SMART WASTE MANAGEMENT SYSTEM

Capstone Project Report

MID-SEMESTER EVALUATION

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ABSTRACT

The Smart Waste Management System is an innovative solution to automate and optimize waste classification, segregation, and disposal processes. The system uses advanced technologies such as AI-based image recognition, IoT integration, and automated control mechanisms to identify and sort waste into biodegradable, non-biodegradable, or hazardous categories in real-time. Servo motors control the appropriate bins, ensuring accurate and efficient segregation at the source. To maximize storage capacity, the system includes a waste compression feature that compacts waste periodically, reducing the need for frequent collection.

Safety is a key focus, with sensors embedded to detect harmful gases like carbon monoxide and sulfur dioxide, triggering alerts to prevent potential hazards. The system's IoT connectivity enables real-time monitoring and remote management through user-friendly web and mobile interfaces. These interfaces provide a comprehensive overview of the system's status, environmental conditions, bin levels, and customizable alerts and reports.

Designed to integrate seamlessly with existing waste management infrastructures, the Smart Waste Management System offers a scalable, sustainable, and efficient approach to waste handling. It addresses the growing need for intelligent waste management solutions in urban areas, reducing operational costs, enhancing safety, and contributing to environmental sustainability. This abstract encapsulates the key features, functionalities, and benefits of the system, emphasizing its role in revolutionizing traditional waste management practices and meeting the demands of modern, Smart cities.

DECLARATION

We hereby declare that the design principles and working prototype model of the project entitled Smart Waste Management System is an authentic record of our work carried out in the Computer Science and Engineering Department, TIET, Patiala, under the guidance of Dr. Tanu Goyal and Dr. Manisha Kaushal during 6th semester (2024).

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Lastly, we would also like to thank our families for their unyielding love and encouragement.

They always wanted the best for us and we admire their determination and sacrifice.

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LIST OF ABBREVIATIONS

Sr. No.	Abbreviation	Word
1.	CNN	Convolutional Neural Network
2.	YOLO	You Only Look Once
3.	SRS	Software Requirement Specification
4.	AI	Artificial Intelligence
5.	Fig	Figure

INTRODUCTION

1.1 Project Overview

The growth of cities and industries has led to an increase in waste, making waste management a significant challenge. Traditional methods of waste management often struggle with issues like improper waste sorting, overflowing bins, and safety concerns related to harmful gases. These problems show the need for a smarter approach to handling waste.

To address these issues, we developed a "Smart Waste Management System." This system uses modern technology to automate waste sorting, optimize space in bins, and detect dangerous gases. By doing so, it makes waste management more efficient and safer.

How the System Works

Our Smart Waste Management System is designed with several key features:

1. **Waste Classification Using a Camera**: The system uses a camera to look at waste items before they are thrown away. The camera takes a picture of each item and uses a computer program to figure out what type of waste it is. The waste is classified into three categories: biodegradable (like food scraps), non-biodegradable (like plastic), and hazardous (like batteries). The system uses artificial intelligence (AI) to make these decisions quickly and accurately.
2. **Automated Bins**: The system has three separate bins, each for one type of waste. Once the camera identifies the type of waste, the correct bin automatically opens. The waste is then dropped into that bin. This ensures that waste is sorted correctly without needing human intervention. Proper sorting is important for recycling and safe disposal.
3. **Compressing the Waste**: To make the most of the space in each bin, the system includes a compressor that squashes the waste down. This reduces the amount of space the waste takes up, allowing the bin to hold more before it needs to be emptied. The compressor works automatically, and when the waste can't be compressed any more, the system sends a notification to the waste collection team that it's time to empty the bin.
4. **Detecting Dangerous Gases**: Some types of waste can release harmful gases like carbon monoxide (CO) or sulfur dioxide (SO2), which can be dangerous. Our system has sensors in the bins that constantly check for these gases. If the sensors detect a dangerous level of gas, the system sends an alert to the waste collectors. This feature is critical for preventing accidents and ensuring the safety of the people who handle the waste.
5. **Real-Time Monitoring and Alerts**: The Smart Waste Management System is connected to a central control system that keeps track of everything in real-time. This system monitors the status of each bin, including how full it is and whether

any dangerous gases have been detected. If a bin is full or if there's a gas hazard, the system sends a notification to the relevant authorities. This real-time monitoring ensures that waste is collected promptly and safely.

System Design

The Smart Waste Management System is built using several interconnected components that work together to ensure efficient waste management:

1. **Camera and AI-Based Classification**: A camera is placed above the waste input area. It captures images of each waste item as it enters the system. These images are analyzed by a computer program that uses AI to classify the waste. The program has been trained on many examples of different types of waste to make accurate classifications. This process happens quickly, allowing the system to sort waste in real time.
2. **Servo Motors for Bin Operation**: Each bin is equipped with a small motor called a servo motor. This motor opens and closes the bin's lid automatically based on the type of waste detected by the camera. The motors are reliable and precise, ensuring that the correct bin opens every time.
3. **Compressor for Waste Reduction**: Inside each bin, there is a compressor that squashes the waste to reduce its volume. This means the bin can hold more waste before it needs to be emptied. The system monitors how full the bin is and uses the compressor when necessary. This feature is especially useful in areas where waste collection doesn't happen frequently.
4. **Gas Sensors for Safety**: The gas sensors are small devices placed inside the bins to detect dangerous gases. These sensors are very sensitive and can detect even low levels of harmful gases. When a dangerous gas is detected, the system sends an alert, helping to prevent accidents.
5. **Wireless Communication and Monitoring**: The system uses wireless technology to send information to a central monitoring station, such as a computer or a smartphone app. This allows waste management teams to check the status of the bins remotely and receive alerts when something needs attention. This feature makes the system very convenient to use.

Implementation and Testing

Building the Smart Waste Management System involved several steps:

1. **Assembling the Hardware**: The physical components, such as the camera, servo motors, compressor, and gas sensors, were assembled and connected to the central control unit, which is the "brain" of the system.

2. **Developing the Software**: The software was developed to run the AI classification, control the servo motors and compressor, and manage the sensors. This software was tested in a simulated environment to make sure it worked correctly.
3. **System Integration**: After the hardware and software were ready, they were integrated into a single system. This step included setting up the communication protocols and calibrating the sensors to ensure everything worked together smoothly.
4. **Testing the System**: Finally, the entire system was tested in various conditions to make sure it could accurately classify waste, manage the bins, and detect gases. The system was fine-tuned based on the results of these tests.

Benefits and Impact

The Smart Waste Management System offers several important benefits:

1. **Environmental Protection**: By accurately sorting waste into biodegradable, non-biodegradable, and hazardous categories, the system helps improve recycling rates and reduce the amount of waste sent to landfills. Compressing the waste also reduces the number of trips needed to collect it, saving fuel and reducing carbon emissions.
2. **Safety for Workers**: The gas detection feature protects waste collectors from harmful gases, reducing the risk of accidents and health problems. The system's alerts ensure that waste is collected before it overflows, which helps maintain cleanliness and safety.
3. **Cost Savings**: Automating the waste sorting and compression process reduces the need for human labor, saving money for waste management companies. The system's efficiency also means fewer trips are needed to empty the bins, further reducing costs.
4. **Scalability**: The Smart Waste Management System can be scaled up or down depending on the needs of different environments, such as residential areas, commercial buildings, or industrial sites. It can also be integrated with other smart city technologies, making it a versatile solution for modern urban management.

1.2 Need Analysis

The amount of waste produced daily by industries and households is increasing at a terrible rate, and the major reason for this is the rising use of packaged items, textiles, paper, food, plastics, metals, glass, etc. Thus, managing this refuse becomes a crucial part of our everyday life. In most developed countries, many efficient techniques are used to manage this waste properly. Still, in some countries, especially developing ones, the careless attitude of people towards maintaining clean surroundings, no proper environmental policies, and no laws for sustainable development are the seed for the fatal results of waste management.

Through this project, we aim to maintain clean surroundings by implementing a smart waste management system. Conventional garbage bins solely collect waste, and sanitation workers must carry out manual inspections to assess the trash level in the bins. This approach is not efficient for routine waste disposal inspections. Moreover, due to the frequent filling of the containers, disease-causing organisms and insects tend to breed on them. Therefore, designing intelligent garbage bin monitoring systems to manage garbage is essential in cities.

Additionally, it is noted that in rural areas, there is often a lack of adequate knowledge regarding proper waste disposal methods among residents. It is observed that waste segregation poses a significant challenge in such areas. Therefore, implementing a system enabling efficient waste segregation without demanding extensive knowledge or effort from residents is essential. As engineers, we strive to create innovative and feasible solutions that help ease people's lives.

1.3 Research Gaps

Previous research and waste management systems have often lacked critical features such as waste compression and gas detection, leaving room for inefficiencies and safety concerns. Our project aims to bridge these gaps by integrating both advanced waste compression technology and sensitive gas detection sensors into each bin.

1. **Innovative Waste Compression Technology:**
   In contrast to earlier systems, our project includes a sophisticated compressor within each bin, designed to significantly reduce the volume of waste. By compacting the waste into a smaller, denser mass, the bin can accommodate a larger amount of material before it needs to be emptied. This innovation is particularly beneficial in areas where waste collection is infrequent or where high volumes of waste are generated. The system continuously monitors the bin's fill level, automatically activating the compressor when needed, thus maximizing the bin's capacity and reducing the frequency of collection.

2. **Enhanced Safety with Gas Detection Sensors:**
   Another crucial feature often missing in previous waste management systems is the ability to detect harmful gases. Our project addresses this by incorporating advanced gas sensors within each bin. These sensors are highly sensitive, capable of detecting even low levels of dangerous gases like methane and carbon monoxide. When a hazardous gas is detected, the system instantly sends an alert, enabling timely intervention to prevent potential accidents such as fires or explosions. By including this safety mechanism, our project not only enhances operational efficiency but also significantly improves safety for both the public and waste management personnel.

1.4 Problem Statement and Scope

Approximately 62 million tonnes of waste are generated annually in India, with only 20% recycled. This is a significant issue for our country, as about 87 lakh metric tonnes of this waste is hazardous.

Waste poses serious health and environmental concerns. It serves as a breeding ground for bacteria, insects, and flies, leading to food poisoning, typhoid, gastroenteritis, and salmonella. Insects like flies also spread diseases such as malaria and dengue. Additionally, rodents and stray dogs thrive in garbage, further contributing to disease transmission.

Moreover, the disposal of hazardous waste like electronic items and plastics in water bodies harms aquatic life and indirectly affects humans. The toxic contaminants emitted by garbage, such as CO2 and methane, worsen air and water pollution, leading to respiratory diseases and other health issues. Overflowing garbage not only creates public inconvenience but also spoils the aesthetics of our surroundings.

Everyone desires fresh, clean cities. However, solving the challenges posed by waste requires innovative solutions. Addressing waste management effectively to safeguard public health and preserve the environment is crucial. Real-time assistance and alerts are needed to ensure a sustainable environment and cleaner surroundings.

The Smart Waste Management System will revolutionize modern waste management by automating critical processes like waste classification, bin capacity optimization, and safety monitoring. Using AI and image recognition, the system will accurately sort waste into categories such as biodegradable, non-biodegradable, and hazardous materials, enhancing recycling efficiency and safety. Built-in compressors will optimize bin capacity, reducing collection frequency and carbon emissions. Additionally, sensors will detect harmful gases, ensuring environmental and worker safety. Scalable and adaptable, this system will integrate seamlessly with existing infrastructure, playing a key role in sustainable urban waste management.

1.5 Assumptions and Constraints:

S. No.	Assumptions
1	The system assumes that users have access to a stable internet connection to transmit data in real-time and receive notifications or alerts.
2	Adequate power supply is available to operate the sensors.
3	Regular maintenance and upkeep are conducted to ensure optimal functionality.
4	The sensors used for detecting harmful gases are assumed to be precise and capable of detecting even low levels of dangerous gases. Reliable sensor performance is crucial for

	ensuring the safety of waste collection personnel and preventing potential hazards

Table:1.5.1 Assumptions

S. No.	Constraints
1	Waste is segregated into limited categories.
2	The camera lens should be adequately clean, and sufficient lighting should be there.

Table:1.5.2 Constraints

1.6 Standards

1. Environmental and Quality Management:

The Smart Waste Management System adheres to **ISO 14001**, which ensures the system is environmentally sustainable by integrating effective Environmental Management System (EMS) practices. This standard helps minimize waste and promote recycling. Additionally, compliance with **ISO 9001** guarantees that system components, including sensors and AI algorithms, meet high-quality standards. This ensures the system's reliability, accuracy, and consistent performance, allowing it to effectively manage waste and meet user expectations.

2. Safety and Compliance:

ISO 12100 is essential for ensuring that all components within the Smart Waste Management System are designed with safety in mind, preventing accidents and ensuring safe operation. The system also complies with **EN 60335**, which addresses the safety of electrical components, ensuring that all electrical parts are safe for public use. This standard is crucial for preventing electrical hazards, making the system reliable and secure in various environments.

3. Data Security and Communication:

The Smart Waste Management System complies with **ISO/IEC 27001** to ensure that all data, such as waste levels and gas detection results, are securely managed and protected from unauthorized access. This standard is vital for maintaining data privacy and security. Additionally, adherence to **IEEE 802.11** ensures that the system's wireless communications are reliable and secure, enabling seamless integration and data transmission between system components and central control units.

1.7 Approved Objectives

1. **Waste Sorting and Categorization:** To develop a smart system capable of accurately sorting waste into categories such as biodegradable, non- biodegradable, and hazardous, thereby improving waste management in smart cities.

2. **Trash Level Monitoring:** To implement a monitoring system that can efficiently track the trash levels in each bin in real-time, ensuring timely waste collection and management.

3. **Automatic Waste Compression:** To automate the compression of waste when trash levels exceed a predetermined limit, maximizing bin capacity and reducing the frequency of waste collection.

4. **Combustible Gas Detection:** To detect the presence of combustible gases that could lead to potential fire hazards, automatically notify authorities if gas levels exceed safety thresholds.

5. **Real-Time Information and Reporting:** To provide specific waste management companies with information on the status of each bin, including waste level, waste type, and bin location, enabling more effective and targeted waste management strategies.

   The proposed project aims to achieve these objectives by integrating advanced sensor technology and automation into a comprehensive waste management system that enhances the efficiency, safety, and sustainability of smart cities.

1.8 Methodology

1. **Research and Review:** Conduct thorough research and review previous advancements related to waste management in smart cities, focusing on sensor technology, automation, and IoT integration, to ensure an effective development process.

2. **Hardware Selection:** Explore and select the optimal hardware components, including sensors for waste sorting, level monitoring, and gas detection, as well as microcontrollers and communication modules, tailored to the project requirements.

3. **IoT Device Assembly:** Assemble the IoT device with a focus on user-friendliness, minimal space occupation, and low maintenance, ensuring that the design is practical and efficient for deployment in urban environments.

4. **Code Development and Upload:** Develop and upload the necessary code to the sensors and microcontrollers to enable functionality, including waste categorization, level monitoring, automatic compression, and gas detection.

5. **System Integration:** Integrate all components, including sensors, actuators, and communication modules, to operate as a unified waste management system that can accurately sort, monitor, and report on waste in real-time.

6. **System Testing:** Test the device to evaluate its accuracy and reliability in sorting waste, monitoring trash levels, compressing waste, and detecting combustible gases.

7. **Model Improvement:** Make necessary improvements to the system based on the testing results, refining algorithms and hardware configurations to enhance performance.

8. **Deployment:** Deploy the device in a real-world setting, ensuring that it effectively integrates with existing waste management infrastructures in smart cities.

1.9 OUTCOMES

1. **Automated Lid Opening for Specific Waste Types:**

   The project implements an intelligent mechanism that automatically opens the lid of a designated smart dustbin upon detecting a specific type of waste, such as biodegradable, non-biodegradable, or hazardous materials. This hands-free operation enhances hygiene and ensures proper waste segregation at the disposal point, reducing the risk of cross-contamination and encouraging effective recycling.

2. **Automatic Waste Compression for Optimized Capacity:**

   The smart dustbin includes an automatic waste compression system that activates when the bin's waste level exceeds a predetermined threshold. This feature maximizes bin capacity by reducing waste volume and allowing for less frequent collection trips.

3. **Detection of Combustible Gases and Immediate Alert System:**

   Equipped with sensitive gas sensors, the smart dustbin can detect combustible gases like methane. If dangerous levels are detected, the system immediately alerts authorities, ensuring timely intervention and preventing potential accidents, thereby enhancing public safety.

4. **Real-Time Notifications to Waste Management Authorities:**

The system includes a real-time notification feature that alerts waste management authorities when the dustbin reaches full capacity. Notifications include the bin's location, enabling more efficient collection planning.

1.10 Novelty

1. Our project introduces an innovative waste management system where waste is collected by different departments based on its type. Through automated waste classification and real-time data analytics, our system identifies waste types accurately. Subsequently, targeted notifications are sent to relevant departments, streamlining disposal processes and optimizing waste recycling.
2. Our project incorporates an innovative compressor mechanism within the waste bins, optimizing space utilization by compressing waste materials. This feature significantly reduces the frequency of collection trips and minimizes overflow issues. It enhances operational efficiency and cost-effectiveness while maintaining environmental sustainability.
3. Our project integrates advanced sensors to detect the presence of combustible gases within waste bins. If a gas buildup exceeds safety limits, automated alerts are immediately dispatched to authorities for prompt intervention, minimizing the risk of fire hazards and ensuring public safety. The bins will also be incorporated with mini exhaust fans to manage the production of gases due to waste decomposition.

2.1 Literature Survey

2.1.1 Theory Associated with Problem Area

The lack of effective waste management policies and sustainable development regulations exacerbates the challenges, especially in developing regions where sanitation practices are often inadequate. In many areas, it is common to observe municipal garbage bins overflowing, as they are not emptied or maintained regularly. This neglect leads to a host of serious consequences. When garbage bins overflow, it contributes significantly to land pollution, as waste spills onto the streets and surrounding areas. This uncontrolled waste not only contaminates the environment but also becomes a breeding ground for harmful pathogens, increasing the risk of disease outbreaks among the local population.

Moreover, the accumulation of uncollected waste creates highly unhygienic conditions, posing a direct threat to public health. The presence of rotting waste attracts pests such as rats, flies, and other vermin, which can spread diseases to nearby communities. The stench and filth generated by these overflowing bins make the area unpleasant to live in, impacting the quality of life for residents. Additionally, the visual blight of trash-strewn streets detracts from the aesthetic appeal of neighbourhoods, contributing to the degradation of urban environments and potentially lowering property values.

2.1.2 Existing Systems and Solutions

A Smart Waste Management System Framework Using IoT and LoRa for Green City Project:

This paper describes the implementation of the waste management system. It deals with three interrelated problems: a) the timely checking of the status of bins to prevent overflow, b) checking the precise location of bins, and c) finding the optimal route to the filled bins. To track the overflow of the bin, the proposed model uses ultrasonic sensors, which are complemented with LoRa to transmit the exact location of the bins in a real-time environment. The Floyd-Warshall algorithm in the proposed model optimizes waste collection to determine the shortest path. Leveraging low-cost IoT technologies, specifically LoRa modules for data transfer, the solution offers simplicity, affordability, and ease of replacement. This study presents a smart waste management solution utilizing Arduino UNO microcontrollers, ultrasonic sensors, and LoRaWAN to measure waste levels accurately. three interrelated problems: a) the timely checking of the status of bins to prevent overflow, b) checking the precise location of bins, and c) finding the optimal route to the filled bins.

Intelligent waste management system using deep learning with IoT:

This paper represents a real-time waste monitoring system utilizing a deep learning paradigm and IoT. The proposed model is classified into two significant parts. One is the architectural model of waste classification using a Raspberry Pi and camera module, along with the mechanism of deep learning. Another one is the embodiment of an IoT based smart trash box utilizing a microcontroller with multiple sensors for real-time waste monitoring. Again, this paper represents the data calculation methodology of the proposed CNN model, ultrasonic sensor, and load measurement sensor. The first limitation of this work is that the model works only with five categories of indigestible waste. Another limitation is that only two sensors are utilized in the developed prototype. Further, the model experiences a limitation: detecting several types of holes in the trash box. The incident occurs only when the bin seems full, but it's not even half full because of the nature of the waste. If the architecture is enriched with a big data set and several types of sensors such as IR sensor and MQ Gas sensor, the solution will be more productive; the accuracy of the scheme will be broadened as well. In the future, this research will fix these three limitations to ensure more optimum results in waste management.

Smart Waste Management Scheme Using IoT for Metropolitan Cities:

This paper proposes a system, and the objective is to design a smart bin with three sections. One for bio-degradable domestic wastes, the second for inert debris (soiled diapers and sanitary napkins), and the third for non-biodegradable wastes. The second level aims to design a smart and small waste treatment system at the Local Garbage Monitoring Centres, which involves three methodologies for treating non-biodegradable wastes. The bin uses an automatic mechanical closing lid. The entire bin has three weight sensors for the three sections to monitor the weight and a lid sensor to check the lid If the weight increases the fixed threshold, the first alarm should be sent. And if the lid cannot be closed due to large sized garbage, then the second alarm should be sent.

Design and Implementation of Intelligent Dustbin with Garbage Gas Detection for Hygienic Environment based on IoT:

This study aims to develop a model of an intelligent trashcan for usage in smart cities. Additionally, it will identify dangerous gases emitted by dustbins for subsequent management operations, monitor the amount of trash in the waste bin, and warn the municipality through SMS. This system includes two ultrasonic sonar sensors for measuring trash levels, a GSM module for sending SMS, three gas sensors for detecting harmful garbage gas, an infrared sensor for counting garbage droplets, and an Arduino Uno for managing all activities. The system notifies you whether the bin is full or empty and can also be controlled by voice command. Additionally, released gas may be monitored to determine the impairment's severity and notify the appropriate authorities. Most significantly, it will identify a failed trash drop in the bin and alert the user through alarm for truly considering the reduction of spilled garbage surrounding bins while using the system.

IOT-Based Garbage Gas Detection System:

This paper discusses implementing a garbage gas monitoring system, a specialized system designed to measure and monitor the concentration of various gases produced by the decomposition of organic waste. These gases, including methane, ammonia, and volatile organic compounds, can pose a significant risk to human health and the environment if they are not adequately managed and controlled. Garbage gas monitoring systems typically consist of sensors and data collection devices installed throughout a landfill or waste management facility. Three gas sensors, MQ-136 for hydrogen sulfide (H_2S), the MQ-137 for ammonia (NH_3), and the TGS-2611 for methane (CH_4) and temperature sensor, an ultrasonic sensor for height and moisture sensor, make up our sensor device. All these sensors are wired to an ESP-32. The web server receives the sensor values via wireless transmission through the ESP-32. These sensors can detect the concentration of gases in various locations and transmit the data to a central control system for analysis and reporting.

2.1.3 Research Findings for Existing Literature

S No.	**Roll No.**	**Name**	**Paper Title**	**Tools/ Technology**	**Findings**	**Citation**
1.	**102116038**	**Sarvika Bhan**	A Smart Waste Management System Framework Using IoT and LoRa for Green City Project	Arduino UNO, Ultrasonic sensors, LoRaWAN (Low Power Wide Area Network), Floyd-Warshall algorithm for shortest path optimization	The use of low-cost IoT technologies, like LoRa modules, offers an affordable and scalable solution for urban waste management.	Laha, S. R.., Pattanayak, B. K.., Pattnaik, S.., & Kumar, S.. (2023). A Smart Waste Management System Framework Using IoT and LoRa for Green City Project. *International Journal on Recent and Innovation Trends in Computing and Communication*, *11*(9), 342–357.

2.	**102116096**	**Jatin Thakur**	Intelligent waste management system using deep learning with IoT	Raspberry Pi, Ultrasonic sensor, Load measurement sensor, Convolutional Neural Network (CNN) for waste classification, Camera module for waste image capture	Future enhancements, including the addition of more sensors (e.g., IR sensor, MQ gas sensor) and larger datasets, are needed to improve accuracy and functionality.	Rahman W., Islam R., Hasan A., Bithi N., Hasan M., Rahman M., “Intelligent waste management system using deep learning with IoT.” *Journal of King Saud University - Computer and Information Sciences*, vol. 34(05), pp. 2072-2087, May 2022.
			Smart Waste Management Scheme Using IoT for Metropolitan Cities	Weight sensors, Lid sensor, Methods for treating non-biodegradable waste, Automatic mechanical closing lid	The system emphasizes efficient waste segregation and provides alerts to avoid overflow or improper disposal.	R. Rathna, "Smart Waste Management Scheme using IoT for Metropolitan Cities," 2023 International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT), Bengaluru, India, 2023, pp. 7-10.
3.	**102116111**	**Loveneet Kaur**	Design and Implementation of Intelligent Dustbin with Garbage Gas Detection for Hygienic Environment Based on IoT	Arduino Uno, Ultrasonic sensors, Gas sensors (for detecting harmful gases), Infrared sensor, GSM module for sending SMS alerts, Voice command	The system reduces the risk of spilled garbage and enhances the safety of waste management operations by monitoring gas emissions.	M. Ahmed, R. Shaha, K. Sarker, R. B. Mahi and M. A. Kashem, "Design and Implementation of Intelligent Dustbin with Garbage Gas Detection for Hygienic Environment based on IoT," 2022 International Conference on Advancement in Electrical and Electronic Engineering (ICAEEE), Gazipur,

				control, Alarm system.		Bangladesh, 2022, pp. 1-7
4.	**102116124**	**Jasmeet Kaur**	IoT-Based Garbage Gas Detection System	ESP-32, MQ-136 (hydrogen sulfide), MQ-137 (ammonia), TGS-2611 (methane), Temperature sensor, Ultrasonic sensor, Moisture sensor, Wireless data transmission to a web server via ESP-32	This solution enhances the safety of waste management by continuously monitoring gas emissions and providing timely alerts.	B. S, V. Pramodini, A. Ashik and V. S. Prasanth, "IoT-Based Garbage Gas Detection System," 2023 4th International Conference for Emerging Technology (INCET), Belgaum, India, 2023, pp. 1-4

Fig 2.1.3 Research Findings

2.1.4 Problem Identified

Limited Bin Capacity and Lack of Waste Compression Technology:

A significant issue identified in earlier waste management systems is the combination of limited bin capacity and the absence of effective waste compression technology. Without the ability to compress waste, bins quickly reach their total capacity, leading to frequent collection requirements and inefficient use of resources. This inefficiency necessitates frequent trips to empty the bins, increasing fuel consumption and operational costs and contributing to environmental concerns, such as higher carbon emissions. The inability to optimize bin space through compression leaves waste management systems struggling to cope with the demands of modern urban environments.

Absence of Gas Detection Sensors:

Another critical issue in earlier waste management systems is the lack of sensitive gas detection sensors. The absence of these sensors leaves bins vulnerable to the accumulation of combustible and harmful gases, such as methane, which can pose serious safety risks, including the potential for fires or explosions. These gases can go undetected without proper monitoring, creating hazardous conditions for waste management personnel and the surrounding environment.

2.1.5 Survey of Tools and Technologies Used

1. Raspberry Pi and Deep Learning for Waste Classification:

A Raspberry Pi coupled with a camera module is utilized to build an architectural model for waste classification. The Raspberry Pi serves as the computational hub, processing images captured by the camera and using trained convolutional neural networks (CNNs) to distinguish between different types of waste.

2. IoT-Based Smart Trash Box with Real-Time Monitoring:

The IoT-based smart trash box integrates a microcontroller with multiple sensors to monitor waste in real-time. Ultrasonic sensors are deployed to detect bin overflow, and LoRa (Long Range) technology is used to transmit the exact location of bins to waste management authorities. Additionally, the Floyd-Warshall algorithm is employed to optimize waste collection routes by determining the shortest paths, thereby reducing operational costs and enhancing efficiency.

3. Comprehensive Sensing with Multiple Modules:

The system uses two ultrasonic sonar sensors to measure trash levels and ensure the bins are not overfilled. A GSM module is integrated to send SMS alerts when certain conditions are met, such as when a bin is full or harmful gases are detected.

4. Advanced Sensor Integration with ESP-32:

The sensor device in this system consists of three specialized gas sensors—MQ-136 for hydrogen sulfide (H2S), MQ-137 for ammonia (NH3), and TGS-2611 for methane (CH4)—alongside a temperature sensor, an ultrasonic sensor for height measurement, and a moisture sensor. These sensors are connected to an ESP-32 microcontroller, which enables wireless data transmission to a web server for remote monitoring.

2.2 Software Requirement Specification (SRS)

2.2.1 Introduction

2.2.1.1 Purpose

The Software Requirement Specification (SRS) document provides a detailed and comprehensive description of the software requirements for the Smart Waste Management System. This document guides the development team, stakeholders, and other parties involved in the project to ensure a clear understanding of the system's functionality, performance, and operational requirements.

The Smart Waste Management System is designed to automate the process of waste classification, segregation, and disposal, using advanced technologies such as AI-based image recognition, sensors for environmental monitoring, and IoT integration for real-time data collection and management.

This document includes detailed descriptions of the system's functional requirements, performance criteria, user interfaces, and constraints. It aims to provide a blueprint for the development process, ensuring that the final product meets the users' needs and addresses the challenges identified in existing waste management systems. The SRS will also be a reference for testing and validation, ensuring the system performs as expected under various conditions and meets all specified objectives.

2.2.1.2 Intended Audience and Reading Suggestions

This document is intended for a diverse Smart Waste Management System audience, including project stakeholders, the development team, and end-users. Project stakeholders, such as clients, sponsors, and management, will gain insight into the system's capabilities and alignment with business objectives. The development team, including software engineers and system architects, will find detailed functional requirements and system architecture necessary for building the system. End-users, specifically waste management personnel and technical support staff, will focus on the system's operational aspects and maintenance needs. Each group is encouraged to review relevant sections that align with their roles and responsibilities.

2.2.1.3 Project Scope

The Smart Waste Management System will revolutionize modern waste management by automating critical processes like waste classification, bin capacity optimization, and safety monitoring. Using AI and image recognition, the system will accurately sort waste into categories such as biodegradable, non-biodegradable, and hazardous materials, enhancing recycling efficiency and safety. Built-in compressors will optimize bin capacity, reducing collection frequency and carbon emissions. Additionally, sensors will detect harmful gases, ensuring environmental and worker safety. Scalable and adaptable, this system will integrate seamlessly with existing infrastructure, playing a key role in sustainable urban waste management.

2.2.2 Overall Description

The Smart Waste Management System project uses advanced technology to create a system that automatically sorts and manages waste. Using a camera and AI, the system will identify waste as biodegradable, non-biodegradable, or hazardous. Once classified, waste will be directed to the correct bin controlled by servo motors.

The project includes a waste compression feature to maximize bin space. When the bin is full and can't be compressed, a notification will be sent for waste collection. Additionally, sensors will detect harmful gases like carbon monoxide to ensure safety, alerting waste management personnel if dangerous conditions are detected.

The project is designed to be scalable, easy to use, and aligned with safety and environmental regulations, ensuring efficient and safe waste management.

2.2.2.1 Product Perspective

The Smart Waste Management System is an innovative solution for enhancing modern waste management practices. The process begins with sensors capturing data from waste, including cameras that utilize AI-based image recognition to classify waste as biodegradable, non-biodegradable, and hazardous. This classification happens in real time, enabling the system to make immediate decisions. Once classified, servo motors automatically direct the waste into the appropriate bins, ensuring accurate segregation at the source. The system also monitors environmental safety by detecting harmful gases like methane. This data is processed in real time and integrated into a central IoT platform, allowing waste management personnel to receive real-time alerts and optimize collection routes based on the actual status of each bin.

The Smart Waste Management System integrates seamlessly with existing waste management infrastructure, introducing advanced automation, safety, and efficiency to create a more sustainable waste management process.

2.2.2.2 Product Features

The Smart Waste Management System has a range of advanced features designed to improve waste management's efficiency and effectiveness. Below are the key features of the system:

1. **Object Detection and Smart Sorting**:
   Using object detection technology, the system can identify different types of waste, such as biodegradable, non-biodegradable, or hazardous, and sort them accordingly.

2. **Automatic Waste Compression**:
   Equipped with an intelligent compression system, the smart bins automatically compress waste when it reaches a certain level. This feature maximizes bin capacity, reduces the frequency of collections, and optimizes space usage.
3. **Trash Level Detection**:
   Ultrasonic sensors monitor the trash levels within each bin, providing accurate measurements and triggering notifications or compression actions when thresholds are met. This feature ensures efficient waste management and prevents overflows.
4. **Gas Detection and Safety Alerts**:
   The system includes sensitive gas sensors that detect combustible gases like methane. If dangerous gas levels are detected, the system sends immediate alerts to authorities, helping prevent potential fire hazards and ensuring public safety.
5. **Real-Time Notifications**:
   The system sends real-time alerts to waste management authorities when bins are full or when specific waste types require immediate attention. This feature ensures timely waste collection, reducing the risk of overflow and maintaining cleanliness.

2.2.3 External Interface Requirements

2.2.3.1 User/Human Interface (UI)

The human interface for this waste segregation project would be the part of the system that users interact with. There is not much human interaction except for:

1. **Camera**: Users show the object they wish to throw to the camera. The camera clicks a picture and sends it to the software for further action
2. **Alerts/Notifications**: Alerts if the methane level in a bin is high or if a bin is full, prompting admins to take necessary actions.

2.2.3.2 Hardware Interface

The hardware interface involves the physical components that interact with each other to perform the waste segregation process. Key elements include:

1. **Camera**: Captures images of the waste item to classify it into one of the three categories (biodegradable, hazardous, non-biodegradable).
2. **Servo Motors**: Mechanically connected to the lids of the bins, these motors open the corresponding bin lid based on the waste classification.
3. **Gas Sensors (MQ4)**: Installed in each bin to monitor methane gas levels. The sensor data triggers alerts or takes preventive actions if gas levels exceed a safe threshold.
4. **Ultrasonic Sensors**: Measure the garbage level in each bin to determine when a bin is full. This data is used to notify users and prevent overfilling.

5. **Raspberry Pi & Arduino Uno**: Coordinates the activities of all sensors, camera, and motors, processes the data, and executes actions based on sensor inputs.
6. **Compressor**: When required, it automatically slides down the dustbin to compress the waste inside.

2.2.3.3 Software Interface

The software interface includes the code, algorithms, and communication protocols that manage the system's functionality. Key components include:

1. **Image Processing Model**: AI model to analyze images captured by the camera and classify the waste type.
2. **Sensor Data Processing**: Code that reads data from the gas and ultrasonic sensors, processes it, and triggers the appropriate actions (e.g., sending alerts or stopping bin operations if the methane level is high).
3. **Motor Control Commands**: Commands that control the servo motors, instructing them to open or close the appropriate bin based on the waste classification.

Together, these interfaces ensure the system functions smoothly, with hardware components interacting seamlessly with the software to provide a user-friendly and efficient waste segregation solution.

2.2.4 Non-functional requirements

Non-functional requirements define the overall qualities and attributes of the system rather than specific behaviours. For the waste segregation project, these might include:

2.2.4.1 Performance requirements

Performance requirements define the system's speed, efficiency, and resource usage. For this project:

1. **Response Time**: The time between waste classification and bin operation (opening/closing) should be minimal, ideally under a few seconds.

2. **Accuracy**: The image recognition system should have a decent accuracy rate, correctly classifying at least 80% of the waste items.\

3. **Reliability**: The system should operate consistently over long periods without failure. It must accurately classify waste and operate the bins without errors.

4. **Usability**: It should be easy to use, even for users with minimal technical knowledge.

5. **Scalability**: The system should be able to handle additional sensors, bins, or different types of waste without requiring significant changes to the architecture.

6. **Maintainability**: The system should be easy to maintain, with modular components that can be replaced or upgraded with minimal downtime.

2.2.4.2 Safety Requirements

Safety requirements ensure that the system operates without causing harm to users or the environment. For this project:

1. **Methane Gas Detection**: The system must immediately trigger an alert and stop operations if methane levels exceed a predefined safe threshold, preventing any risk of explosion or health hazards.
2. **Bin Operation Safety**: The servo motors should operate smoothly, with safety mechanisms to prevent the bins from closing unexpectedly or causing injury to users.
3. **Electrical Safety**: All electrical components should be adequately protected to prevent electrical hazards such as short circuits or fires.

2.2.4.3 Security Requirements

Security requirements protect the system from unauthorized access and data breaches. As our project doesn’t involve any confidential or sensitive data, there is not much need for security other than basic security requirements. The system should have secure access controls, ensuring that only authorized personnel can access critical functions like system reset, data logging, or manual override.

2.3 Cost Analysis

Object	Price per piece (Rs)
Ultrasonic sensor (3)	110
GPS: sim800l gsm module	600
ESP8266	380
MQ135 (3)	180
servo motor (5)	150
Arduino camera	200
Arduino uno	400
bread board (2)	145
jumper wires set	335
plastic bin – 2L (3)	300
MQ-4	300
Raspberry Pi - 4	3519

5V batteries	184

Table 2.3 Cost Analysis

2.4 Risk Analysis

Risk analysis identifies potential challenges and uncertainties that could impact the project's success. Key risks include:

1. **Technical Risks:**
   i. Sensor Malfunction: Inaccurate readings from gas or ultrasonic sensors can compromise system performance.
   ii. Software Bugs: Errors in algorithms may lead to incorrect waste classification or bin operations.
   iii. Integration Issues: Challenges in hardware-software integration could cause delays or added costs.

   Mitigation: Regular testing, sensor calibration, and incorporating backup sensors.

2. **Operational Risks:**
   i. Power Supply Issues: Power disruptions could affect operations and damage equipment.
   ii. Mechanical Hazards: Servo motor failures might result in unsafe bin operations.

   Mitigation: Implement redundancy and train operators on proper system use.

3. **Regulatory Risks:**
   i. Compliance: Failure to meet electronic waste management and safety standards could lead to fines or restrictions.

   Mitigation: Ensure compliance with local regulations and provide adequate maintenance training.

3.1 Investigative Techniques

In developing a waste segregation system that uses advanced technology such as cameras, sensors, and servo motors, choosing the proper project technique is critical to ensuring success. Among the standard techniques such as descriptive, comparative, and experimental, the experimental technique is the most suitable for this type of project. This discussion will explore why the experimental technique is ideal, its application in the context of waste segregation project, and its benefits over other methods.

S. No.	Investigative Projects Techniques	Investigative Description	Investigative Projects
1	Descriptive	This approach involves systematically observing and recording the functioning of the Smart Waste Management System without manipulating any variables. The goal is to document the system's behaviour in various scenarios, such as detecting different types of waste, gas levels, and bin capacities.	Monitoring and documenting how the Smart Waste Management System categorizes waste over time, capturing data on how accurately it identifies biodegradable, non-biodegradable, and hazardous materials.
2	Comparative	This method compares different systems, algorithms, or methodologies to determine which is more effective. The project could involve comparing different object detection algorithms or hardware setups to see which performs better in waste classification or gas detection.	Comparing the accuracy and efficiency of YOLO versus other object detection models like R-CNN in classifying waste types.
3	Experimental	This technique involves testing hypotheses under controlled conditions, typically involving manipulation of one or more variables.	Conducting controlled experiments to test how variations in sensor

		In this project, it includes experimenting with different configurations of the Smart Waste Management System to optimize performance.	placement or sensitivity impact the system's ability to accurately detect and respond to different types of waste and gas levels. Another example could be testing the impact of different levels of data augmentation on the CNN model's accuracy in waste classification.

Table 3.1 Investigated Techniques

These investigative techniques allow you to systematically explore different aspects of your project, ensuring thorough analysis and optimization.

3.2 Proposed Solution

The proposed waste segregation system is a comprehensive, automated solution designed to efficiently manage and categorize waste into biodegradable, hazardous, and non-biodegradable categories. This system integrates advanced image processing, machine learning, and sensor technologies to enhance waste management operations.

Key Components and Functionality:

1. Waste Classification System:
    i. CNN Model: Trained using a well-augmented dataset for real-time object detection, ensuring accurate waste classification.
    ii. Camera & Image Processing: High-resolution images of waste items are processed using CNN algorithms to identify waste types.
2. Automated Bin Operation:
    i. Servo Motors: Control bin openings based on waste classification, ensuring smooth and reliable operation.
    ii. Real-Time Operation: Waste is quickly directed to the correct bin without delays.
3. Sensor Integration:
    i. Methane Detection: MQ4 sensors monitor methane levels to prevent hazardous conditions.
    ii. Ultrasonic Level Monitoring: Sensors track bin fill levels to avoid overflow.
4. System Integration & Continuous Improvement:

i. Central Processing: Coordinates all components for seamless operation.
ii. IoT Connectivity: Enables real-time monitoring and data-driven adjustments.
iii. Stress Testing: Ensures reliability and optimal performance under various conditions.

Expected Outcomes:

1. Increased Efficiency: Automated sorting reduces manual effort and improves accuracy.
2. Safety: Monitoring methane and waste levels enhances environmental safety.
3. Scalability: Easily adaptable to different environments and waste categories.
4. Continuous Improvement: Ongoing optimization ensures long-term effectiveness and risk mitigation.

This system offers a scalable, safe, and efficient solution for modern waste management needs.

3.3 Work Breakdown Structure

The Work Breakdown Structure (WBS) is a hierarchical decomposition of the total scope of work required to complete a project. It breaks down the project into manageable sections, making planning, executing, monitoring, and controlling it easier. In the waste segregation system context, the WBS helps identify the essential tasks, deliverables, and components that must be developed, tested, and integrated.

1. Literature Survey
   i. Conduct a comprehensive review of existing research and advancements related to the project.
   ii. Analyze relevant technologies and methodologies in waste segregation systems.
2. Hardware Selection
   i. Identify required hardware components (sensors, cameras, microcontrollers, etc.).
   ii. Evaluate and select optimal hardware based on project specifications.
3. Data Collection
   i. Gather images and data to train the object detection model.
   ii. Organize and preprocess the dataset for analysis.
4. Model for Object Detection
   i. Develop YOLO model for object detection.
   ii. Train the model using the collected and augmented dataset.
   iii. Evaluate model performance and make adjustments as necessary.
5. Hardware Assembly and Code Development
   i. Assemble the IoT device components.
   ii. Write and upload code to the sensors and other hardware.

6. Integration
    i. Integrate all components into a cohesive operational system.
    ii. Ensure seamless communication and functionality among components.
7. Testing and Model Improvement
    i. Test the integrated device to assess performance.
    ii. Analyze test results and identify areas for model and system improvement.
    iii. Implement necessary adjustments to enhance accuracy and functionality.

3.4 Tools and Technology

1. **Hardware Components**
    i. **Cameras**: High-resolution OV7670 camera captures images of waste items for classification.
    ii. **Servo Motors**: Precision SG90 servo motors control the opening and closing of waste bin lids based on classification results.
    iii. **Gas Sensors**: MQ4 methane gas sensors monitor bin methane levels, triggering alerts if concentrations exceed safe limits.
    iv. **Ultrasonic Sensors**: HC-SR04 ultrasonic sensors measure the fill level of each bin to prevent overflow.
2. **Software Tools and Frameworks**
    i. **Image Processing and Classification**: YOLO or PyTorch classify waste images as biodegradable, hazardous, or non-biodegradable.
    ii. **Microcontroller/Embedded Systems**: Arduino Uno controls sensors and motors, while Raspberry Pi runs the classification algorithm and coordinates the system.
    iii. **Software Development Tools**: Arduino IDE is used for programming microcontrollers, and Visual Studio Code is used for Python development.
3. **Power Management**
    i. **Power Supply Units**: Regulated DC power supplies ensure all components receive appropriate voltage and current.

These tools and technologies create a robust and reliable waste segregation system, leveraging advanced sensors and machine learning algorithms to operate effectively in real-world environments.

DESIGN SPECIFICATIONS

4.1 System Architecture

4.1.1 Block diagram

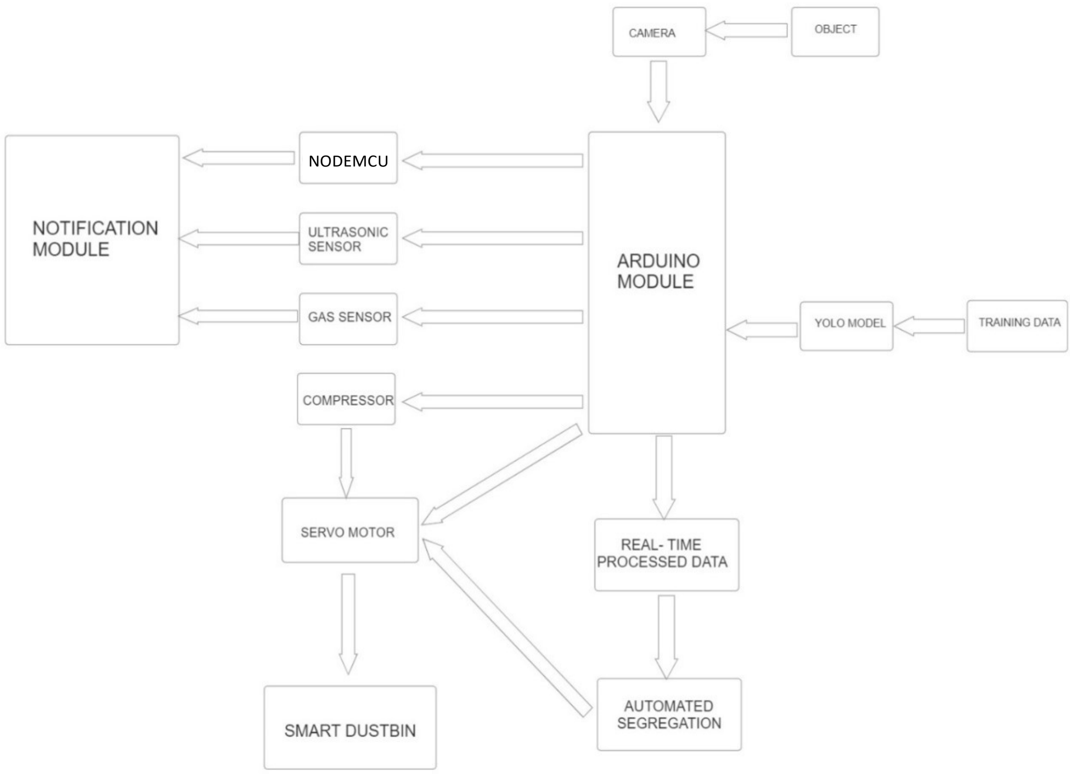

Fig.4.1.1 Block Diagram

This block diagram illustrates the architecture of a smart waste segregation system. Here's a brief explanation:

1. **Camera**: Captures images of the waste objects and sends them to the Arduino module.
2. **YOLO Model**: Utilizes training data to classify the waste objects based on the images processed by the Arduino module.
3. **Arduino Module**: Serves as the central control unit, receiving data from the camera, sensors, and YOLO model. It processes real-time data and coordinates actions.
4. **Sensors**:
   - **Ultrasonic Sensor**: Measures the fill level of the smart dustbin.

- **Gas Sensor**: Monitors gas levels within the bin.
- **NodeMCU**: Sends notifications based on sensor data.

5. **Compressor**: Controlled by the Arduino module to compact the waste.
6. **Servo Motor**: Operates the lid of the smart dustbin, facilitating automated segregation based on the classification results.
7. **Smart Dustbin**: Receives and stores segregated waste.
8. **Notification Module**: Informs users about the status of the bin, including fill levels and gas concentrations.

4.1.2 MVC Architecture

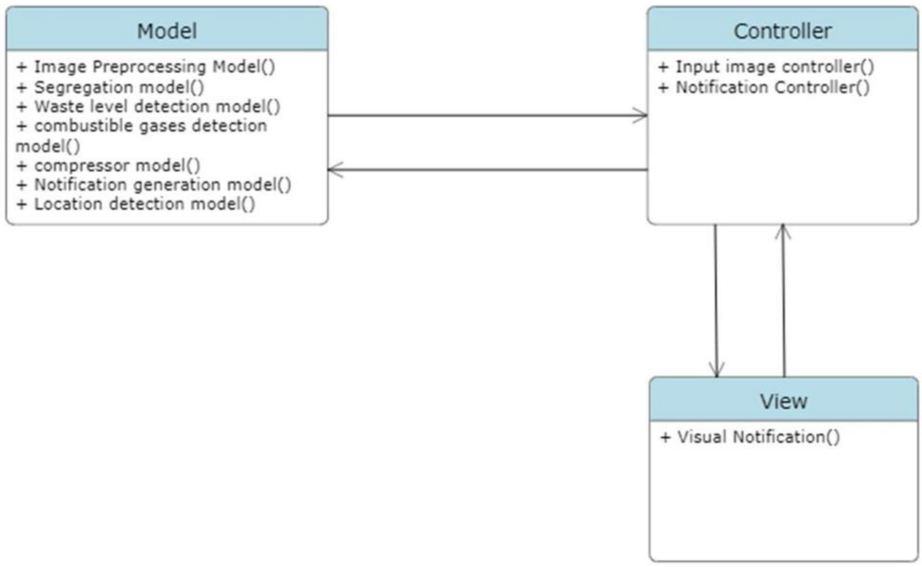

Fig.4.1.2 MVC Architecture

This MVC architecture diagram outlines the structure of a smart waste management system:

1. **Model**: Handles the core functions, including image preprocessing, waste segregation, level detection, gas detection, waste compression, and notification generation. Each model is responsible for processing data and making decisions in the system.
2. **Controller**: Acts as a bridge between the Model and the View. It processes inputs and applies the appropriate models, managing tasks like image classification and notification handling.
3. **View**: Represents the user interface, displaying visual notifications and system status based on the data processed by the Controller.

This architecture ensures efficient separation of responsibilities, with the Model managing data, the Controller processing information, and the View presenting it to the user.

4.2 Design Level Diagram

4.2.1 Data Flow Diagrams

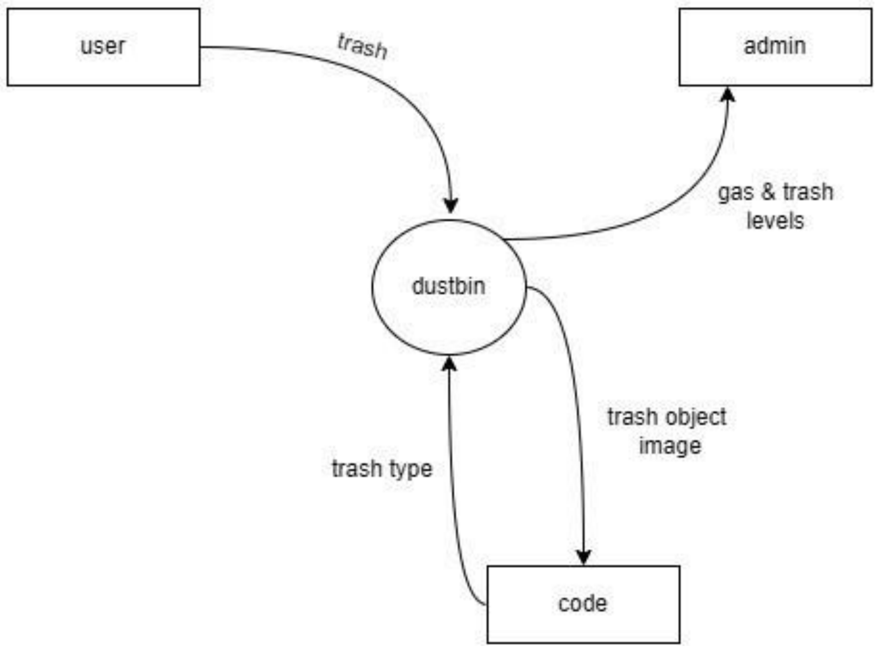

Fig.4.2.1.1 DFD Level 0

This Level 0 Data Flow Diagram (DFD) illustrates the smart waste management system's data interactions. The user disposes of trash into the dustbin, which captures images and sends them to the system's code for classification. The code processes the images to determine the type of trash and sends the results back to the dustbin for appropriate sorting. Additionally, the dustbin monitors gas and trash levels, providing this data to the admin for real-time system management.

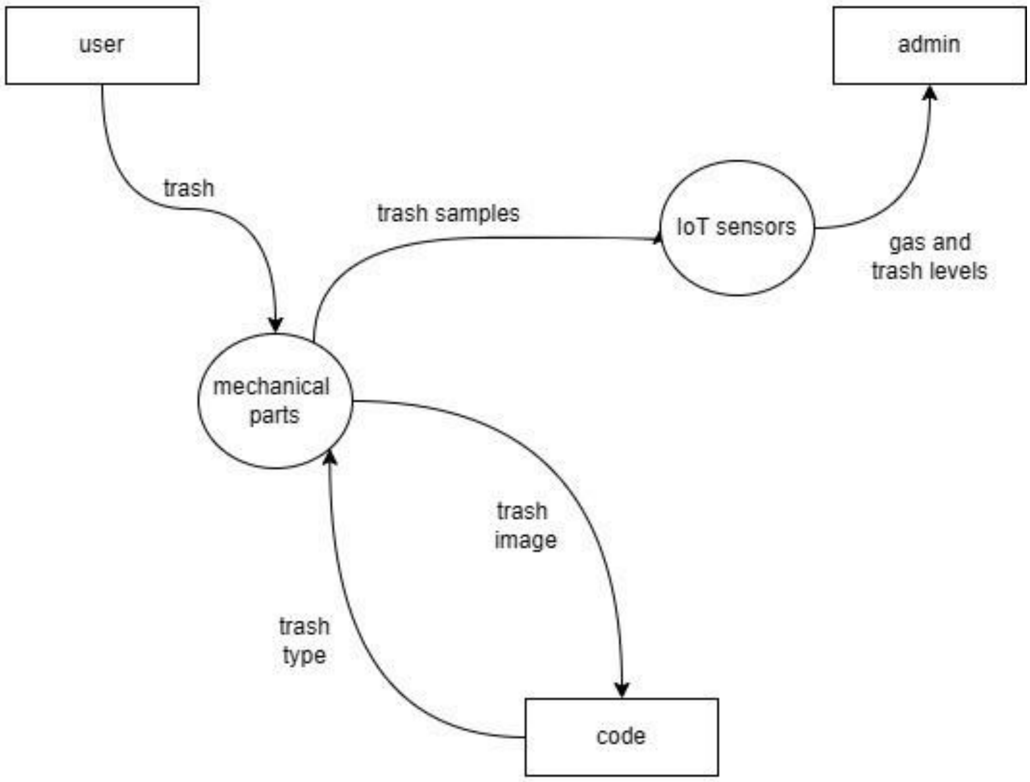

Fig.4.2.1.2 DFD Level 1

The Level 1 DFD of the smart waste management system provides more detailed interactions. When the user disposes of trash, the mechanical parts process it, capture an image, and send trash samples to IoT sensors. The sensors analyze gas and trash levels, sending the data to the admin for system management. Simultaneously, the captured trash image is sent to the code for classification, which identifies the trash type and informs the mechanical parts for proper sorting. This expands on the Level 0 DFD by detailing the roles of mechanical parts, IoT sensors, and code in the system.

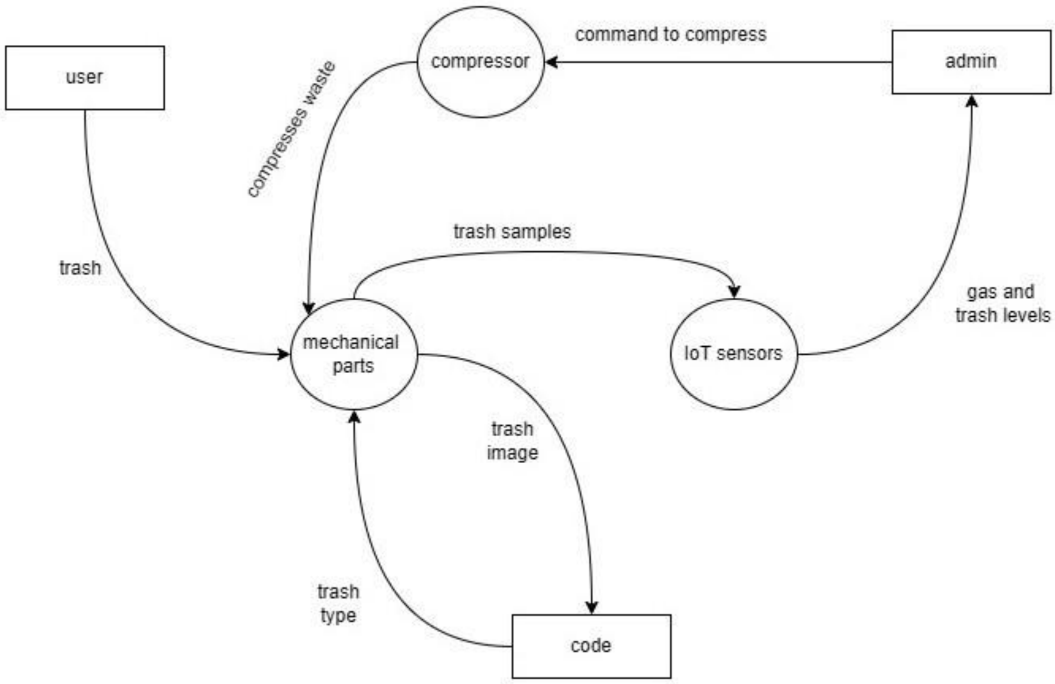

Fig.4.2.1.3 DFD Level 2

This Level 2 Data Flow Diagram (DFD) adds further detail to the smart waste management system. The user disposes of trash, which is processed by mechanical parts. The mechanical parts send trash samples to IoT sensors, which monitor gas and trash levels and relay the information to the admin. The mechanical parts also capture a trash image, which is sent to the code for classification. Based on the trash type, the system may issue a command to the compressor to compress the waste. The admin oversees the process by issuing commands to compress when necessary. This DFD introduces the compressor component and emphasizes its role in waste management.

4.2.2 Class Diagram

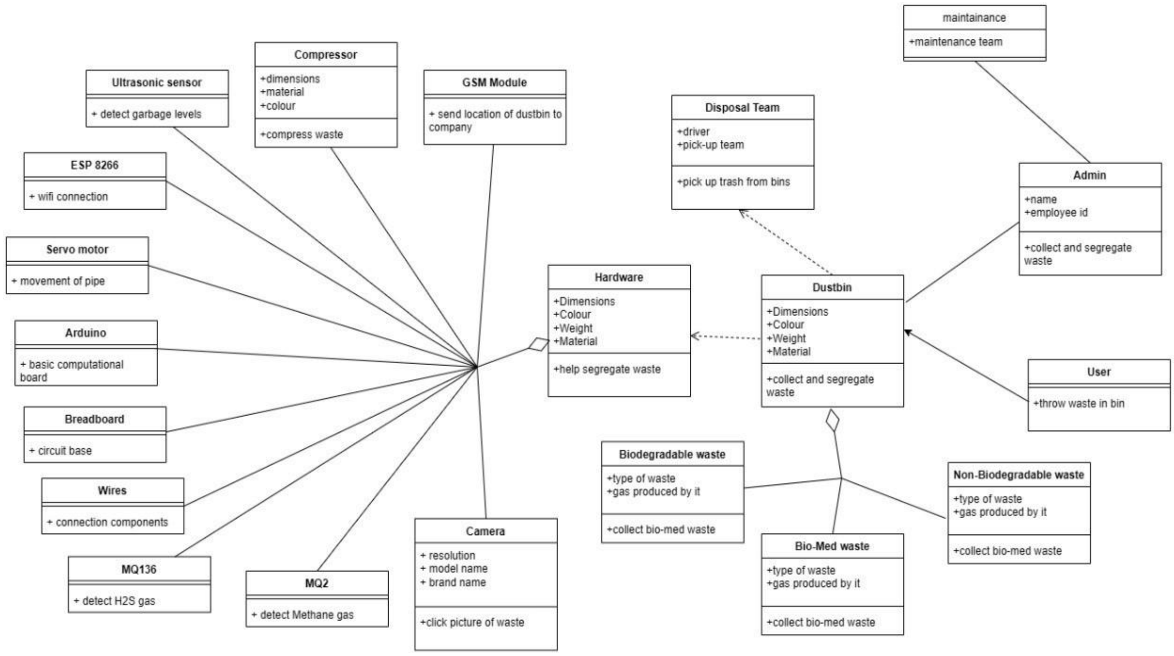

Fig.4.2.2 Class Diagram

This class diagram shows how various components of the smart waste management system are interconnected. The dustbin serves as the central element, connected to various hardware components such as the ultrasonic sensor (to detect garbage levels), ESP8266 (for Wi-Fi connectivity), servo motor (for pipe movement), and Arduino (for computation). These components enable the dustbin to collect and segregate waste into categories like biodegradable, non-biodegradable, and bio-medical.

The camera captures waste images for classification, while gas sensors (MQ4) detect harmful gases like methane. The compressor compacts the waste based on commands, and the GSM module sends the dustbin's location to the company. The disposal team collects trash from the bin, as the system sends a notification to them. The admin manages data flow, overseeing collection and segregation, while the maintenance team ensures the smooth functioning of all components. Users throw waste into the bin, triggering the system to handle the rest.

4.2.3. ER Diagram

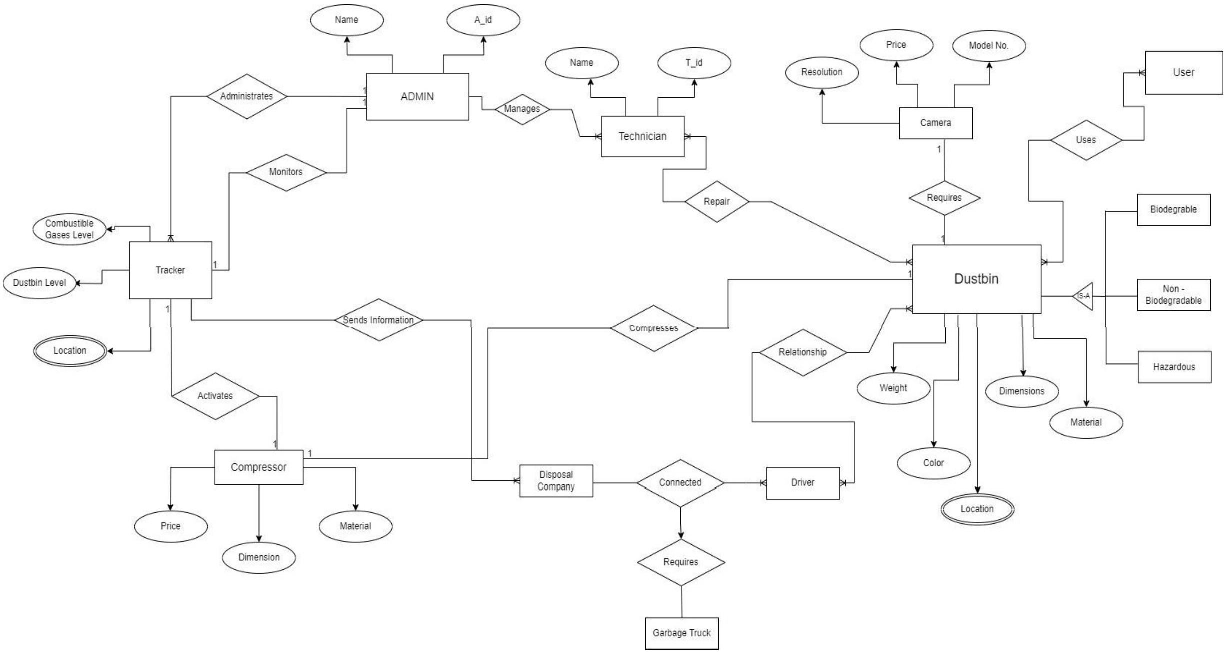

Fig.4.2.3 ER Diagram

This Entity-Relationship (ER) diagram represents a smart dustbin management system that includes various components and their interactions. The dustbin is at the system's center, which has attributes such as location, weight, color, dimensions, and material. The dustbin interacts with several other entities. Users define the type of waste the dustbin will handle, whether it is biodegradable, non-biodegradable, or hazardous.

A camera is associated with the dustbin to segregate the waste into different categories, with attributes like price, resolution, and model number. The dustbin's levels and the presence of combustible gases are monitored by an ultrasonic sensor and a gas sensor, respectively along with a tracker, which sends information to activate a compressor that compresses the waste. The compressor is linked to the disposal process, involving a disposal company and a driver who requires a garbage truck to transport the waste.

The system is managed by an admin who oversees the entire operation, including monitoring the tracker and managing technicians responsible for repairing dustbins. The admin and technicians have their attributes, such as names and identification numbers.

The diagram effectively outlines how these entities work together to ensure efficient waste management and disposal, integrating monitoring, maintenance, and logistical components.

4.3 User Interface Diagrams

4.3.1 Swimlane Diagram

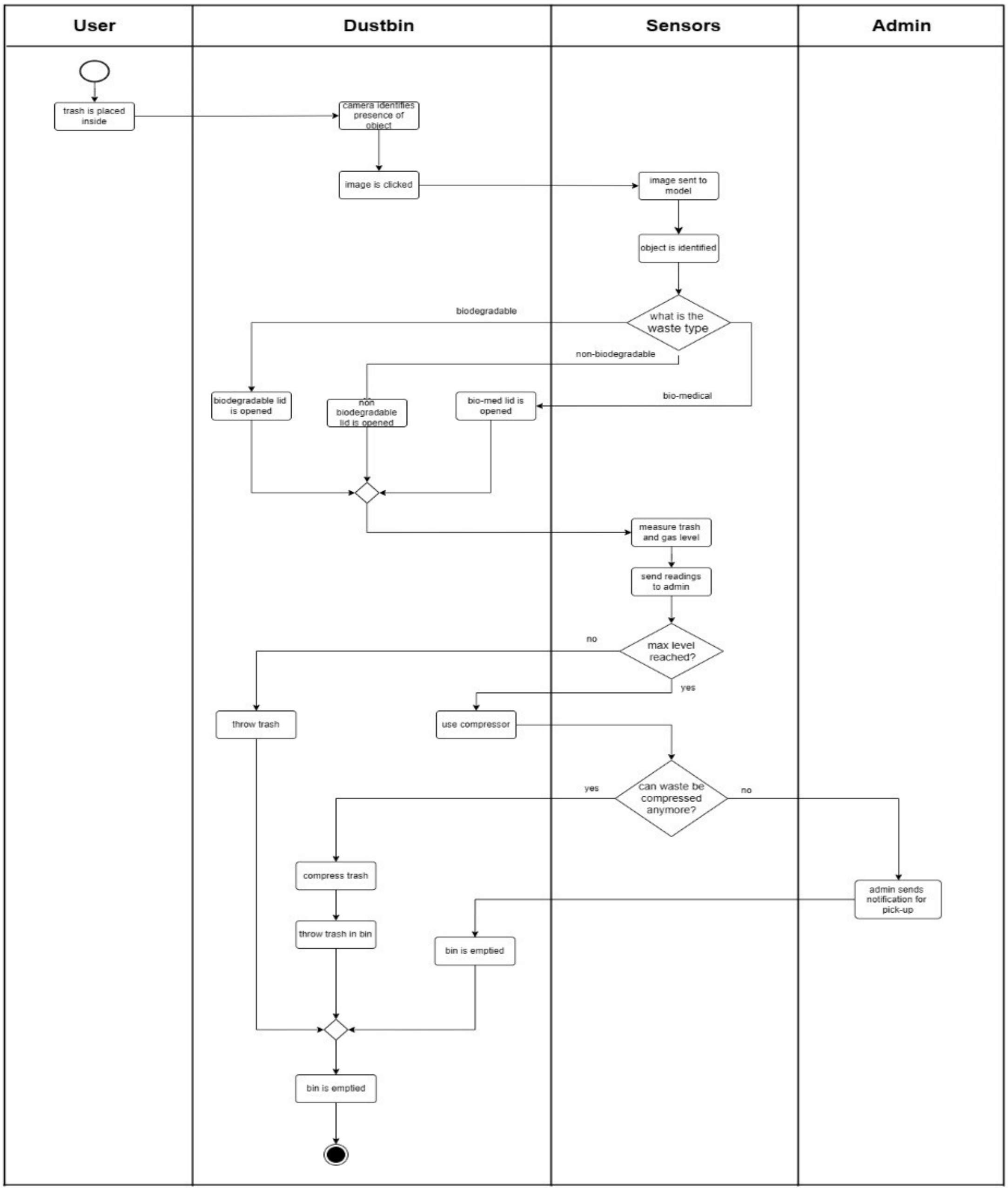

Fig.4.3.1 Swimlane Diagram

This swimlane diagram represents the waste management process in a smart dustbin system, illustrating the roles and interactions of four key participants: the User, Dustbin, Sensors, and Admin. The process begins with the user placing trash into the dustbin. The dustbin, equipped with sensors, detects the presence of the trash and captures an image, which is then analyzed to identify the type of waste—whether it is biodegradable, non-biodegradable, or hazardous. Based on this identification, the dustbin opens the appropriate lid for the user to dispose of the trash.

Once the trash is inside, sensors measure the trash level and the presence of any combustible gases, sending this information to the admin. The system checks if the bin has reached its maximum capacity. If the bin is full, it assesses whether the waste can be further compressed. If compression is possible, the waste is compressed within the bin. If not, the admin will be notified to arrange to empty the bin. The process concludes with the trash being compressed or removed, ensuring the bin is ready for further use. This swimlane diagram delineates the responsibilities of each participant in the system, showing how they collaborate to manage waste efficiently.

4.3.2 Use Case Diagram

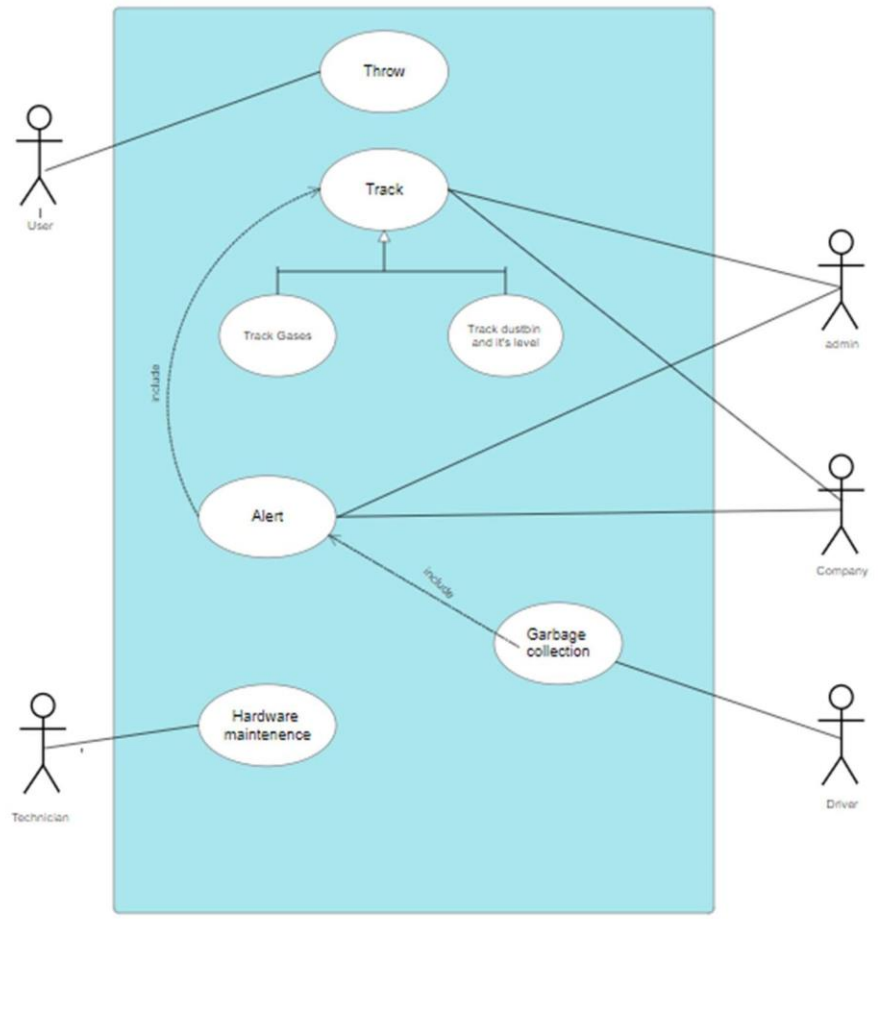

Fig.4.3.2 Use Case Diagram

This use case diagram illustrates the interactions between different actors (User, Admin, Company, Driver, and Technician) within a smart dustbin management system. The User is responsible for throwing trash into the dustbin. The system tracks various parameters, including the dustbin's fill level and the presence of gases, represented by the Track dustbin and its level and Track gases use cases. The Admin and the Company monitor these tracking activities. If certain conditions are met, such as the full dustbin or detecting hazardous gases, the system triggers an Alert. The Technician is responsible for hardware maintenance, ensuring the system's smooth operation, while the Driver is involved in the Garbage collection. The diagram shows how these actors interact with the system to manage waste efficiently and safely.

Use Case templates are used to organize and clarify the requirements and goals of our project.

<table>
<tr><td>1. Use Case Title</td><td>Throw Trash in Smart Dustbin</td></tr>
<tr><td>2. Abbreviated Title</td><td>Trash in Dustbin</td></tr>
<tr><td>3. Use Case Id</td><td>1</td></tr>
<tr><td>4. Actors</td><td>User (Resident)</td></tr>
<tr><td colspan="2">5. Description
The user can dispose of trash by utilizing a smart dustbin.</td></tr>
<tr><td colspan="2">6. Pre-Conditions
The user has access to a smart dustbin and has waste to dispose of.</td></tr>
<tr><td colspan="2">7. Task Sequence
a. Approach the Smart Dustbin.
b. Activate the Sensor.
c. Deposit the trash into the dustbin.</td></tr>
</table>

8. Alternate Scenario a. The hardware fails to activate or does not detect the trash presented by user. b. The smart dustbin is already full and cannot accept more waste.	
9. Post-Conditions a. The trash is successfully deposited in the smart dustbin. b. The smart dustbin records the trash deposition.	
10. Modification History	Date: 28 April, 2024
11. Authors	Jatin Thakur, Loveneet Kaur, Sarvika Bhan, Jasmeet Kaur

Description:
This use case involves a user (resident) disposing of trash using a smart dustbin. The process starts with the user approaching the dustbin, activating its sensor, and then depositing the trash.
The use case also considers alternate scenarios where the dustbin fails to detect the trash or is already full.
After successful disposal, the dustbin records the trash deposition, ensuring that the waste is managed properly.

1. Use Case Title	Smart Dustbin segregates waste
2. Abbreviated Title	Smart Dustbin segregates waste
3. Use Case Id	2
4. Actors	User (Admin, Resident)
5. Description The Smart Dustbin Segregates Waste use case enables users to deposit waste into a smart dustbin, which automatically segregates the waste into different	

categories (e.g., recyclable, organic, non-recyclable) using sensors, camera and sorting mechanisms.	
6. Pre-Conditions a. The smart dustbin is installed and operational. b. The user has waste items to dispose of. c. The user has access to the smart dustbin.	
7. Task Sequence a. User approaches the smart dustbin. b. User deposits waste items into the smart dustbin. c. Smart dustbin sensors detect the type of waste deposited. d. Sorting mechanisms segregate the waste into appropriate categories.	
8. Post-Conditions a. The waste is effectively segregated into different categories. b. Data regarding the type and quantity of waste deposited is recorded for monitoring and analysis purposes. c. Data is monitored by the Admin. d. The smart dustbin is ready for subsequent use.	
9. Modification History	Date: 28 April, 2024
10. Authors	Jatin Thakur, Loveneet Kaur, Sarvika Bhan, Jasmeet Kaur

Description:

This use case describes how a smart dustbin automatically segregates waste into different categories, such as biodegradable, hazardous, or non-biodegradable after the user (either an admin or resident) deposits the trash.

The smart dustbin uses sensors and sorting mechanisms to detect and categorize the waste. The system also records data about the type and quantity of waste, which can be monitored by the admin, ensuring the dustbin is ready for continued use.

<table>
<tr><td>1. Use Case Title</td><td>Garbage Collection</td></tr>
<tr><td>2. Abbreviated Title</td><td>Garbage Collection</td></tr>
<tr><td>3. Use Case Id</td><td>3</td></tr>
<tr><td>4. Actors</td><td>User (Admin, Garbage Collector)</td></tr>
<tr><td colspan="2">5. Description

With this facility, the garbage collector can collect waste from the smart dustbin after receiving a notification that the dustbin level has reached a certain threshold.</td></tr>
<tr><td colspan="2">6. Pre-Conditions

a. The smart dustbin is installed and operational.
b. The garbage collector has the necessary access rights and permissions.
c. The notification system is enabled and functioning properly.</td></tr>
<tr><td colspan="2">7. Task Sequence

a. Garbage collector receives a notification that the dustbin level has reached a certain threshold.
b. Garbage collector navigates to the location of the smart dustbin.
c. Garbage collector opens the smart dustbin.
d. Garbage collector collects waste from the smart dustbin.
e. Garbage collector closes the smart dustbin.
f. Garbage collector disposes of the waste appropriately.</td></tr>
<tr><td colspan="2">8. Post-Conditions

a. The smart dustbin is emptied and ready to receive more waste.
b. Garbage collector completes the collection process successfully.
c. The notification system may send another notification if the dustbin level reaches the threshold again.</td></tr>
<tr><td>9. Modification History</td><td>Date: 28 April, 2024</td></tr>
<tr><td>10. Authors</td><td>Jatin Thakur, Loveneet Kaur, Sarvika Bhan, Jasmeet Kaur</td></tr>
</table>

Description:
This use case covers the garbage collection process, where a garbage collector, notified by the system when the smart dustbin reaches a certain threshold, empties the bin. The collector receives a notification, goes to the dustbin's location, collects the waste, and disposes of it properly. The dustbin is then ready to receive more waste.
The use case ensures that the smart dustbin remains functional and that the waste collection process is efficiently managed, with the notification system prepared to alert the collector again if needed.

4.4 Snapshots of Work Accomplished

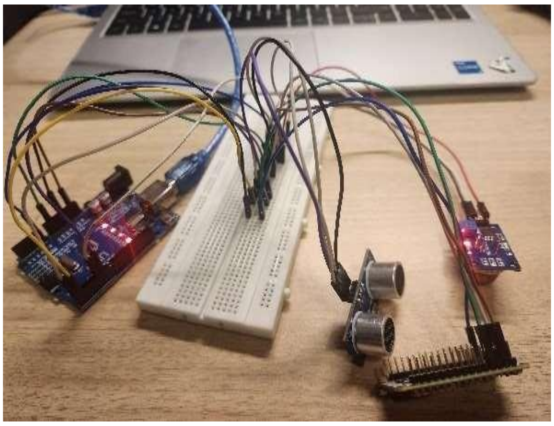

Fig.4.4.1 Circuit

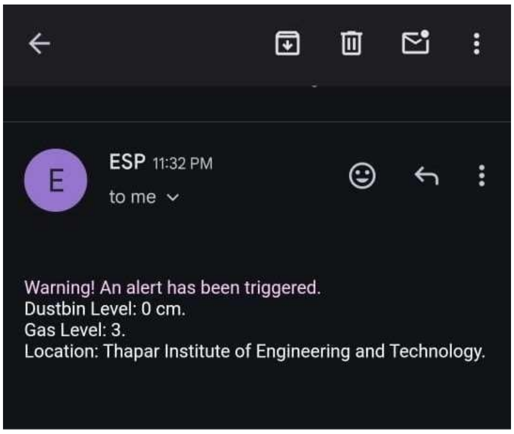

Fig 4.4.2 Email Notification

Fig.4.4.1 Dustbin's Back

Fig 4.4.4 Dustbin's Front

CONCLUSION AND FUTURE SCOPE

5.1 Work Accomplished

In this project, we have completed several critical components that enhance the functionality and safety of the Smart Waste Management System. First, we have implemented an advanced gas detection system to identify combustible gases like methane. This feature is designed to prevent potential fire hazards by continuously monitoring the environment within the waste bins and alerting authorities if dangerous gas levels are detected.

Additionally, we have developed and integrated an ultrasonic detection system to determine how full each bin is accurately. This system works by measuring the distance between the sensor and the waste within the bin—if the distance is short, it indicates that the bin is nearing total capacity through a notification. This feature ensures that waste is collected on time, preventing overflow and maintaining cleanliness in the area.

Moreover, we have successfully developed and trained an AI model for detecting and classifying waste. This model can accurately distinguish between hazardous, biodegradable, and non-biodegradable waste. By automating the sorting process, the system streamlines waste management operations. It ensures that different types of waste are processed appropriately, contributing to improved recycling rates and safer waste-handling practices.

5.2 Conclusion

In conclusion, we have achieved several key milestones in this project. The gas detection system has been successfully implemented to identify combustible gases, preventing potential fire hazards. The ultrasonic detection system has been completed to measure bin fill levels accurately, ensuring timely waste collection. The notification system for detecting combustible gases or dustbins being full is also implemented. The AI model has also been developed to classify waste into hazardous, biodegradable, and non-biodegradable categories, streamlining the sorting process. These accomplishments collectively enhance the safety, efficiency, and effectiveness of the Smart Waste Management System.

5.3 Environment Benefits

The Smart Waste Management System will play a vital role in environmental protection by automating precise waste sorting into biodegradable, non-biodegradable, and hazardous categories. This system will boost recycling rates and ensure waste is processed responsibly, diverting significant amounts from landfills, where they would otherwise release harmful chemicals and greenhouse gases.

Biodegradable waste will be directed to composting facilities, reducing methane emissions from landfills. Non-biodegradable materials will go to recycling centers, minimizing the need for raw material extraction, while hazardous waste will be carefully isolated to prevent environmental contamination and protect public health.

The system's ability to compress waste before collection will reduce the number of collection trips, lowering fuel consumption and greenhouse gas emissions, while extending the lifespan of collection vehicles. Additionally, by integrating with city initiatives and providing real-time data, the system will enable optimized waste management strategies, contributing to zero-waste goals and a more circular economy.

In summary, the Smart Waste Management System will not only address waste management challenges but also support broader sustainability goals by enhancing recycling, reducing landfill use, and lowering carbon emissions, contributing to the global fight against climate change.

5.4 Future Plan

In the future, we plan to build on our progress by integrating the completed modules into a fully operational system. One of our primary goals will be implementing a compressor within the bins to enhance the system's efficiency further. This compressor will activate when the bin is nearing full capacity, automatically compressing the waste to create additional space. By doing so, the system can hold more waste, reducing the frequency of collection trips and optimizing waste management operations.

Additionally, we will integrate a camera module, which will play a crucial role in the system's functionality. The camera will be used to identify waste types, and based on the output, it will control the opening and closing of the bin, ensuring that only the correct waste is deposited. These planned integrations will streamline the waste management process and significantly improve the system's overall functionality, making it more responsive, efficient, and capable of addressing the demands of modern urban environments.

APPENDIX A: REFERENCES

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APPENDIX B: PLAGIARISM REPORT

I, Jasmeet Kaur, affirm the originality and authenticity of the content presented in the document titled "Smart Waste Management System." As one of the authors of this work and the leader of the group, along with Sarvika Bhan, Jatin Thakur, and Loveneet Kaur, I assert that we have collectively created every word, sentence, and idea contained within this document and reflects our intellectual contributions. Throughout the process of crafting this document, we have meticulously upheld the principles of academic integrity by avoiding any form of plagiarism. This document manifests our collaborative research, creative thinking, and dedicated effort on our Capstone Group Project. We have conscientiously undertaken measures to verify the uniqueness of the content, ensuring that it remains distinct from any pre-existing works. Any semblance between this document and other works is purely coincidental, unintentional, and a testament to the shared exploration of the subject matter. We acknowledge the severe implications of plagiarism in academic and professional contexts, including its negative impact on the credibility of our work and the erosion of ethical values. We are committed to upholding the principles of academic honesty, integrity, and responsible scholarship. With the highest regard for intellectual authenticity, we submit this document as an authentic representation of our contributions.

Date: 22.08.2024

Signatures: