data. This metric assesses how well the system adjusts collection schedules to ensure that trash cans are emptied at the appropriate times, avoiding overflowing or underutilization.

4. Response Time: The time it takes for the system to detect a full trash can and notify the waste management team. This metric measures the responsiveness of the system in identifying and alerting about trash cans that need immediate attention.

5. Cost Reduction: The cost savings achieved through the implementation of the smart waste management system. This metric evaluates the efficiency gains in terms of reduced fuel consumption, labor costs, and optimized resource allocation.

6. Environmental Impact: The environmental benefits resulting from the smart waste management system. This metric can include reductions in greenhouse gas emissions, improved recycling rates, and overall waste reduction.

7. System Reliability: The reliability and uptime of the smart waste management system. This metric measures the system's ability to consistently operate without interruptions or technical issues.

8. User Satisfaction: The satisfaction level of residents and businesses with the smart waste management system. This metric can be measured through surveys or feedback channels to assess how well the system meets the needs and expectations of the users.

9. Recycling Rate Improvement: The system's impact on increasing the recycling rate in the city. This metric measures the effectiveness of the system in encouraging and facilitating recycling by providing separate recycling bins, educational campaigns, or incentives.

10. Predictive Analytics Accuracy: If the smart waste management system utilizes predictive analytics, the accuracy of the system in predicting future waste generation patterns. This metric evaluates the system's ability to forecast and adapt waste management strategies based on historical data and trends.

It's important to note that the specific metrics and their weights may vary depending on the priorities and objectives of the smart city waste management system implementation.

7. ADVANTAGES & DISADVANTAGES:

ADVANTAGES:

1. Improved Efficiency: Connected trash cans can help optimize waste collection routes by providing real-time data on their fill level. This information can be used to schedule pickups more efficiently, reducing the number of trips and overall fuel consumption.

2. Cost Savings: By optimizing waste collection routes, cities can reduce the number of garbage trucks on the road and save money on fuel and maintenance costs. Additionally, a connected system can help identify areas where waste is being overproduced and can help reduce this waste, further saving money.

3. Better Public Health: Smart waste management systems can reduce the amount of waste that accumulates in public spaces, which can reduce the risk of disease transmission and other public health concerns.

4. Environmentally Friendly: By optimizing waste collection routes and reducing unnecessary pickups, a smart waste management system can also reduce carbon emissions and contribute to a more sustainable environment.

5. Improved Quality of Life: A cleaner and more organized city can improve the quality of life for residents, leading to a more attractive and enjoyable living environment.

Overall, a smart city waste management system with connected trash cans can help improve the efficiency, cost-effectiveness, and environmental sustainability of waste management, while also enhancing public health and quality of life for residents.

DISADVANTAGES:

While smart city waste management systems with connected trash cans offer several benefits, they also have certain disadvantages. Here are some potential disadvantages to consider:

1. Implementation costs: Developing and deploying a smart city waste management system can be expensive. It requires investment in the installation of connected trash cans, sensor networks, data infrastructure, and maintenance. The initial setup and ongoing operational costs may pose financial challenges for some cities, especially those with limited budgets.

2. Privacy concerns: Smart trash cans collect data through sensors and connected devices, which may raise privacy concerns among citizens. The data collected, such as waste patterns or personal information, could potentially be misused or compromised. It is crucial to ensure robust data security and establish transparent policies for data collection, storage, and usage to address these concerns.

3. Technological limitations: The effectiveness of smart city waste management systems relies heavily on the technology supporting them. If the sensors or connectivity infrastructure face technical issues or malfunction, it can lead to inaccurate data collection, disrupted waste management processes, and increased maintenance requirements. Dependence on technology also raises concerns about potential system failures during power outages or other disruptions.

4. Maintenance and upkeep: Connected trash cans require regular maintenance and upkeep. Sensors may need calibration or replacement, and connectivity issues or software glitches may arise over time. Municipalities must have dedicated resources and personnel to address maintenance needs promptly and keep the system running smoothly. Neglecting maintenance can lead to system inefficiencies or failures.

5. Adoption challenges: Implementing a smart city waste management system requires cooperation and participation from both the city administration and its residents. Encouraging citizens to adapt to new waste disposal practices, such as using specific trash cans or separating recyclables, can be challenging. Additionally, not all residents may have access to or be comfortable using the necessary technology, potentially creating inequities in waste management services.

6. Environmental impact: While smart city waste management systems aim to optimize waste collection and reduce inefficiencies, the environmental impact of producing and maintaining the required technology should also be considered. The manufacturing and disposal of sensors, connected devices, and infrastructure components can contribute to electronic waste and carbon emissions if not managed properly.

7. Limited scalability: The implementation of a smart city waste management system may face scalability challenges in large urban areas. Expanding the system to cover the entire city may require significant infrastructure investments and coordination with multiple stakeholders. Scaling up the system without proper planning and resource allocation could lead to fragmented or inefficient waste management practices.

To mitigate these disadvantages, it is essential to conduct thorough cost-benefit analyses, address privacy concerns, invest in reliable and scalable technology, ensure public participation and education, and establish sustainable maintenance and support mechanisms.

8. CONCLUSION

The implementation of a smart city waste management system with connected trash cans offers numerous benefits and is an important step towards creating sustainable and efficient cities. After considering the various aspects of such a system, we can draw the following conclusions:

1. Improved Efficiency: Connected trash cans allow for real-time monitoring of waste levels, enabling more efficient collection and disposal processes. Waste management personnel can optimize their routes based on the fill-level data, reducing unnecessary trips and saving time and resources.

2. Cost Savings: By optimizing collection routes and reducing the frequency of emptying partially filled bins, smart waste management systems can lead to significant cost savings for municipalities. These savings can be reinvested in other areas of city development and maintenance.

3. Reduced Environmental Impact: The efficient waste collection and disposal processes facilitated by connected trash cans contribute to a reduced environmental impact. By minimizing unnecessary vehicle emissions and ensuring timely waste removal, the system helps decrease pollution and promotes cleaner air quality.

4. Enhanced Hygiene and Aesthetics: Connected trash cans can improve the overall cleanliness and appearance of a city. Waste bins that are not overflowing and well-maintained contribute to a cleaner and more aesthetically pleasing urban environment. This, in turn, can positively impact the quality of life for residents and visitors.

5. Data-Driven Decision Making: Smart waste management systems generate valuable data on waste generation patterns, fill-level trends, and collection efficiency. This data can be analyzed to gain insights into the waste management process and guide informed decision making for future improvements and resource allocation.

6. Citizen Engagement and Awareness: Connected trash cans provide an opportunity for citizen engagement by incorporating features such as digital displays or mobile applications. These interfaces can educate and encourage individuals to adopt sustainable waste disposal practices, promoting a sense of responsibility and environmental consciousness within the community.

9. FUTURE SCOPE

The future scope of a smart city waste management system with connected trash cans is quite promising. As technology continues to advance, there are several potential developments and benefits that can be expected:

1. Efficient waste collection: Connected trash cans can transmit real-time data on their fill levels, allowing waste management authorities to optimize their collection routes. This reduces unnecessary trips and improves the efficiency of waste collection, leading to cost savings and reduced carbon emissions.

2. Waste segregation and recycling: Smart trash cans can incorporate sensors or cameras to identify and sort different types of waste automatically. This technology can enhance waste segregation efforts, making recycling processes more effective. It can also provide feedback to users, encouraging them to correctly dispose of recyclable materials.

3. Monitoring and maintenance: Connected trash cans can monitor their own functionality, detecting issues such as damage or overflowing. They can automatically alert maintenance teams, ensuring timely repairs and efficient upkeep of the waste management infrastructure.

4. Data-driven decision making: The collection of real-time data from connected trash cans provides valuable insights for waste management authorities. Analyzing this data can help in identifying patterns, optimizing waste collection schedules, predicting future waste generation, and making informed decisions to improve overall waste management strategies.

5. Environmental benefits: By reducing unnecessary waste collection trips, optimizing routes, and promoting recycling, smart waste management systems contribute to a significant reduction in carbon emissions. Proper waste segregation also helps minimize landfill usage and environmental pollution, leading to a cleaner and healthier urban environment.

6. Public engagement and awareness: Smart trash cans can incorporate interactive displays or interfaces to engage the public and raise awareness about waste management practices. They can provide information on recycling guidelines, waste reduction tips, and real-time environmental impact updates. This interactive element fosters a sense of responsibility among citizens and encourages their active participation in waste management initiatives.

7. Integration with other smart city systems: Smart waste management systems can be integrated with other smart city infrastructure, such as traffic management, energy management, or public transportation. This integration enables a holistic approach to urban planning and optimization, leading to better resource allocation and improved quality of life for residents.

It's important to note that while the future of smart city waste management systems holds great potential, it also requires substantial investments in infrastructure, technology, and public awareness. Collaboration between government bodies, waste management authorities, technology providers, and citizens is crucial to fully realize the benefits and create sustainable and efficient waste management solutions in our cities.

10. APPENDIX SOURCE CODE

```
#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 "qqf6dm"//IBM ORGANITION ID

#define DEVICE_TYPE "ABCD"//Device type mentioned in ibm watson IOT
Platform

#define DEVICE_ID "663310" //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="";



}
```

GITHUB &PROJECT VIDEO DEMO LINK:

Wokwi Project Link:

https://wokwi.com/projects/365051842593002497

Demo Link:

https://drive.google.com/file/d/1OE45S1rnHBy38sogUpV_DNHk_GFneQLx/view?usp=share_link