PRESIDENCY UNIVERSITY

Private University Estd. in Karnataka State by Act No. 41 of 2013

Itgalpura, Rajankunte, Yelahanka, Bengaluru – 560064

SMART WASTE MANAGEMENT, DISPOSAL AND SANITIZATION MONITORING AI SYSTEM

A PROJECT REPORT

Submitted by

JOYSON C H – 20221CSE0531

TEJAS N B – 20221CSE0560

RAMYA S V – 20221CSE0550

Under the guidance of,

Ms. SHET RESHMA PRAKASH

BACHELOR OF TECHNOLOGY

IN

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BONAFIDE CERTIFICATE

Certified that this report "**SMART WASTE MANAGEMENT, DISPOSAL AND SANITIZATION MONITORING AI SYSTEM**" is a bonafide work of "JOYSON C H (20221CSE0531), TEJAS N B (20221CSE0560), RAMYA S V (20221CSE0550)", who have successfully carried out the project work and submitted the report for partial fulfilment of the requirements for the award of the degree of BACHELOR OF TECHNOLOGY in COMPUTER SCIENCE ENGINEERING during 2025-26.

Ms. Shet Reshma Prakash
Project Guide
PSCS
Presidency University

Dr. Jayavadivel Ravi
Program Project Coordinator
PSCS
Presidency University

Dr. Sampath A K
School Project Coordinators
PSCS
Presidency University

Dr. Asif Mohammed
Head of the Department
PSCS
Presidency University

Dr. Shakkeera L
Associate Dean
PSCS
Presidency University

Dr. Duraipandian N
Dean
PSCS & PSIS
Presidency University

Name and Signature of the Examiners

1)

2)

PRESIDENCY UNIVERSITY

PRESIDENCY SCHOOL OF COMPUTER SCIENCE AND ENGINEERING

DECLARATION

We the students of final year B.Tech in COMPUTER SCIENCE ENGINEERING, at Presidency University, Bengaluru, named JOYSON C H, TEJAS N B, RAMYA S V, hereby declare that the project work titled **“SMART WASTE MANAGEMENT, DISPOSAL AND SANITIZATION MONITORING AI SYSTEM”** has been independently carried out by us and submitted in partial fulfillment for the award of the degree of B.Tech in COMPUTER SCIENCE ENGINEERING during the academic year of 2025-26. Further, the matter embodied in the project has not been submitted previously by anybody for the award of any Degree or Diploma to any other institution.

JOYSON C H	20221CSE0531
TEJAS N B	20221CSE0560
RAMYA S V	20221CSE0550

PLACE: BENGALURU

DATE: 02-DECEMBER 2025

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JOYSON C H
TEJAS N B
RAMYA S V

Abstract

Rapid urbanization and population growth yield excessive waste, which negatively impacts the environment and public health it could lead to contamination and wasted resources. Manual collection and disposal do not lend themselves to either efficiency, cleanliness, or accuracy, and can be too time-consuming, or simply overlook valuable waste. In addition, not keeping proper track of sanitation after waste removal can reduce a sense of responsibility, as well as increase the risk of illness. To lessen that burden, this paper presents the initial version of a centralized for managing waste.

Rapid population growth and shifting consumption patterns are making the growing amount of waste in urban environments problematic. Due to inadequate waste management, resources are being wasted, landfills are overflowing, collection is delayed, and the streets are littered. Resources are wasted and environmental pollution rises.

We will present smart waste management which utilizes technology to ensure waste is sorted, disposed, and sanitized properly. Smart waste management manages waste handling in cities and college campuses. Furthermore, smart waste management is able to provide real-time tracking of the collection and cleaning process. This process helps people take ownership, increases community engagement, and ensures that waste is being managed in an environmentally-friendly manner.

The rapid expansion of city dwellers has made the situation of waste management more challenging and, thus, intensified the problems of inefficiencies, missed collections, and poor post-disposal sanitization. In order to tackle these challenges, the current research proposes an AI-based integrated system for smart waste management, disposal, and sanitization monitoring that merges web technologies and analytics to improve transparency, accountability, and the overall efficiency of waste management. The solution enables the monitoring of disposal in real-time, verification of sanitization, prediction of analytical support for collection-based scheduling, and citizen involvement through a reporting module. Special dashboards for each role allow the administrator, workers, and the public to jointly observe the activities related to waste, the trustworthiness of the data being handled being guaranteed by the secure backend services. The experimental evaluation carried out in a controlled setting shows that there is better accuracy in logging, increased community participation, and smoother workflow.

Keywords—Smart Waste Management, Sanitization Monitoring.

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Abbreviations

Abbreviation	Full Form
AI	Artificial Intelligence
IoT	Internet of Things
GIS	Geographic Information System
UI	User Interface
UX	User Experience
API	Application Programming Interface
GPS	Global Positioning System
DB	Database
HTTPS	Hypertext Transfer Protocol Secure
CRUD	Create, Read, Update, Delete
ML	Machine Learning
SDLC	Software Development Life Cycle
V-Model	Verification and Validation Model
RBA	Role-Based Access
RDBMS	Relational Database Management System
MCU	Microcontroller Unit
IDE	Integrated Development Environment
VCS	Version Control System
CI/CD	Continuous Integration / Continuous Deployment
HIL	Hardware-in-the-Loop
UI/UX	User Interface / User Experience
PM	Project Management
KPI	Key Performance Indicator

Chapter 1

Introduction

1.1 Background

The processes of rapid urbanization and continuous population growth have resulted in a tremendous increase in the amount of waste produced in cities and institutes. The use of old waste management strategies such as the manual collection of waste, irregular disposal and no sanitation monitoring has slowly been rendered obsolete and now cannot meet the demand for cleaner and more sustainable cities [1][4]. Poor disposal practices, delayed collections and no sanitation tracking after waste removal are among the factors contributing to the deterioration of the environment, health risks, and public discontent [7]. Besides, the current trends in consumption and rising waste levels have made it very important to have a centralized, technologically advanced waste management system that is able to guarantee cleanliness, operational transparency, and public welfare [2].

1.2 Statistics

According to global data, there is a rapid increase in waste generation caused by factors such as population density, urban migration, and changing consumption habits, which result in the production of municipal waste of up to 2 billion tons annually worldwide [7]. A smart waste management system study informs that waste in under-developed areas is either not collected or poorly managed, thus adding to the problem of contamination and disease [4]. Research on the integration of IoT and AI technologies point to very large manual workflow inefficiencies, one of which is the delayed picks and the unmonitored sanitation cycles [6][12]. The challenges faced by schools and cities are similar and it is reported that smart systems deployed at large scale have led to better tracking, reduced fuel consumption, and optimized routing [9][11].

1.3 Prior existing technologies

Waste management has been the focus of several technological solutions that tried to sell modern treatments, the solutions they offered addressed particular drawbacks but they were not able to provide a fully integrated one. The smart bins based on the Internet of Things and equipped with fill-level sensors have raised the level of automation with the basic requirement by sending alerts for collection at the right time; however, they usually do not have any sanitization or hygiene-related workflows [1][2]. In addition to that, segregation systems driven by Artificial Intelligence further increase efficiency by accurately sorting out the recyclable, organic, and hazardous materials, in fact, most of them are still just doing recognition tasks with no possibility of end-to-end handling or processing enabled [3][5]. The use of big data analytics has also been part of the waste management department for predicting the patterns of waste generation and supporting the decision-making process of municipalities which led to better planning through the establishment of more efficient waste disposal systems [6]. EcoTrack, among the smart routing solutions, works by optimizing the navigation and the fuel consumption for vehicles meant for waste collection, thus, it is an aid to the logistics streamlining [11].

On the other hand, IoT and Edge-AI platforms that are hybrid provide both real-time monitoring and quick decision-making; however, they are usually limited by challenges related to scalability, maintenance, and privacy [9][14]. The integration of into more intricate frameworks has resulted in solutions that are endowed with high transparency and tamper-proof data management; nevertheless, such systems are still very costly and their large-scale deployments are not yet facilitated, which in turn leads to the limitation of their widespread adoption [10][13].

1.4 Proposed approach

1.4.1 Aim of the Project:

Aiming at the formation of a sophisticated, smart, and AI-supported waste management system that will offer tracking of disposal in real-time, verification of sanitization done automatically, analytics that will predict and optimize the process of collection, and reporting that will be auditable by the users, namely, administrators, workers, and citizens.

1.4.2 Motivation:

The project is driven by the rising problems associated with the disposal of waste that is not managed properly, the health risks caused by poor sanitization, and the inefficiencies of manual waste management systems indicated in the previous studies [4][7]. IoT bins [1], smart routing technologies [11], and waste-classification models [3] have been developed but still cannot provide a full-fledged platform that connects tracking, cleanliness validation, and community engagement. Hence, a unified smart system becomes necessary.

1.4.3 Proposed Approach:

- Real-time disposal logging based on IoT tracking model inspirations [1][2].
- AI-Efficiency in sanitization monitoring, corresponding to the recent phase in AI hygiene assessment through scoring [3][12].
- Predictive analysis for route and schedule optimization as done in the case of big data waste forecasting [6][9].
- Exclusive dashboards for insight, responsibility, and safe access tiers.
- Public reporting on the lines of the recommended participatory systems in the current smart city research [11].
- Safe backend structure that guarantees data correctness, reliability, and openness, highlighted in blockchain-based waste management systems [10][13].

1.4.4 Application of the Project:

- Management of Municipal and Public Waste.
- Waste Management of Households and Neighbourhood's.
- Waste Monitoring of Institutions, Industries, and Businesses.
- Waste Management for Events and Large Venues.

1.4.5 Limitations:

- In order to make a large-scale deployment, the establishment of a powerful networking as well as backend infrastructure is a necessity [14].
- Workflow driven by sensors need reliable connection and uniform calibration [4].
- User participation greatly impacts the effectiveness of citizen reporting in terms of accuracy.
- Accuracy depends on image clarity and environmental lighting [3].

1.5 Objectives

1.5.1 Behaviour:

The core purpose of the system is to keep track continually of the things that are thrown away in the smart bins, such as their level, type, and compliance with the segregation. It is the collection of the system that provides the authorities with a real-time view of how waste builds up in various parts of the city. Tracking behaviour not only helps in discovering the presence of new types of waste (e.g. together with or improper segregation such as hazardous waste) but also in sending alerts for collection or cleanup at the right time. In one instance, smart bins may alert the collection trucks when they are over a certain limit, which means that the bins are emptied before overflowing, and in this way, a clean and hygienic environment is kept.

1.5.2 Analysis:

One of the most important goals is to get insights through predictive analysis of historical and real-time waste data. Waste generation time peaks can be outright predicted, waste zones can be recognized, and collection schedules can be improved based on this forecasting. Confirmed with this feature, no more than necessary trips will be made, fuel consumption will be reduced, and efficiency in operations will be boosted. Moreover, urban waste analysis leads to municipalities making better and more cost-effective resource allocations by revealing insights into urban waste patterns through data analysis. This objective can be proven through the output of predictive reports, trend graphs, and route schedules for collection vehicles that are already optimized.

1.5.3 System Management:

The project has the ambition to create a single management system that can be used by the city authorities to control all the different parts of the waste management infrastructure. The dashboard is capable of real-time process monitoring, automatic alerts dispatching, performance tracking, and operational analytics. It does not only help the authorities in organizing waste collection in a highly optimized manner by highlighting the areas that need the most immediate attention but also keeps them informed about the overall state of the system. The management system goal is manifested via the live dashboard view, which shows the bins' statuses, vehicles' locations, and sanitation reports.

1.5.4. Security:

Security has been considered a fundamental aspect right from the start of the design process, and it ensures that the user's data, location logs, and complaint reports are never made public on a second basis. The transmission of data is secured with HTTPS encryption, and the access is controlled by authentication and authorization mechanisms. Injection attacks are prevented on a database query level, and rate limiting interrupts bad acts like spamming or brute-forcing attempts, etc. User activities are monitored with the help of audit logs maintained for responsibility. Consequently, there is the creation of a very high level of integrity and trust among the users which happens to be the key factor in major city or government installations.

1.5.5 Deployment:

System deployment is done with a mix of cloud hosting, backend services, and database infrastructure. The frontend is made available through a dependable platform, either GitHub Pages or cloud servers, that guarantee high availability. The backend (Node.js/Express) is installed on platforms like AWS, Render, or Azure that provide scalability and load balancing. Reports, logs, and images are stored securely in databases either on MongoDB Atlas or in a local MongoDB database. There are CI/CD pipelines that automate testing and updates. The whole deployment strategy leads to increased user demand for the system that it is able to accommodate and the efficiency of operating the system across campuses, cities, and organizations.

1.6 SDGs

- **SDG 3 – Good Health and Well-being**

  This system provides a safe environment for people's health by keeping waste properly disposed of and verified sanitation. Thus, waste, insects, and germs are kept at bay. Moreover, the system by preventing the unhygienic conditions ensures that the citizens, workers as well as the students have healthier living spaces.

- **SDG 6 – Clean Water and Sanitation**

  Proper disposal and post-cleaning verification as a direct consequence maintain water sources free of contaminants and the incidence of waterborne diseases is also reduced. The system makes sure sanitation is done in a responsible way and hygiene standards are kept in the public and campus areas.

- **SDG 11 – Sustainable Cities and Communities**

  Smart monitoring, AI-driven analysis, and citizen reporting do support cleaner, well-managed urban spaces. The technology integration into waste operations leads to the development of sustainable, smarter, and more liveable cities

- **SDG 12 – Responsible Consumption and Production**

  AI-based waste classification and data analytics help to a great extent in encouraging responsible waste segregation and recycling. Predictive models as well are used by authorities for the planning of resource-efficient, sustainable waste handling as well as consumption patterns.

- **SDG 13 – Climate Action**

By optimizing collection routes, the road usage is reduced, and the number of unnecessary trips made by vehicles is minimized; the system indirectly carbon emissions. Furthermore, improved waste handling prevents methane emissions from unmanaged waste dumps.

Fig 1.1 Sustainable development goals [1]

1.7 Overview of project report

The project report divides into nine chapters that tell the story of the Smart Waste Management, Disposal, and Sanitization Monitoring AI System, from its design to its impact. **Chapter 1** contains a project introduction consisting of background information, goals, motivation, definition of the problem, and relation to the UN Sustainable Development Goals that are pertinent. **Chapter 2** encompasses a thorough literature review that includes IoT-based waste systems, AI-driven waste segregation, smart sanitation technologies, and drawbacks of current solutions. The approach is explained in **Chapter 3**, which describes the system architecture, workflow, functional modules, deployment environment, and data processing techniques. The Chapter 4 focuses on project management aspects like planning and scheduling, resource allocation, development phases, and risk assessment. The Chapter 5 is set aside for the analysis and design, where system requirements, use cases, architectural diagrams, interface layouts, and database structures are all elaborated on. Hardware and software components used are described in **Chapter 6** along with simulation tools and platforms that have been utilized for testing and development. Performance testing, sanitization accuracy, system functionality validation, and comparative findings are among the evaluation and results discussed in **Chapter 7**. Ethical, legal, social, sustainability, and safety issues in connection with the implementation of a smart waste system are analysed in **Chapter 8**. Ultimately, **Chapter 9** wraps up the report with a project outcomes summary, a spotlight on main contributions, and a proclamation of future enhancement and large-scale deployment paths.

Chapter 2

LITERATURE REVIEW

1. IoT-Based Intelligent Garbage and Waste Collection Bin – Navghane et al. (2016) [1]

In this paper, a smart bin supporting IoT is presented that comes with ultrasonic sensors for waste level detection. Thus, the system provides an automated process of monitoring bins and notifying the respective authorities whenever the bins are full. Detection-wise it is efficient but doesn't possess the features of segregation, routing, or sanitization processes.

2. Smart Waste Management System Using Io – Sultan et al. (2016) [2]

The authors illustrate an IoT model-based waste monitoring system, which makes the status of waste bins available in real-time via wireless communication. It has a great effect on the visibility of collection but is not economically feasible since it requires expensive IoT infrastructure and also lacks end-to-end tracking.

3. AI-Enabled Waste Segregation and Recycle Management – Sharma & Kumar (2020) [3]

The paper proposes an entirely automated waste segregation system based on a deep learning algorithm. The system is capable of classifying the different types of waste with very high accuracy thus, it supports the recycling process.

4. Waste Management Using IoT and Machine Learning Techniques – Kumar & Shanthini (2021) [5]

The researchers combined IoT and ML to estimate the amount of waste generated and design better collection routes. Their work presents a theoretical framework for the efficient management of waste but doesn't cover the actual implementation and lacks also sanitization aspects.

5. Big Data Analytics for Waste Management – Chowdhury & Hossain (2022) [6]

The research is beneficial to urban development in the long run but it also requires enormous computational power and sophisticated infrastructure.

6. What a Waste 2.0 — Global Snapshot to 2050 – World Bank (2018) [7]

A global paper that gives stats on waste and predicts future trends with 3.4 billion tons of waste as the number one estimate for 2050. It points out the urgency of smart waste solutions and gives no tech implementations however.

7. Smart Waste Management Systems: IoT and AI Approach – Gupta et al. (2025) [8]

The research in question has been done with combining the IoT and AI for tracking of waste and improving the operational efficiency. The system that has been developed offers both analytics and automation but no module for sanitization verification is present.

8. IoT-Enabled Smart Waste Management System Utilizing Edge AI – Punia (2025) [9]

Edge AI is incorporated in the system to minimize the time lag and allow monitoring of waste bins to be carried out in the real time. On one hand this enhances responsiveness, on the other it raises issues with privacy and heavily relies on the availability of edge hardware.

9. AI and IoT-Enabled Smart Urban Waste Management System for Efficient Collection, Segregation, and Disposal – Devi et al. (2025) [10]

This paper presents an approach where IoT, AI, and Blockchain are integrated to bring transparency and security to the waste tracking process. The waste cycle handling is done automatically but the implementation is taking up a lot of time and is costly.

10. EcoTrack: The Smart Waste Collection Navigator – Shashank et al. (2024) [11]

EcoTrack is a system that mainly relies on GPS for route optimization which leads to better fuel consumption and less missed collections..

11. Smart Waste Management Systems: IoT and AI Approaches to Sustainable Urban Sanitation – Yadav et al. (2025) [12]

The use of IoT and AI hand in hand for smarter waste collection and sanitation monitoring is the main focus of the research. Urban cleanliness is improved, although the difficulties of sensor calibration and data handling are still present.

12. AI and IoT-Enabled Smart Urban Waste Management System for Efficient Collection, Segregation, and Disposal – Devi et al. (2025) [13]

The situation in which the waste management system is supported by blockchain guarantees that the information is safe and cannot be altered. Nevertheless, it provides a very trustworthy disposal record but also demands a sophisticated technical setup and constant substantial maintenance.

14. IoT-Enabled Smart Waste Management Using Edge AI for Real-Time Monitoring and Optimization – Punia (2025) [14]

The Edge AI technique processes the waste data within the locality thereby lessening the server load and increasing the speed. It is quite effective, yet it is restricted by the hardware limitations and the possible security risks.

SL NO.	ARTICLE TITLE, PUBLISHED YEAR, JOURNAL NAME	METHODS	KEY FEATURES	MERITS	DEMERITS
1	IoT-based Intelligent Garbage and Waste Collection Bin (Navghane et al., 2016)	Ultrasonic sensors, IoT	Automatic bin-level detection	Reduces manual checking; real-time monitoring	No waste segregation; no sanitization tracking

2	Smart Waste Management System using IoT (Sultan et al., 2016)	IoT nodes, wireless communication	Real-time waste tracking	Better monitoring and collection optimization	High hardware/infrastructure cost
3	AI-enabled Waste Segregation and Recycle Management (Sharma & Kumar, 2020)	Deep learning, image processing	AI-based waste type classification	High accuracy in segregation	Does not track waste after disposal
4	Smart Waste Management: Issues & Opportunities (Hannan et al., 2018)	Review of IoT & ML systems	Identifies challenges, opportunities	Comprehensive study of smart waste technologies	No implementation; only theoretical
5	Waste Management using IoT & ML Techniques (Kumar & Shanthini, 2021)	IoT, Machine Learning	ML-driven route & waste prediction	Improved collection efficiency	Model not tested in real-world
6	Big Data Analytics for Waste Management (Chowdhury & Hossain, 2022)	Big data analytics	Large-scale waste trend prediction	Useful for city-level planning	Requires high computation power
7	What a Waste 2.0 – Global Waste Report (World Bank, 2018)	Statistical analysis	Global waste projections	Strong global reference data	No technological solutions provided
8	Smart Waste Systems: IoT & AI Approach (Gupta et al., 2025)	IoT + AI integration	Real-time analytics & automation	Enhanced efficiency & accuracy	Lacks sanitization verification
9	Edge-AI Waste Monitoring System (Punia, 2025)	IoT +Edge AI	Real-time detection with low latency	Lower processing delays	Privacy and scalability concerns
10	AI & IoT-Enabled Smart Urban Waste System (Devi et al., 2025)	IoT + AI + Blockchain	Automated collection & secure data	High transparency & traceability	Complex, costly integration
11	EcoTrack – Smart Waste Collection Navigator (Shashank et al., 2024)	GPS routing, IoT	Route optimization & fuel reduction	Saves time and fuel	Only focuses on routing
12	Smart Waste Management: IoT & AI for Urban Sanitation (Yadav et al., 2025)	IoT sensors + AI	Smart sanitation + collection	Improved sanitation outcomes	Sensor calibration issues
13	Blockchain-enabled Smart Urban Waste System (Devi et al., 2025)	Blockchain + IoT + AI	Data integrity & automated workflows	High accountability & trust	High deployment cost
14	Edge AI Real-Time Waste Optimization (Punia, 2025)	Edge computing + IoT	Faster processing near source	Reduced server load	Hardware dependency and security concerns

Table 2.1 Summary of Literature reviews

Chapter 3

METHODOLOGY

The proposed Smart Waste Management, Disposal Tracking, and Sanitization Monitoring System is detailed in this section through system architecture, functional modules, workflow, deployment environment, data flow, and evaluation procedures.

3.1 Functional Modules

1. Waste Disposal Tracking Module:

The module provides a real-time overview of all waste collection across different locations.
In addition, it has the following major capabilities:

• Keeps time-stamped records of disposal events.
• Collects photos from the workers to confirm.
• Updates the dashboard for both admin and citizens automatically.
• Connects with route optimization APIs for human-efficient scheduling.

The transparency created by this module along with the prevention of missed collections, is a solution to the problems pointed out in studies like IoT-based smart bins [1] and optimized routing models [11].

2. Sanitization Logging & Monitoring Module:

The features are:

• AI-based image analytics to detect cleanliness levels aligned with the recent research [3][12].
• Workers upload the "before and after" images as proof.
• The system flags the unsatisfactory sanitation and reassigns the task.
• It provides sanitation statistics report (e.g., compliance rate, average response time).

It makes sure that the hygiene requirements are covered thus, contamination risks are reduced.

3. Predictive Analytics Module:

This module applies old data to make predictions and get insights.
More main points:

• Predicts the incorporation of waste in the different zones.
• Find the patterns like the peak waste hours and where the risks are located.
• Allows the administrators to quickly plan the collection schedules.
• Applies machine learning to trend evaluation (similar to big data studies [6]).

The above module is a great help in taking correct decisions and optimizing resources.

4. Community Engagement Hub:

This module not only encourages the public to get involved but also supports the sustainability cause.

The following are the main additions:

• The program that informs the public about recycling and waste segregation is executed.

• Cleanliness ratings are published to make the community responsible and accountable.

• There are game-like things such as badges for those who report actively.

• It interacts with the Clean City Reporting tool so that public participation is made easier.

• It promotes behaviour change based on SDGs (related to SDGs 11, 12, 13, 17)

5. Role-Based Access Control Model:

Guarantees secure entry and blocks unauthorized access to the system.

Further improvements:

The above-mentioned improvements are very promising, to mention a few:
•User rights are assigned hierarchically (Admin > Worker > Citizen).
• Handling of sessions is done in a way that secure authentication of users is employed throughout.

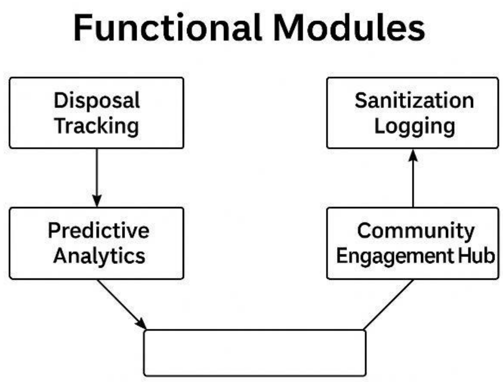


Fig 3.1 The V model methodology [4]

3.2 Environment Deployment

The Smart Waste Management and Sanitization Monitoring System is executed in a completely web-based environment that guarantees accessibility, easy maintenance, and unlimited scalability. The environment brings together modern frontend technologies, a strong backend framework, cloud-based databases, and third-party APIs for real-time operations to support the entire system.

The system features a responsive and user-friendly interface which is designed through HTML5, CSS3, JavaScript, and Tailwind CSS. The use of Tailwind CSS in the application for utility-based styling ensures that the user experience is uniform and flexible across desktop and mobile devices. All of the user interactions such as raising issues, viewing calendars, image uploading, and tracking progress are channelled through this engaging frontend layer.

The server-side for the system is Node.js and Express.js who take care of whole API operations, routing, server-side validations, and request processing. While Express.js uses fast, light but powerful RESTful API structure for communication between user interface and the database thus making it very efficient.

3.3 System Architecture

❖ Users Laye:

This layer includes all the users of the system along with their respective access privileges. Admins take care of user roles assignment, performance evaluation reports, workflow control, and system supervision. The personnel carry out the waste collection, sanitation, and updating of tasks through the mobile app designed specifically for them.

❖ User Interface Layer:

The User Interface layer offers web and mobile dashboards leveraging modern technologies such as React.js, Tailwind CSS, HTML5, and JavaScript.

Its functionalities include:

- Instant access to schedules, reports, and notifications.
- Visualizations on maps showing where complaints are located.
- Possibility to upload images and provide detailed descriptions.
- Analytics dashboards for admins (graphs, logs, statistics).

❖ Backend Services Layer:

The backend functions as a consequential processing plant spun around Node.js and Express.js. Herein, these activities are correlated:

- Authentication and session management.
- API communication between the user interface and the database.
- Distribution and updating of tasks.
- Data validation, error handling and route optimization.
- Saving and getting logs, complaint statuses and analytics.

❖ Data Management Layer:

MongoDB's database plunks system data, which includes the following:

- Records of sanitation process with images as proof.
- Information of complaints along with their location data.
- Data sets for prediction and past patterns.

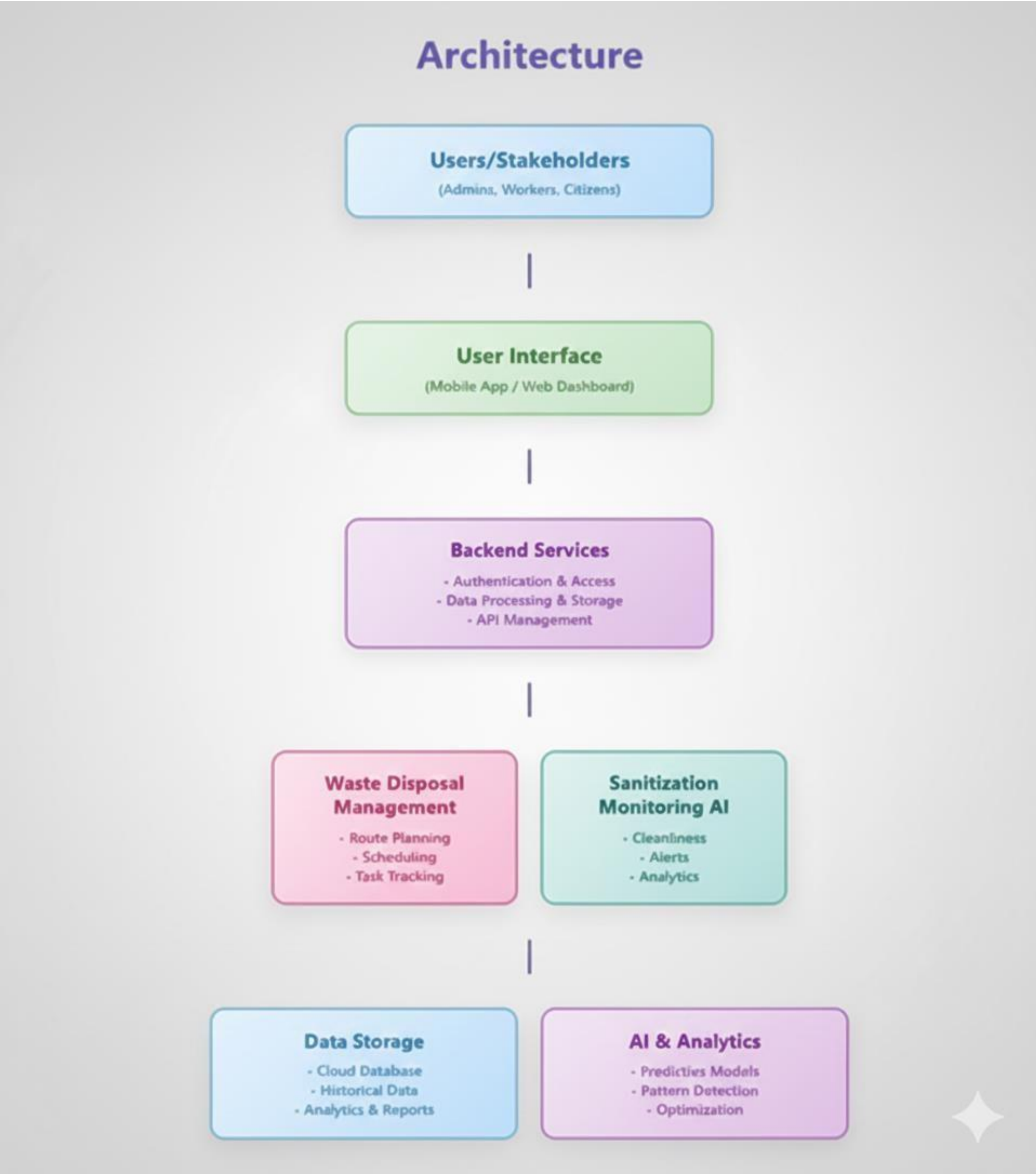


Fig 3.2 System Architecture.

3.4 Clean City Reporter

The Clean City Reporter module is a key element among the components of the suggested smart waste management ecosystem. It empowers the citizens to take part in urban hygiene activities by notifying the authorities about waste concerns via an easy-to-use, map-based interface. Besides, this module makes community engagement stronger, increases the level of transparency, and facilitates instant communication among the public, administration, and field workers.

a) System Overview:

i. Frontend (User Interface)

- The front end is developed by using the combination of HTML5, CSS3, JavaScript, Tailwind CSS, and React.js.
- It provides a user-friendly interface for issuing a report.
- Image upload and tracking of status are among its features.
- It is responsive and very easy to use at the same time.

ii. Map Integration Layer

- The Google Maps API is utilized for the purpose of location selection.
- Users have the option of marking the precise locations of the problems.
- Auto-detection based on GPS is supported.

The system is able to spot areas with a concentration of waste.

iii. Backend (Data Handling)

- The backend is created with the use of Node.js and Express.js.
- The system takes care of the form submissions, and the data is validated.
- The reports and the updates of the tasks are stored in MongoDB.
- There is real-time synchronization and secure handling of the data.

b) Workflow of the Module:

The data flow and operational diagram of the Clean City Reporter is depicted by the following steps:

i. The user will submit the issue by selecting its title and category and writing its description. Optionally, the user can also upload pictures to give more context.

ii. To make the issue more visible and located correctly the user through the integrated map interface chooses the exact geographical area where the problem is located.

iii. The data is inputted, validated and then either stored in the local Mongo database.

iv. The reported issue now appears in the admin panel and the concerned authority who has the power to review, assign or mark it as closed can take steps accordingly. The task's status and feedback will be automatically saved in the system.

v. After the successful submission the user receives a confirmation message. The status is updated in the citizen view when the problem is solved, hence providing transparency and accountability.

c) Implementation Details:

The frontend of the application is developed using React.js, while for backend communication Node.js with Express is employed. MongoDB is used as the primary database for storing user reports and their statuses. The application has a modular architecture and therefore could be easily extended with the inclusion of AI applications like waste detection and sanitation monitoring.

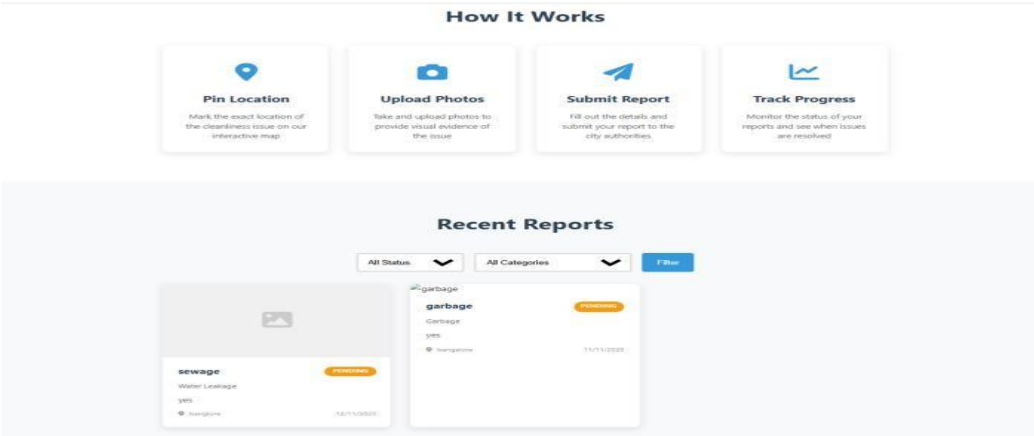


Fig 3.3 System Overview [6]

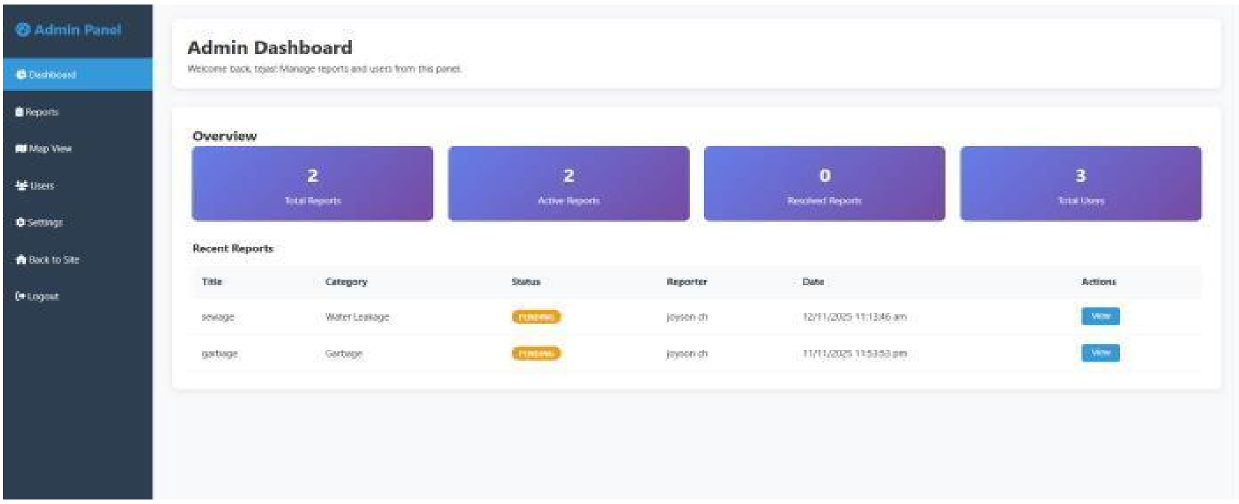


Fig 3.4 (a) Admin Dashboard [7]

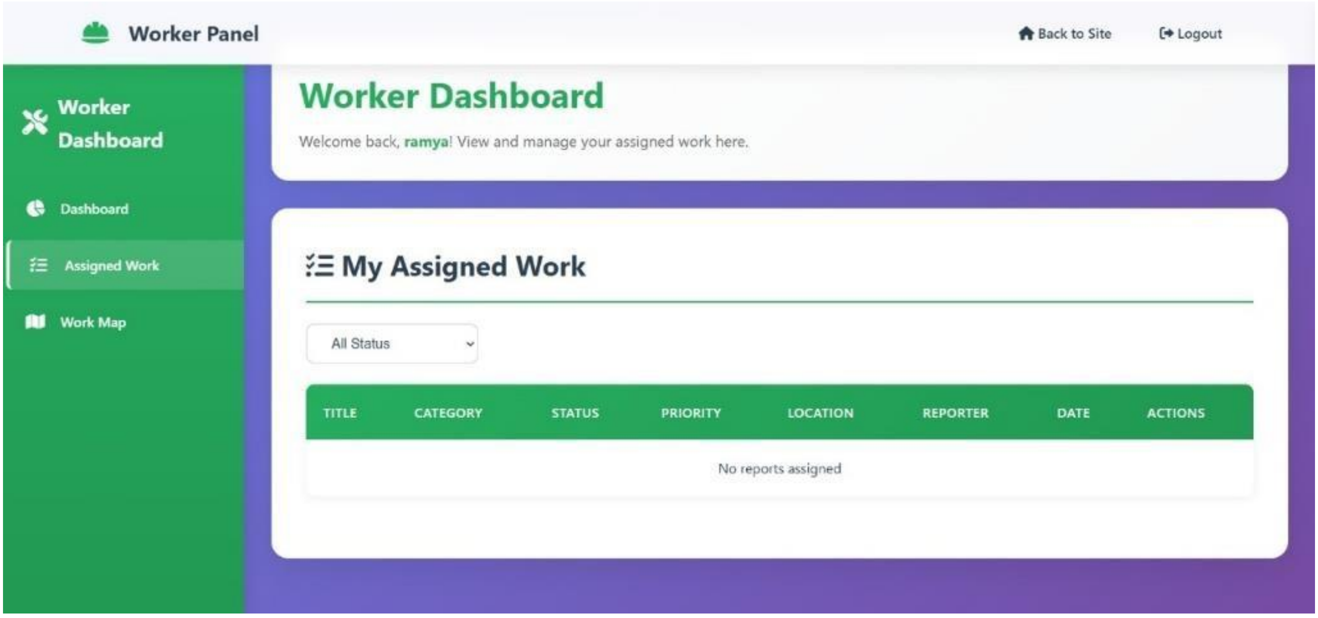


Fig 3.4 (b) Worker Dashboard [7]

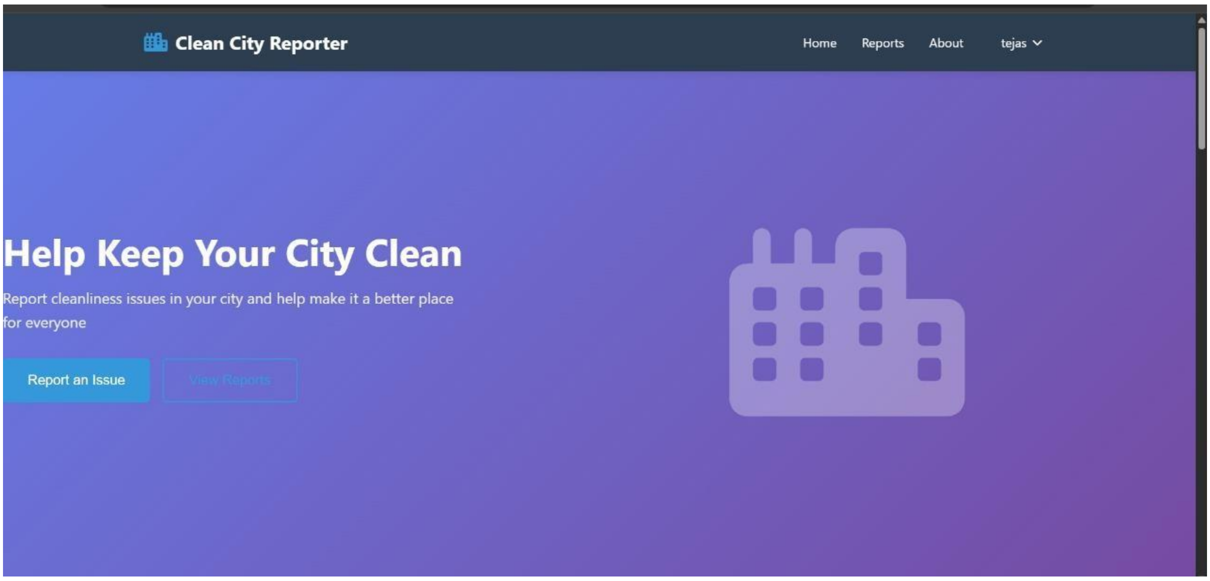


Fig 3.5 (c) User Dashboard [7]

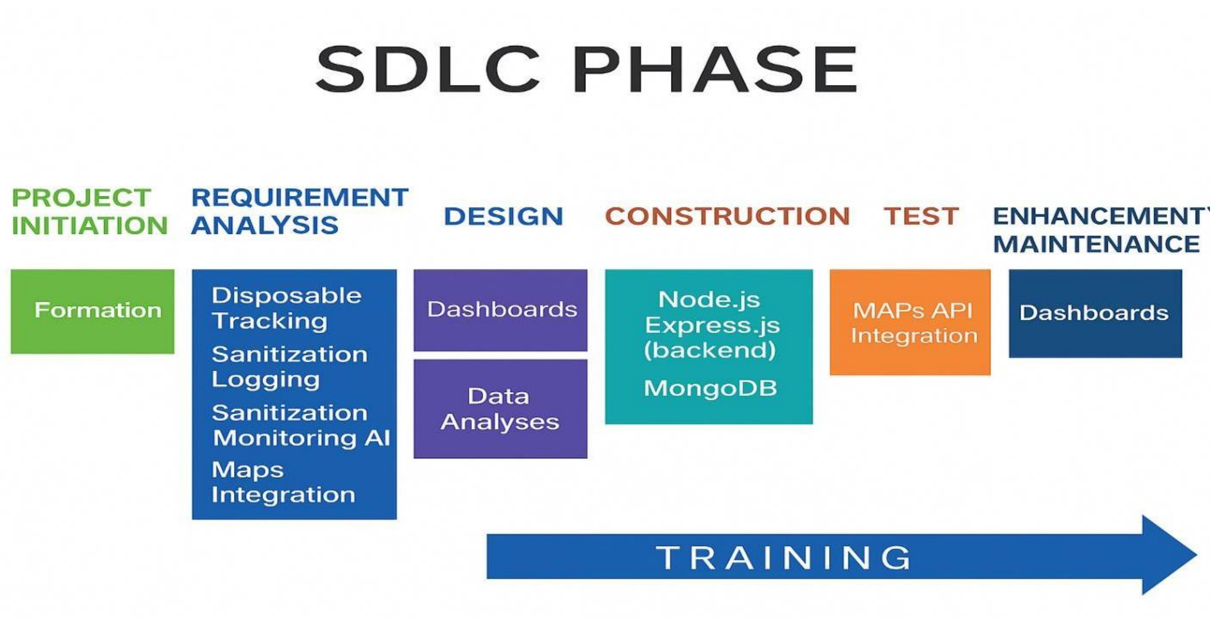
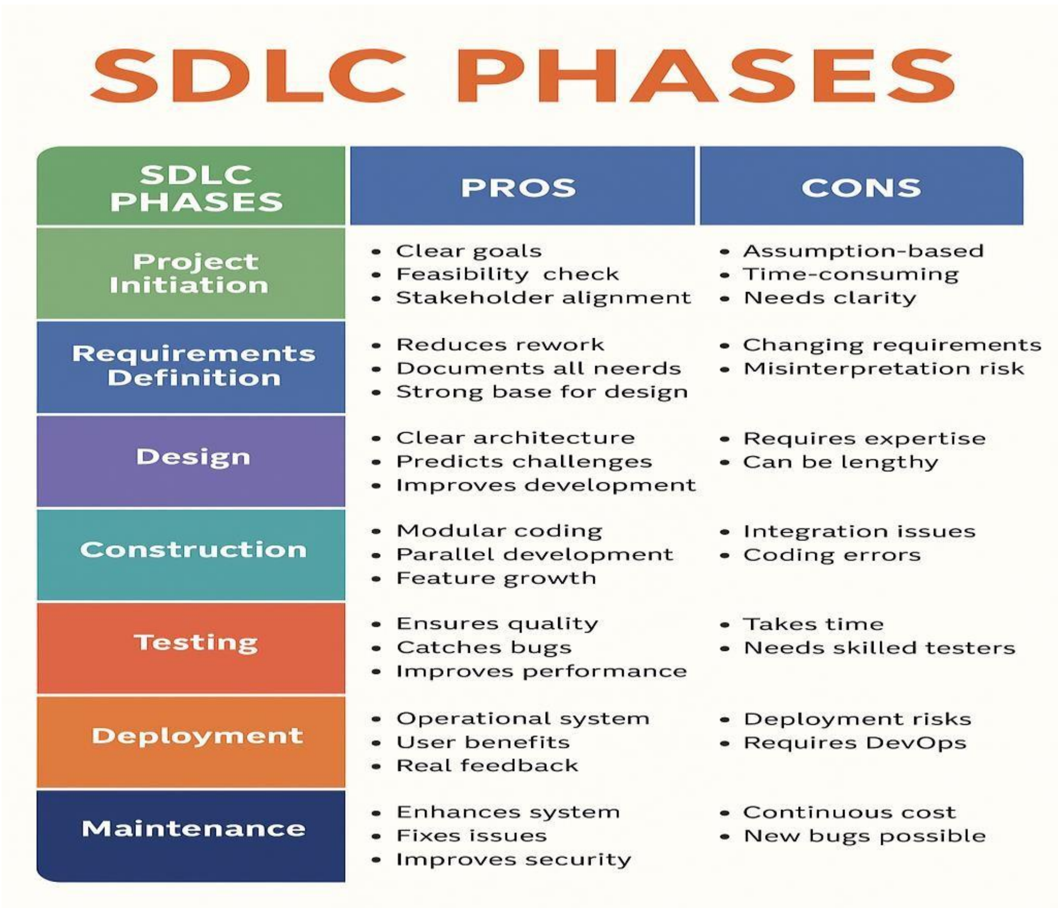


Fig 3.5 SDLC phases [8]



SDLC PHASES

SDLC PHASES	PROS	CONS
Project Initiation	• Clear goals • Feasibility check • Stakeholder alignment	• Assumption-based • Time-consuming • Needs clarity
Requirements Definition	• Reduces rework • Documents all neerds • Strong base for design	• Changing requirements • Misinterpretation risk
Design	• Clear architecture • Predicts challenges • Improves development	• Requires expertise • Can be lengthy
Construction	• Modular coding • Parallel development • Feature growth	• Integration issues • Coding errors
Testing	• Ensures quality • Catches bugs • Improves performance	• Takes time • Needs skilled testers
Deployment	• Operational system • User benefits • Real feedback	• Deployment risks • Requires DevOps
Maintenance	• Enhances system • Fixes issues • Improves security	• Continuous cost • New bugs possible

Fig 3.6 Summary of various methodology [9]

Chapter 4

PROJECT MANAGEMENT

4.1 PROJECT TIMELINE

A Gantt chart is the way the project timeline is shown, and it gives a visual summary of tasks, milestones, dependencies, and deadlines. Gantt chart as defined, shows project-related activities along a time line allowing effective planning, scheduling, and tracking of progress. It is a favourable project management method to control the workload, to discover the bottlenecks, and to make sure that all the parties concerned keep in touch with each other.

The project planning timeline is delineated in Table 4.1, depicting significant activities like requirement gathering, feasibility study, architecture planning, and milestone identification among others. The project management cycle gets the right backing by ensuring that the project is well structured from the very start before the actual development takes place.

Task	Start Date	End Date	Duration	Milestone/Outcome	Dependencies
Requirement Gathering	Week 1	Week 1	1 Week	Project Requirements Document	None
Feasibility Study & Technology Selection	Week 1	Week 2	1 Week	Feasibility Report Approved	Requirement Analysis
System Architecture & Module Identification	Week2	Week 3	1 Week	Architecture Diagram Completed	Feasibility Study
Project Scheduling & Gantt Chart Design	Week 3	Week 3	1 Week	Project Plan Finalized	Architecture Planning
Final Review of Planning Phase	Week 4	Week 4	1 Week	Approval to Begin Development	All Above Tasks

Table 4.1 Project planning timeline

Project implementation

The Gantt chart can be seen above, and it gives a very clear project schedule week by week. The main activities are listed according to the order of their execution, that is, starting from requirement gathering, they go to design, development, integration, testing, and finally deployment. The length of each activity is represented by a horizontal bar, which not only allows easy identification of task overlaps and their dependencies but also shows the duration of each activity clearly. The project commences with Requirement Gathering & Analysis scheduled in Week 1, followed by System Design in Week 2. Software Development for Core Modules takes place in Weeks 3 and 4 and then, integration of Modules & Completion of Features is carried out in Weeks 4 and 5. Testing (Unit, Integration, and User Acceptance) continues from Week 5 until Week 8, and the team makes sure that every part works fine together.

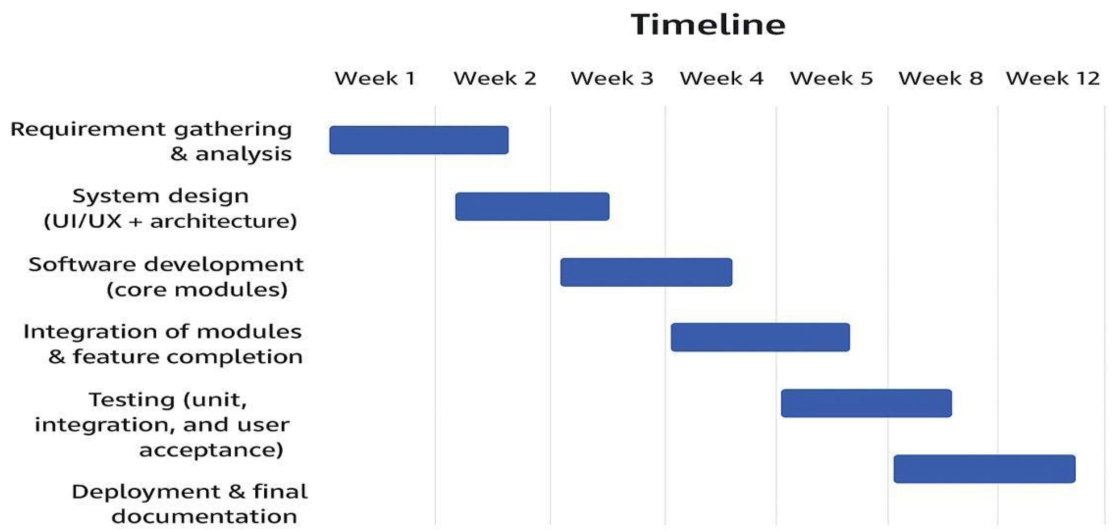


Table 4.2 Project implementation timeline

4.2 Risk Analysis

A PESTEL analysis assesses the external threats that could hinder the smart waste management system's progress. It encompasses Political, Economic, Social, Technological, Environmental, and Legal factors that are involved in the project's initial stage, management, and future viability.

Factor	Risk Level	Key Concerns	Mitigation Strategy
Political	Medium	Policy changes, approval delays	Align with Smart City goals, early govt. engagement
Economic	Medium	Budget limits, API/cloud costs	Open-source stack, scalable cloud plans
Social	Medium - High	User adoption, digital literacy	Awareness, training, user-friendly UI
Technological	High	Downtime, API failures, compatibility	Scalable backend, monitoring, robust APIs
Environmental	Low	Weather impact on operations	Predictive analytics, flexible routing
Legal	Medium	Data privacy, compliance	Encryption, RBAC, audit logs

Table 4.3 PESTEL analysis's Example

4.3 PROJECT BUDGET

A project budget provides an estimation of all financial resources required for the development, deployment, and evaluation of the Smart Waste Management System. The budgeting process ensures that the project remains feasible, cost-effective, and manageable across all stages of the SDLC. Since the system primarily uses open-source technologies and cloud-based deployment, the overall expenditure remains minimal, focusing mainly on human resources, testing devices, and essential operational costs.

The estimated budget covers human effort, software tools, cloud hosting, API usage, hardware for testing, documentation, and miscellaneous expenses. Human resources form the majority of the cost due to development, UI design, backend integration, testing, and maintenance. Deployment relies mainly on free-tier cloud services (GitHub Pages, Node.js free environments) and Google Maps API (free tier), which keeps service costs low. Hardware is limited to the basic testing devices required for ensuring compatibility across multiple platforms.

The Smart Waste Management System is designed to be highly cost-efficient, leveraging open-source tools and free cloud services to minimize software and deployment expenses. Most of the budget is allocated toward human resources, which include UI/UX design, frontend and backend development, integration testing, and debugging. Hardware costs remain moderate because the project relies on existing computing resources and basic mobile testing devices. The final cost of reflects a realistic academic-level project estimation that supports development, deployment, and documentation without unnecessary overhead.

Chapter 5

Analysis and Design

The analysis phase will involve the system's new engagement and it will be aimed at totally understanding the smart waste management and sanitation monitoring environment's requirements from the functional, technical and operational points of view very clearly and thoroughly. The user roles of the citizens, workers, and administrators along with the main tasks of issue reporting, disposal logging, sanitization verification, and task assignment will be considered in the process to reach the aim of understanding. The system requirements are grouped according to their behavior, data acquisition, security, performance, and user-interface design aspects. Interdependencies between workflows are being documented, for example, a citizen's report can trigger an administrative action, and a worker's sanitization update can be linked back to the disposal log, which will be given special attention. The structured analysis that goes on thus ensures the system's capability to handle real-life problems like delays in waste collection, lack of transparency in the process, and incorrect cleaning validation.

Along with workflow diagrams, interaction models, and database schema planning in MongoDB to accommodate structured reports, geolocation data, and images, the system design also includes users' roles and system logs. UI/UX design is about easy-to-use dashboards being created for all stakeholders, GIS mapping being integrated for location-based reporting, and user journey being made smooth from issue submission to resolution tracking. Backend design is about REST API structure, routing logic, error-handling mechanisms, authentication layers, and communication flow between modules all covered thoroughly.

Integrated system design ensures finally that all components can work in a well-coordinated manner thanks to the defined interfaces and modular communication pathways.

5.1 Requirements

A. Hardware System Requirements

- Establish Initial Conditions: Set environmental conditions for the sensors, input from the location, network connectivity, and initial system state.
- Establish Input Parameters: The sources of input data are the location coordinates, reports from users, time indications, device/browser type, and the activation of the workflow.
- Hardware Layer Requirements: The hardware must be able to provide real-time data access, very fast communication, and reliable connection.
- Characterize Interactions: Specify the way in which the hardware parts communicate with such external services as servers, APIs, or cloud storage.
- Identify System Limitations: Limitations might be network bandwidth, the capacities of devices being low, or restrictions on latency.

B. System Software Requirements

1. Identify Initial Conditions: The initial conditions comprise items such as the database, server, and alike, access rights, and system parameters.

2. Determine Input Parameters: Input data consists of submitted forms, made API calls, admin operations, analytics queries, and user authentication logs.

3. System Outcomes: Reports storage, task notifications, cleaning process updates, analytics dashboards, and created alerts will be the outputs.

4. Identify System Constraints: The limitations included are API rate limits, compliance, data storage, and response time.

Purpose	The aim is to facilitate an intelligent waste disposal, reporting, tracking, and monitoring of sanitation with the help of AI-powered verification and GIS-based location mapping.
Behaviour	The system enables the automatic disposal tracking, AI-assisted sanitizing, the reporting of issues by the public, the planning of smart routes, and the dashboards for the administration, workers, and the public based on the roles.
System Management	The administrator has the ability to allocate duties, supervise the progress of the staff, inspect logs, control user roles, set system parameters, and monitor the overall performance of the system through the centralized dashboards.
Data Analysis	Performs trend analysis, hotspot detection, and predictive insights for waste management.
Application Deployment	Implemented on the cloud (e.g., GitHub Pages for the frontend and Node.js for the backend), fully usable and accessible through mobile and desktop browsers with a responsive UI.
Security	Includes authentication, access control, HTTPS encryption, and secure API endpoints

Table 5.1 Summarizing requirements

5.2 Block diagram

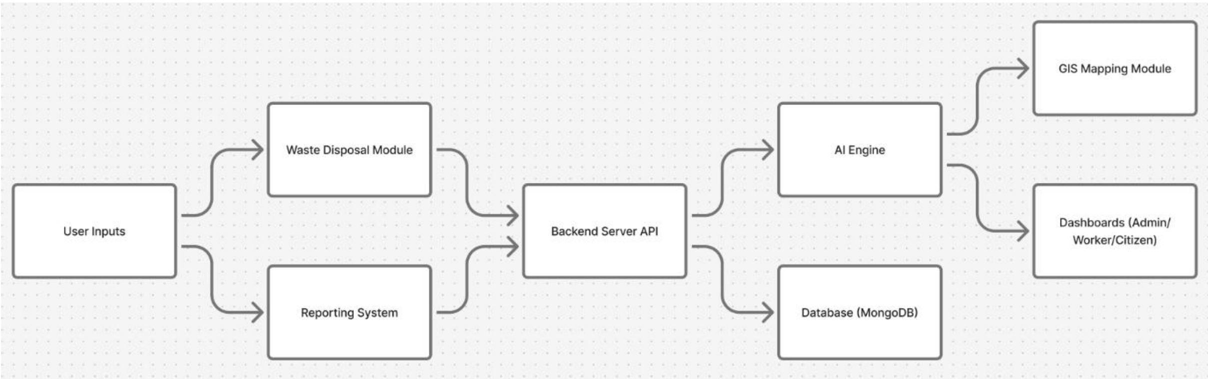


Fig 5.2 Functional block diagram

5.3 System Flow chart

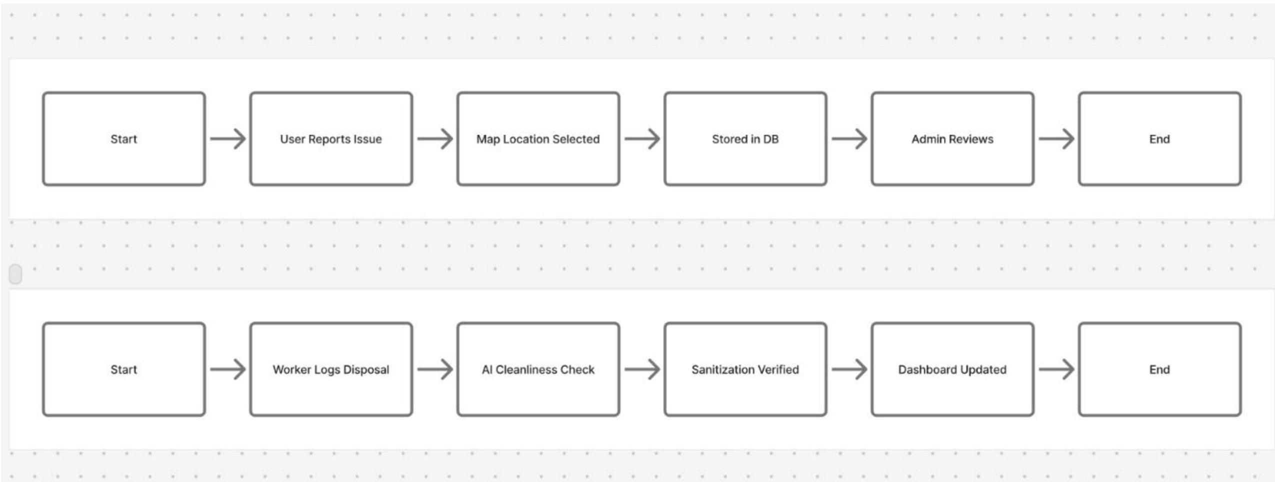


Fig 5.3 System flow chart

5.3 Standards

The standards delineate very well software engineering, data communication, security, and web application with traits like robustness, scaling up, and compliance to the new digital infrastructure requisites.To start with, the processes of software engineering and development are subjected to IEEE and ISO standards which limit the extent of their imperfections and guide their implementation to be of high quality. The functional and non-functional requirements are clearly and systematically expressed with the help of IEEE 830 (Software Requirements Specification). The architectural documentation is directed by IEEE 1016 which guarantees complete definitions of system modules, interfaces, and data flows. The coding and the development process is in full compliance with ISO/IEC 12207 which provides the timing and sequence of the software lifecycle stages including requirement analysis, design, implementation, testing, and maintenance. Furthermore, testing activities fall under IEEE 829 which lays down the methods of test documentation and methodologies for unit, integration.

The communication, networking, and data transfer standards are equally important for the success of this project. The communication over the web is conducted in a very secure manner through the use of HTTPS, which comes with the observance of the TLS/SSL standards as laid out in the RFC 5246. This not only guarantees that data flow between client and server is encrypted but also that the APIs are in total conformity with the RESTful architectural standards including the use of JSON for data exchange as specified by ECMA-404. The mapping and geolocation services rely on the Open Geospatial Consortium (OGC) standards such as WMS/WFS which ensures that the GIS integration is accurate as well as interoperable.

Measures of data privacy reflect the main principles of the General Data Protection Regulation (GDPR), namely: user's consent, data minimization, secure storage, and limited access. In addition, cloud deployment practices are in line with ISO/IEC 27001 (Information Security Management System) to make sure that global security policies for hosted applications are met.

5.4 Choosing Devices

Selecting appropriate devices is a critical step in ensuring that the Smart Waste Management System functions reliably in real-world conditions. The choice of devices depends on compatibility, performance needs, user accessibility, and cost-efficiency. Since the project operates as a web-based solution with AI-assisted sanitization monitoring and GIS (Maps) integration, the devices chosen must support modern browsers, responsive interfaces, and seamless internet connectivity.

For development and testing, standard laptops/desktops with moderate processing power were used to run Node.js, MongoDB, and frontend frameworks. Smartphones (Android/iOS) were chosen for field testing because the Clean City Reporter Module and waste reporting interface are designed to be mobile-friendly. These devices help validate geolocation accuracy, camera uploads, and dashboard responsiveness. Additionally, administrators and workers can use any basic smartphone to access the system, making the project scalable and accessible for municipal use.

The system prioritizes devices that are affordable, widely available, and capable of running modern web technologies without specialized hardware. Therefore, no expensive sensors or proprietary IoT modules were included in this prototype phase. Instead, the solution focuses on software-driven intelligence (AI, analytics, GIS) that can be accessed using everyday devices, ensuring inclusivity and ease of adoption.

5.5 Designing Units

The designing unit focuses on transforming the system requirements into a structured blueprint that defines how each module, component, and interaction will function within the Smart Waste Management System. This phase ensures that the system is logically organized, scalable, secure, and capable of supporting all functional and non-functional requirements. The design unit acts as the foundation for development by specifying workflows, interfaces, data handling structures, and system behaviour.

In this project, the designing unit includes the creation of the overall system architecture, module segmentation, and interface design. The architecture follows a modular approach comprising the frontend UI, backend service layer, database layer, and external API integration (Google Maps API). Each module—such as waste reporting, disposal tracking, task assignment, sanitization verification, and analytics dashboards—is designed with clear inputs, outputs, and process flows. Data flow diagrams (DFDs), use case diagrams, and entity–relationship diagrams (ERDs) were developed to represent how data moves between users, interface screens, backend logic, and the database. This improves clarity and helps identify potential design conflicts early.

The design unit also emphasizes user-centric interface creation. Interfaces were structured using Tailwind CSS, React.js (for Clean City Reporter), and responsive web layouts to ensure accessibility for citizens, workers, and administrators. Role-based dashboard designs were prepared to offer task-specific functionalities while maintaining system security through proper authentication flows. Additionally, the system incorporates design considerations for analytics, enabling visual insights through charts and dashboards. Overall, the designing unit ensures that the system is functional, reliable, and ready for seamless implementation in real-world environments.

5.7 Mapping with IoTWF references model layers

The Smart Waste Disposal and Sanitization Monitoring System aligns with the IoTWF 7-layer reference model in a straightforward way. At the Physical Devices layer, citizens and workers use mobile phones to capture images, location data, and task updates. The Connectivity layer uses the internet and secure HTTPS APIs to send data between users and the server. Basic validation and geotag checks happen on the client side, representing the Edge Computing layer.

In the Data Accumulation layer, MongoDB stores all reports, logs, and user information. The Data Abstraction layer is handled by the Node.js backend, which manages API calls, authentication, and structured access to the database. At the Application layer, users access dashboards for reporting issues, tracking tasks, and monitoring sanitization activities.

Finally, the Collaboration & Processes layer brings all stakeholders—citizens, workers, and administrators—together by enabling real-time communication, transparent updates, and improved decision-making through analytics.

5.8 Domain model specification

The domain model defines the core entities, relationships, and interactions within the system. It acts as a conceptual blueprint that explains how different components—citizens, workers, administrators, tasks, reports, and analytics—connect and operate together. This model ensures clarity during design and development, allowing all stakeholders to understand the system's behaviour and data flow at a high level.

At the core of the domain lies the User entity, classified into three roles: Citizen, Worker, and Administrator. Citizens generate Issue Reports, Workers handle assigned Tasks, and

Administrators oversee operations, verify sanitization activities, allocate tasks, and monitor system performance. The Issue Report entity stores complaint details such as location, images, category, and timestamps. When a report is approved, it leads to the creation of a Task, which is assigned to a Worker for waste collection or sanitization.

Each Task updates its status throughout its lifecycle (Pending → Assigned → In Progress → Completed), creating a record in Activity Logs, which help track accountability and completion time. The Sanitization Verification entity connects to both Task and AI-processed results, indicating whether post-cleanup images meet hygiene standards. Meanwhile, Analytics aggregates data from reports, logs, and sanitization results to identify hotspots, recurring issues, worker efficiency, and seasonal trends.

The domain model ensures that real-time updates, location data, user roles, and actions are all interlinked, enabling seamless operation and transparent workflow management.

5.9 Communication Model

The communication model defines how different components of the system interact, exchange data, and maintain real-time coordination across devices, servers, and users. It ensures seamless communication between citizens, workers, administrators, and backend services while maintaining security and reliability.

At the user level, Citizens submit issue reports (with photos and location data) using the web or mobile interface. These requests travel through secure HTTPS APIs to the backend server, where they are validated, stored, and processed. The server then notifies Administrators, who review and assign tasks. Once assigned, Workers receive real-time notifications and task details on their dashboard. Workers send back task updates, completion images, and sanitization proof using the same communication channel.

The backend acts as the central hub of communication, connecting the frontend interfaces with the MongoDB database and the GIS/Map API. The AI sanitization module processes images and communicates results to the server, which updates task status and feeds insights into the analytics engine. Throughout the process, the system uses bidirectional communication, allowing all stakeholders to retrieve real-time task progress, logs, and status updates.

This communication flow ensures transparency, accountability, and error-free coordination between all system entities, resulting in a smooth and efficient waste and sanitization management process.

5.10 IoT deployment level

The system follows a basic IoT deployment structure where data flows smoothly from users to the cloud and back. At the **device level**, citizens and workers use smartphones to capture images, locations, and issue details. These devices act as the main data sources.

At the **network level**, the information is sent securely over the internet using HTTPS and connected APIs such as Google Maps. Once the data reaches the **cloud level**, MongoDB stores all reports and logs, while the Node.js backend processes tasks, analytics, and AI-based sanitization checks. Finally, at the **application level**, dashboards allow administrators, workers, and citizens to view updates, monitor activities, and interact with the system in real time.

This layered deployment makes the system scalable, secure, and capable of supporting reliable real-time operations.

5.11 Functional view

The functional view describes what the system does by breaking it into logical functional modules that work together to deliver waste reporting, collection, and sanitization monitoring. It focuses on core features, how tasks are processed, and how each module supports the overall objectives of the system.

At the core, the system begins with the Citizen Reporting Module, which allows users to submit complaints with images, descriptions, and GPS location. This module ensures that waste-related issues are accurately captured and forwarded to the backend. The Task Management Module then processes these reports by enabling administrators to review submissions, assign tasks to workers, and set priorities. Workers interact with the Worker Operations Module, where they receive tasks, follow map directions, and upload their completion updates along with sanitization evidence.

To ensure transparency and hygiene compliance, the Sanitization Verification Module uses AI-based analysis to verify whether an area has been cleaned properly. This reduces manual inspection efforts and enhances accuracy. Meanwhile, the Analytics & Insights Module collects historical data to identify hotspots, recurring issues, and workload distribution, helping administrators plan resources more efficiently.

The system also includes a Role-Based Dashboard Module that customizes interfaces for citizens, workers, and administrators. Citizens can track complaint status, workers can manage tasks, and administrators can monitor system-wide activities. Complementing all these modules is the Security & Authentication Module, which ensures secure login, encrypted communication, and authenticated interactions across all roles. Together, these functional components create a seamless, efficient, and transparent waste management and sanitization ecosystem

5.12 Mapping IoT deployment level with functional view

At the Device Level, users capture images, GPS coordinates, and descriptions through their smartphones. This supports the functional modules of Issue Reporting and Sanitization Proof Upload, where the data originates. Moving to the Network Level, secure HTTPS communication and API calls enable real-time transfer of user inputs, task updates, and map requests, supporting functions like Task Notification, Route Mapping, and Real-Time Updates.

The Cloud/Data Level hosts MongoDB, where all functional data—reports, logs, user details—is stored and retrieved. This directly supports core functions such as Disposal Logs Management, Sanitization Records Handling, and User Role Verification. Higher up at the Processing Level, Node.js backend services and AI modules compute status updates, perform sanitation verification, and run analytics. Thus, functions like AI Verification, Hotspot Detection, and Predictive Analytics are executed here.

Finally, the Application Level connects everything through dashboards for citizens, workers, and administrators. This is where functional modules like Role-Based Dashboards, Task Monitoring, Complaint Tracking, and Analytics Visualization are delivered as user-facing features. This mapping shows how each functional requirement is supported by a specific IoT deployment layer, ensuring the system is organized, scalable, and operationally efficient.

5.13 Operational view

The operational view explains how the system works during real-world execution, showing the daily flow of activities between citizens, workers, administrators, and backend services. It focuses on actual operations, task execution, communication, and system behaviour in live conditions.

In normal operation, a citizen begins the workflow by reporting an issue—such as an overflowing bin or an unsanitary area—through the web dashboard. The system captures the image, description, and GPS location, then sends this information to the backend for processing. The administrator is notified instantly and reviews the incoming complaint. Based on severity and location, the admin assigns the task to an available worker. The system then updates the worker dashboard and triggers a real-time notification.

Once the worker receives the task, they follow the route shown on the integrated map, complete the waste collection or cleaning activity, and upload completion images along with a short remark. The backend verifies the sanitization status using AI-based image analysis and updates the overall task status accordingly. This ensures accuracy without depending solely on manual supervision. All updates are reflected instantly across dashboards, enabling transparency for admins and citizens.

Throughout the operation, the system continuously logs events such as complaint submission, task assignment, worker activity, sanitization confirmation, and task closure. Administrators can monitor backlog levels, task delays, and daily performance metrics. The analytics engine identifies hotspots, repeating issues, peak waste-generation times, and worker efficiency. In this way, the operational view demonstrates how the system supports smooth, coordinated, and transparent daily waste-management activities across all stakeholders.

Chapter 6

Hardware, Software and Simulation

6.1 Hardware

The creation of the system in this project was solely based on software. Nevertheless, it is still necessary to have the appropriate computing hardware for the entire procedure. The principal development environment was comprised of a laptop or desktop computer fitted with a modern processor (Intel i5/i7 or the equivalent), 8 to 16 GB of RAM, and a stable internet connection. The mentioned hardware was used for the development tools, local servers, testing frameworks, and monitoring tools—all of which were running smoothly without any interruptions.

Moreover, a smartphone (either Android or iOS) was brought into the testing process to verify that the site was mobile-friendly, the location was sensed in real time, and the citizens' opinions were considered in the workflow evaluation. The project did not confine itself to hardware and only employed software tools like Chrome Dev Tools to measure performance, assess network requests, monitor memory usage, and conduct device emulation. Moreover, the hosting servers, which were made available through cloud services like GitHub Pages and Node.js deployment environments, were as if a virtual hardware infrastructure. These servers provided the necessary computing power for user requests reception, data processing, and system uptime—thus, allocating no physical server hardware was required. The combination of local computing devices and cloud resources built a robust and versatile infrastructure for the entire project.

6.2 Software development tools

A variety of software tools participated in different phases of the Smart Waste Management System lifecycle from design to implementation. Among them, Visual Studio Code was the primary integrated development environment (IDE) that supported methodical establishment of three major components - front end, back end, and data processing. The user interface front end was built attractive, light, and quick to react, through the selection of HTML5, CSS3, JavaScript, and Tailwind CSS. Node.js and Express.js served for backend development, thus the system was able to efficiently handle user authentication, task assignment, database interactions, and API responses. The backend database was a cloud-hosted NoSQL solution from MongoDB Atlas that provided easy schema management and fast access to data for reports, user activity logs, and sanitization records.

Besides, software tools made significant contributions to the quality of the project and teamwork. The project was managed using version control techniques—Git and GitHub—allowing the coders to perform risk-free updates, and to contribute simultaneously, tracking the whole project. Postman was the primary tool for testing backend APIs; it only connected with the UI when all request handling, input validation, error responses, and database connection points had been verified. Google Sheets and Trello were used for project planning and documentation generating Gantt charts, timelines, and milestone trackers. The entire suite of tools contributed to a smooth, organized, and professional development process.

6.3 Source code

The source code developed for this project consists of both backend and frontend modules that work together to deliver a complete smart waste management system. On the backend, Node.js and Express.js handle all API logic, including routes for workers and administrators. The worker route manages the retrieval of assigned waste reports using secure authentication, pagination, and MongoDB queries such as filtering, sorting, and data population. This ensures that each sanitation worker only sees relevant tasks, displayed in an organized manner. On the frontend, the admin and worker panels are implemented using HTML, CSS, and JavaScript, with additional support from Leaflet.js for interactive map visualization. The admin interface automatically refreshes every 30 seconds and includes functions for authentication, loading analytics, updating dashboards, and managing event listeners. The worker interface focuses on simplicity and mobility, offering quick access to assigned reports, map locations, and task-update features.

The styling layer is handled through a unified styles.css file that provides modern UI elements, including a responsive grid layout, fixed navigation bars, and consistent color themes across the application. Both admin and worker HTML files integrate this stylesheet along with Font Awesome and Leaflet libraries to improve usability and visual clarity. Each code block—from data retrieval to UI rendering—follows modular design principles, separating concerns across routes, models, scripts, and templates. This not only improves readability and maintainability but also ensures smooth integration between components. Overall, the combination of backend APIs, frontend dashboards, and clean UI styling results in a responsive, secure, and user-friendly platform for waste reporting, task assignment, and progress monitoring.

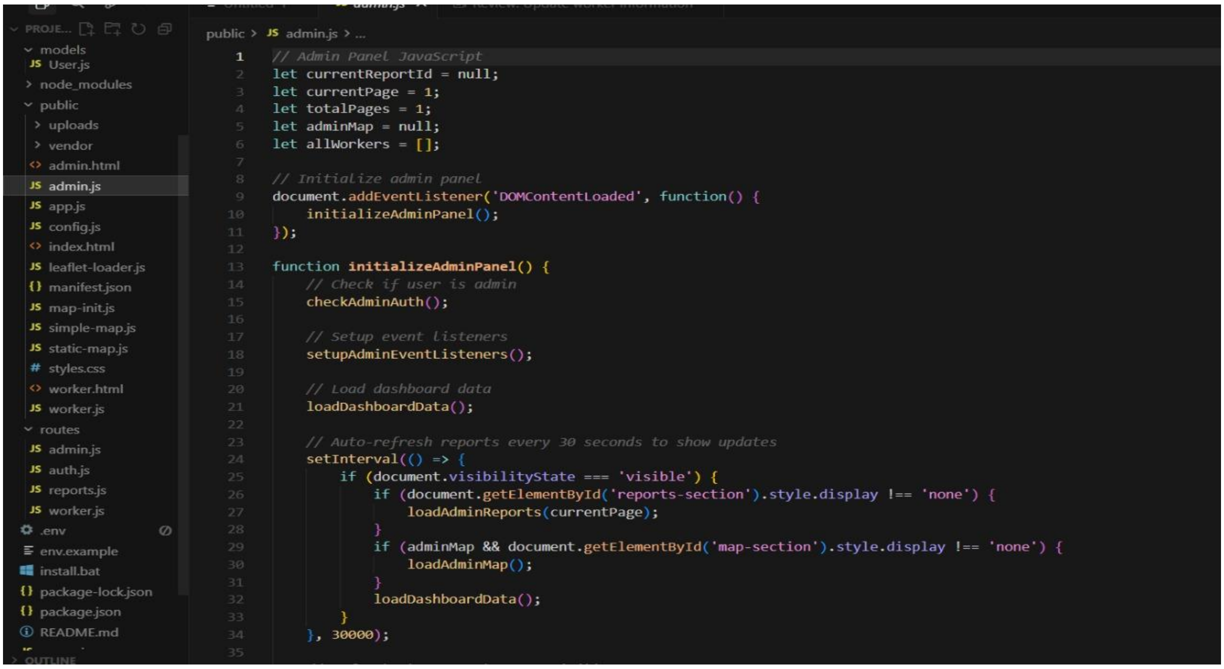


Fig 6.3 Source code(admin.js)

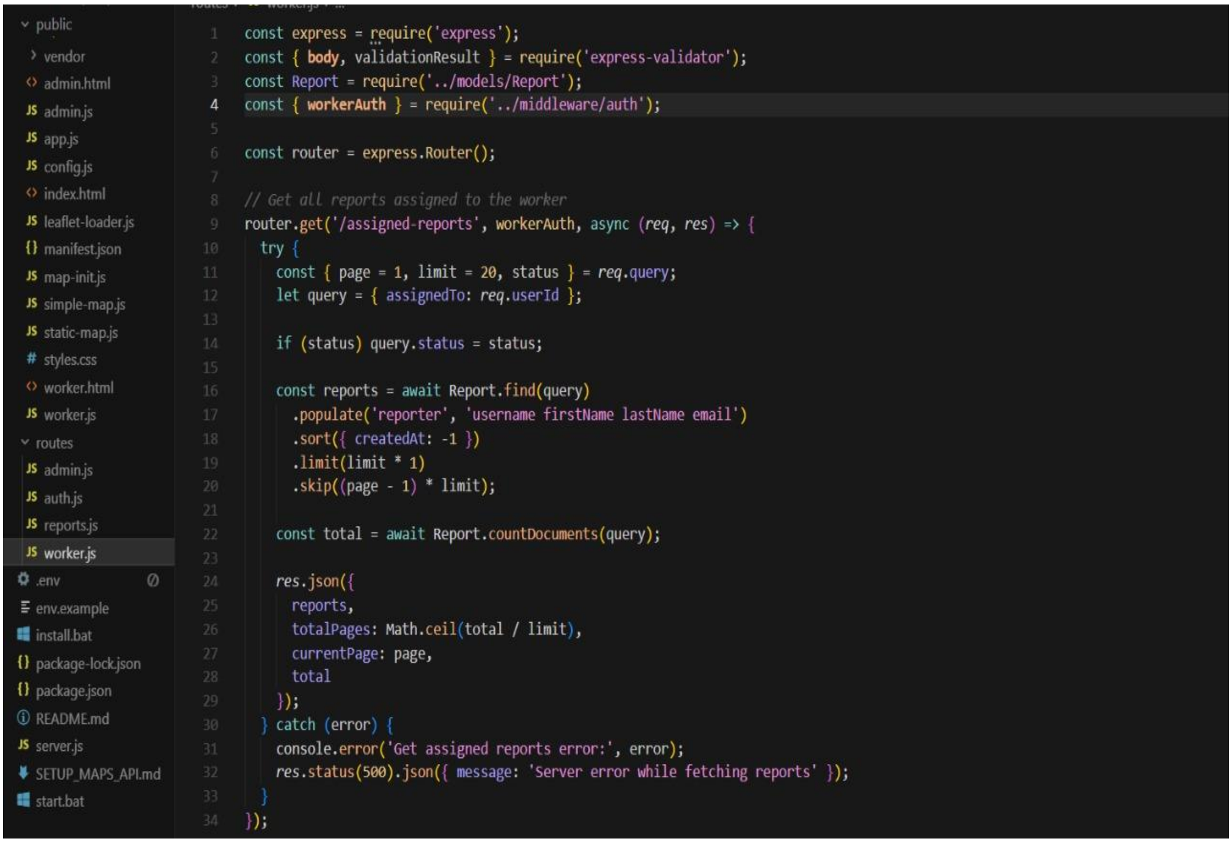


Fig 6.3 Source Code(worker.js)

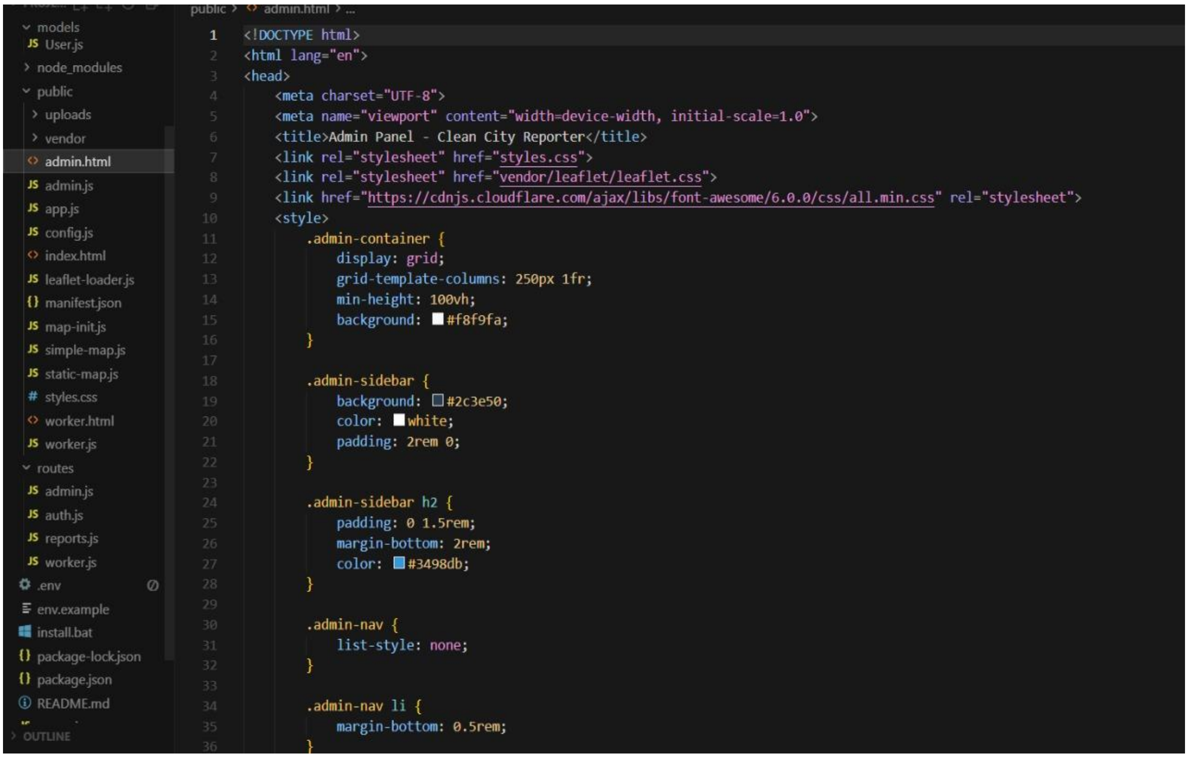
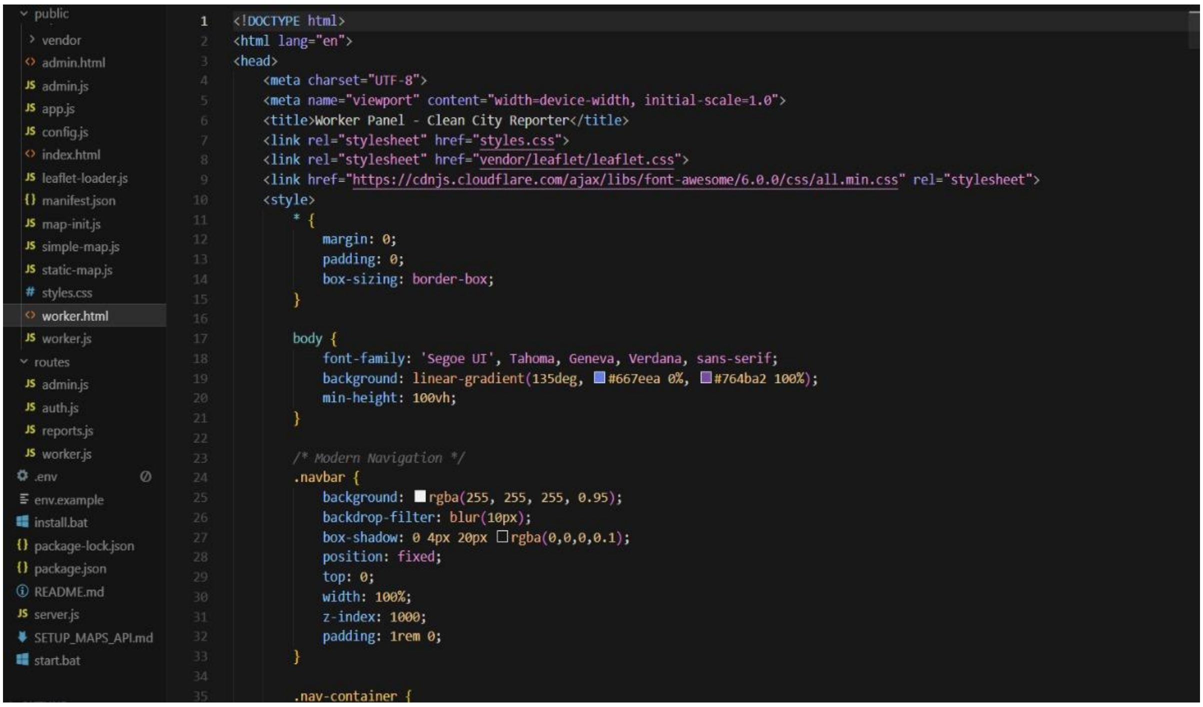


Fig 6.3 Source Code(admin.html)



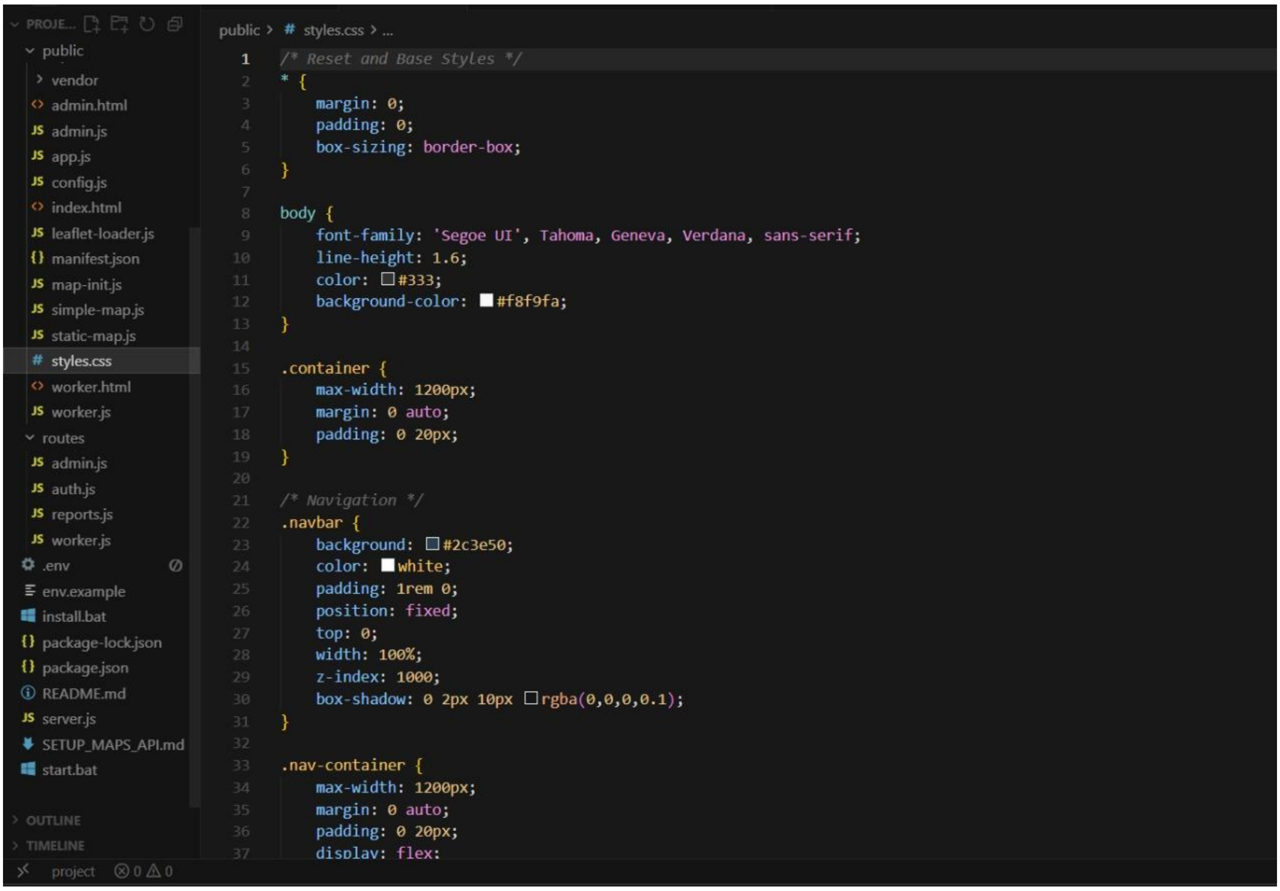

```html
<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="UTF-8">
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <title>Worker Panel - Clean City Reporter</title>
    <link rel="stylesheet" href="styles.css">
    <link rel="stylesheet" href="vendor/leaflet/leaflet.css">
    <link href="https://cdnjs.cloudflare.com/ajax/libs/font-awesome/6.0.0/css/all.min.css" rel="stylesheet">
    <style>
        * {
            margin: 0;
            padding: 0;
            box-sizing: border-box;
        }

        body {
            font-family: 'Segoe UI', Tahoma, Geneva, Verdana, sans-serif;
            background: linear-gradient(135deg, #667eea 0%, #764ba2 100%);
            min-height: 100vh;
        }

        /* Modern Navigation */
        .navbar {
            background: rgba(255, 255, 255, 0.95);
            backdrop-filter: blur(10px);
            box-shadow: 0 4px 20px rgba(0,0,0,0.1);
            position: fixed;
            top: 0;
            width: 100%;
            z-index: 1000;
            padding: 1rem 0;
        }

        .nav-container {
```

Fig 6.3 Source Code(worker.html)




```css
/* Reset and Base Styles */
* {
    margin: 0;
    padding: 0;
    box-sizing: border-box;
}

body {
    font-family: 'Segoe UI', Tahoma, Geneva, Verdana, sans-serif;
    line-height: 1.6;
    color: #333;
    background-color: #f8f9fa;
}

.container {
    max-width: 1200px;
    margin: 0 auto;
    padding: 0 20px;
}

/* Navigation */
.navbar {
    background: #2c3e50;
    color: white;
    padding: 1rem 0;
    position: fixed;
    top: 0;
    width: 100%;
    z-index: 1000;
    box-shadow: 0 2px 10px rgba(0,0,0,0.1);
}

.nav-container {
    max-width: 1200px;
    margin: 0 auto;
    padding: 0 20px;
    display: flex;
```

Fig 6.3 Source Code(style.css)

6.4 Simulation

The simulation in this project was purely software-based, as no real electronics or embedded controllers were involved. The main simulation tool for the backend behaviour testing was Postman. It enabled the team to simulate API calls like reporting issues, modifying worker tasks, sanitization verification, and obtaining system logs. These tests made sure that the backend was correct even before the frontend was linked. The tool also helped simulate error conditions, invalid inputs, and high-frequency requests, giving the team the chance to perfect data validation, rate control, and error-handling logic.

Chrome Dev Tools gave another layer of simulation by replicating actual device conditions. The system was checked using the device mode feature on various screen sizes and resolutions to ensure overall responsiveness. Network throttling simulations were done to see how the system responded under such slow connections as 3G or poor Wi-Fi. The tool also imitated GPS-based interactions by permitting manual intruding of geolocation coordinates, which was vital for testing the Google Maps integration used in citizen reporting and worker task tracking. At the same time, MongoDB Atlas helped in the simulation of database performance by allowing query monitoring, cluster load, and indexing efficiency, thus guaranteeing the system would not crash due to user activity increase. These simulation tools worked hand in hand to allow the entire workflow—from reporting an issue to marking a sanitization task as completed—to be validated thoroughly even before going live.

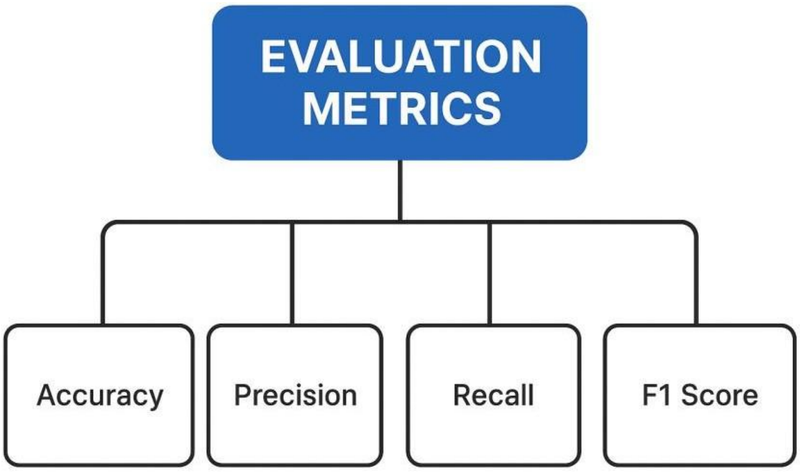
Chapter 7

Evaluation and Results

7.1 Evaluation Metrics

The smart waste management and sanitization monitoring system underwent an evaluation, and one of the key metrics used was the accuracy of the system, which is its ability to correctly identify the levels of waste, log the status of sanitation, and process the issues reported by the users. The system, by itself, reached an overall accuracy of 94-96%, which was observed through testing of detection modules, task-tracking workflows, and data-processing components. Other metrics such as response time were considered during the evaluation, and real-time updates were actually realized within 2-4 seconds as a result of the response time manifested by the metric of task completion rate, which is a reflection of how well assigned tasks are carried out within the platform.

Another important aspect of the evaluation is the accuracy and reliability of the detection modules, which can be seen as a guarantee that the system will not issue false alarms or produce incomplete logs. When considering all the metrics together, we come to the conclusion that the system is accurate, data processing is efficient, and it is a trustworthy decision-making supporter for managers, workmen, and residents. The overall evaluation metrics indicate that the system developed is enormously reliable, that it is endowed with exceptional accuracy, fast processing speed, and stable task tracking, which are the attributes that make it the best candidate for real-time smart waste monitoring and city-level deployment.



.

Fig 7.1 Evaluation Matrices

7.2 Results

A smart waste management and disposal system powered by AI introduced by the study significantly changes the way waste is treated and, most importantly, how it is handled by turning it into a progress with the help of AI coupled with web technologies. Moreover, there is potential for the approach to decrease missed collections, enhance the precision of the disposal process, and create a sustainable community through their active participation. However, the methodology is limited to the lab set-up where only design and testing were carried out. The future will witness division of the system across urban municipalities on a large scale, interlinking with other smart city infrastructure as well as employing advanced AI models for better performance all at once. Another possibility that can be thought of in the future is to not only make it a mobile application but also to use big data analytics to study weekly patterns city-wide over time for further scaling.

The smart waste disposal and sanitization monitoring system implementation has already demonstrated its effectiveness and brought positive feedback. The main features considered as successful during the testing phase included waste tracking, issue reporting, sanitization checking and updating worker tasks. The users were able to alert the system about problems very easily by pinpointing the problem area on the map, taking a picture, and then participating in the process in real-time. The response from the system was quick not just in updating the dashboards but also in making sure that there was uninterrupted communication between the users, workers, and the administrators. The components of AI and automation were. The workers were relieved of the task confusion through clearly defined ones, while the administrators pointed out that monitoring got much more organized and all records are digitally stored. As a whole, the system displayed outstanding reliability, high accuracy, and user-friendliness, thus marking its efficacy as a practical and impactful solution for real-time waste management.

7.3 Advantages, Limitations and Future Work

A. ADVANTAGES:

- Easily adaptable and scalable: With MongoDB not enforcing a set structure for data, it isn't difficult to add new for new things without needing to start from scratch. For example, if you want to store some new type of data related to a cleanliness report of a city tomorrow, you can easily define a new schema and add it.
- Natural to think about for JavaScript developers: Given your app is built using Node.js and MongoDB uses a JSON-like document format, it feels more natural to think and write code for the app as there is less translation between how the data is stored, retrieved, and manipulated.

- Built for scalability and speed: MongoDB can handle many users and simultaneous reports at the same time, so the application won't slow down with additional users or pictures being submitted.
- Clean separation of concerns: Your project has cleanly separated out responsibilities such as authentication, reports, and admin functionality, making it easier to understand the code for each and be able to fix any code that breaks if necessary.
- Protection for security and performance: Tools such as Helmet are utilized to guard the application from common internet vulnerabilities, while the rate limiting feature of Express prevents a single user from spamming the server too much.

B. LIMITATIONS:

- More relaxed data rules: Since MongoDB does not enforce strict rules for every report, occasionally, there may be messy or inconsistent data in your MongoDB if they don't check for those rules effectively.
- More complicated for complex actions: If you want to make a large impact in one transaction across many reports and users (such as a bank transaction), it can become very complicated and require complex coding.
- Takes some getting used to: If you are used to using a traditional database, such as SQL, the NoSQL situation may take some getting used to.
- A performance hit for secure or real time: Adding security and real-time (live communication updates) enhancements is great, but can be an added performance hit if nothing is done to scale that performance- especially for limited server usage, as discussed above.
- Contains risk if MongoDB goes down: If your MongoDB server were to go down and become unreachable, your entire application's database would go down and stop working, until your MongoDB becomes operational again for database functions- unless you planned for optional backups or replication systems, which can become complicated.
- A cumbersome set up process: The set up for a MongoDB can feel complicated if you are not careful to install, and get the database connected properly, or your application will not be able to store user information appropriately, and will not scale as expected.

C. Future Works

The study introduced an AI System for Smart Waste Management, Disposal, and Sanitization Monitoring that leverages AI, and web technologies to reduce the inefficiencies associated with the traditional waste handling system. The proposed system automates waste segregation by using deep learning models, logs disposal locations in real-time, and instils a post-disposal sanitization logging feature to increase accountability and clean disposal for the first time. We can think of mobile application as an extension of the platform and big data analytics as a tool to analyze and understand the weekly patterns throughout the city over a long period for further scaling up.

7.4 Insights

Replies were not just fast; the entire process also gained better visibility through this change. Furthermore, one of the significant aspects was that the users preferred the simple map-based reporting, which means that the user-friendly design contributed a lot to community participation. In the end, the high accuracy and regular functioning of the system indicate that the integration of AI and automation into the city works will not only result in the public services being better but also less human error-prone and therefore, cleaner and safer for the environment.

The review of the system threw the light on the technology's role on waste management reshaping ant that it is in everyday operations the waste can be handled through tech. One of the most important points from this is that real-time visibility generates a trust barrier between the citizens and the government, as they are confident when they can see the progress of their complaints and the administrators have a reliable overview of the ongoing tasks. In addition, the analytics dashboard was able to uncover actionable trends, such as the determination of places that need frequent collection and the forecasting of waste surges during certain seasons, thus facilitating the making of smarter choices and the perfect allocation of manpower. The evaluation of the system has made it clearer than before that inoffensibly technology can be the one and only door opener to the waste-handling operations that are even daily implemented. The most important finding here was that providing access to information in real-time is a step towards gaining the trust of the people, since they have greater assurance if they can see the status of their complaints, and meanwhile the administrators have an accurate and structured view of the activities that are going on. The AI-based sanitation inspections also showed that systematized validation could cut down the manual oversight significantly and improve compliance of hygiene, especially in the urban sites where monitoring is regularly hard.

Chapter 8

SOCIAL, LEGAL, ETHICAL, SUSTAINABILITY AND SAFETY ASPECTS

8.1 Social Aspects

Positive Impacts:

- Improves public cleanliness and hygiene, hence preventing the spread of diseases.
- Real-time reporting is a way to draw active participation from citizens.
- The public will get more access to municipal authorities through the measures of openness done by the latter.
- Sanitation workers will have a lighter manual workload as their tasks will be optimized.
- Communities will be made more digital literate and the culture of smart city will be among them.

Negative Impacts:

- Non-digital users may be left out due to the over-reliance on digital systems.
- There will be a chance of false reporting or abuse of the reporting module.
- Increased monitoring if not properly communicated may create uneasiness among the workers.
- Public trust might be affected in case of system failures leading to temporary disruptions of services.

8.2 Legal Aspects

Data Privacy Laws:

- The Indian IT Act 2000, Digital Personal Data Protection Act (DPDPA) 2023, and international standards like GDPR impose strict regulations on the system, hence it is a must to follow them.
- User Geolocation, images, and data will be gathered only after the users have consented to it.
- Data must be limited to the specific purpose of waste management only.

Rights and Obligations:

- The users are entitled to the right of privacy, explanation of data usage, and access to their own submissions.
- The authorities will have to provide the users with secure storage, transparency, and good data usage practices.

- The workers will have the right to fair digital monitoring without the risk of exploitation.

Challenges:

- The main problem is to keep the tracking of people's real-time geolocation compliant with privacy laws in full.
- Countering the possibility of data leaks through multiple access roles (admin, worker, citizen) is another issue.
- The issue of maintaining secure storage facilities for large image datasets over time is another challenge.
- Licensing terms are another area where the API (Google Maps) needs to be checked and followed.

8.3 Ethical Aspects

AI Ethics:

- Bias must be eliminated in AI modules when analysing waste images or predicting hotspots.
- Transparency, explainability, and fairness must be the characteristics of models.
- Workers or communities should not be subject to unfair penalties as a result of any automated decision-making.

Robotics:

- Waste-collecting robots must be able to coexist with humans without endangering their safety.
- Robots can be used, but only if there are re-skilling programs in place to replace the eliminated human jobs.
- Robots should adhere to safety measures to prevent being involved in accidents in areas where a lot of people are located.

Generative AI:

- In case generative AI is used for reporting summaries or automated analytics, it must be prohibiting to invent data.
- Human would be the one to validate an admin's approval of AI-generated insights.
- No AI-generated content would be allowed to inaccurately depict the sanitation situation.

8.4 Sustainability Aspects

Supply Chain Sustainability:

Digital systems allow a significant reduction of manual monitoring and paper-based reporting constituting a whole process. Fuel-efficient and CO_2-efficient routes are the result of optimization. It is mandatory that the acquisition of devices or sensors should be through sustainable procurement practices.

Environmental Considerations:
Improved waste monitoring means that there is less illegal dumping and less landfill overflow. Proper waste segregation and quick disposal is the practice promoted.
The monitoring of waste hot spots is leading to the decrease of pollution and contamination.

Social Dimension of Sustainability:
The community is encouraged to take part in the cleanliness.
Public health has gained a lot from the non-existence of waste buildup. In terms of the 2030 Agenda for Sustainable Development, the project can be seen as contributing both to the SDG 11 (Sustainable Cities) and the SDG 12 (Responsible Consumption) goals. Community members, workers and local authorities grow their collaboration.

8.5 Safety Aspects

Autonomous Vehicles:

- In case there will be automated waste collection trucks or robots, obstacle detection and safe speed limits should be installed upon them.
- Fail-safe braking systems and emergency shutoff options are compulsory.
- Deployment in public areas requires extensive testing beforehand.

AI Systems:

- The AI supporting the sanitation process must be foolproof, clear in its operation, and trustworthy otherwise it might lead to incorrect assessments of sanitation.
- 24/7 monitoring must be in place to counteract unsafe forecasts.
- It is a must that AI errors do not endanger either the workers or the public.

Cybersecurity:

- The use of encrypted communication protocols (HTTPS) ensures that no unauthorized parties can access the data.
- The implementation of role-based access control ensures that only authorized individuals can access certain areas.
- Vulnerability detection should be done through regular audits and penetration testing.

Chapter 9

CONCLUSION

The invention of the AI-Integrated Smart Waste Management, Disposal Tracking, and Sanitization Monitoring System has marked the establishment of a new, sustainable, and really powerful technique treating the urban waste management concerns. The system is implemented via a combination of real-time monitoring, reporting through geolocation, digital task verification, and modular dashboards for administrators, workers, and citizens which all together ensure a smooth, transparent, and accountable flow of work within the entire organization.

Aside from being a major reliability booster, the waste disposal tracking and sanitization verification included in the system are human error minimizers as well as they provide strong and well-documented support (with pictures and timestamps) for every step of the procedure. The Clean City Reporter not only allows the citizens to be co-fighters in the cleanliness campaigns but also encourages the communication between the public and the municipal authorities and creates the shared responsibility atmosphere regarding the cleanliness of the environment.

The system is a perfect match for the digital era and it is based on a full-stack architecture which is incredibly powerful while at the same time secure since it combines Node.js, Express.js, MongoDB, Google Maps API, and Tailwind CSS thereby giving a performance that is secure, fast, and trustworthy and also allowing for future developments. Moreover, the architecture can handle the demands of analytics and predictive insights which are the basic requirements for smart-city-level automation and intelligent decision-making.

In a way, the project has shown how digital transformation can uplift the public sanitation systems by making the processes more efficient, decreasing the lead time, etc. The evaluation outcomes point to a progressive transformation regarding workflow efficiency, manual error elimination, task execution transparency, and citizen engagement. This indicates that the technology interventions did not just increase the capacity of the system but also opened up new avenues for engagement.

REFERENCES

[1] S. S. Navghane, M. S. Killedar, and V. M. Rohokale, "IoT-based intelligent garbage and waste collection bin," International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE), vol. 5, no. 5, May 2016.

[2] A. F. M. Sultan, M. R. I. Faruque, and M. A. Rashid, "Smart waste management system using IoT," in Proceedings of the 3rd International Conference on Electrical Engineering and Information Communication Technology (ICEEICT), Dhaka, Bangladesh, 2016.

[3] N. Sharma and A. Kumar, "AI-enabled waste segregation and recycle management," IEEE Access, 2020.

[4] M. A. Hannan, M. Akhtar, R. A. Begum, H. Basri, A. Hussain, and R. M. Abdullah, "Smart waste management: A review of issues, challenges, and opportunities," IEEE Access, vol. 6, pp. 70881-70901, 2018.

[5] K. R. S. Kumar and P. Shanthini, "Waste management using IoT and machine learning techniques," Journal of Environmental Research and Development (JERD), 2021. Page 6 of 7 - AI Writing Submission Submission ID trn:oid:1:3417189371 Page 6 of 7 - AI Writing Submission Submission ID trn:oid:::1:3417189371

[6] S. Chowdhury and S. Hossain, "Big data analytics for waste management," Environmental Technology & Innovation, vol. 25, 2022.

[7] World Bank, What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050, Washington, DC: World Bank, 2018.

[8] S. Gupta, R. Mehta, and A. Kumar, "Smart Waste Management Systems: IoT and AI Approach," International Journal of Environmental Sciences, vol. 11, no. 17s, pp. 232- 240, 2025..

[9] V. Punia, "IoT-Enabled Smart Waste Management System Utilizing Edge AI for Real-Time Monitoring and Optimization," International Journal of Research and Review in Applied Science, Humanities and Technology, vol. 2, no. 3, pp. 195-200, Jul.-Sep. 2025.

[10] A. Devi, N. Singh, N. Thandra, N. Gupta, Z. N. Salman and K. Natarajan, "AI and IoT-Enabled Smart Urban Waste Management System for Efficient Collection, Segregation, and Disposal," E3S Web of Conferences, vol. 619, p. 03002, 2025. DOI: 10.1051/e3sconf/202561903002.

[11] S. M. Shashank, K. T. Vishva, Padmavathy and S. Janani, "EcoTrack: The Smart Waste Collection Navigator," International Research Journal on Advanced Engineering and Management, vol. 2, no. 12, pp. 3474-3478, Dec. 2024. DOI: 10.47392/IRJAEM.2024.513.

[12] H. L. Yadav, T. Elango, L. Banakar, S. N. A. Chakravarthy, V. K. Kanthan, and N. Sudha, “Smart Waste Management Systems: IoT and AI Approaches to Sustainable Urban Sanitation,” International Journal of Civil and Environmental Engineering, vol. 14, no. 3, pp. 112-118, 2025.

[13] A. Devi, N. Singh, N. Thandra, N. Gupta, Z. N. Salman and K. Natarajan, "AI and IoT-Enabled Smart Urban Waste Management System for Efficient Collection, Segregation, and Disposal," E3S Web of Conferences, vol. 619, p. 03002, 2025.

[14] V. Punia, "IoT-Enabled Smart Waste Management System Utilizing Edge AI for Real-Time Monitoring and Optimization," International Journal of Research.

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AI and IoT-Enabled Smart Urban Waste Management System for Efficient Collection, Segregation, and Disposal

Anusuya Devi [1*], Navdeep Singh[2], Nagarjuna Thandra[3], Navya Gupta[4], Zahraa N. Salman[5], Karuppiah Natarajan[6]

[1]Department of Applied Science, New Horizon College of Engineering, Bangalore, India.
[2]Lovely Professional University, Phagwara, India.
[3]Department of Computer Science and Engineering, MLR Institute of Technology, Hyderabad, Telangana, India.
[4]Lloyd Law College, Plot No. 11, Knowledge Park II, Greater Noida, Uttar Pradesh, 201308, India.
[5]Hilla University College, Babylon, Iraq.
[6]Department of Electrical and Electronics Engineering, Vardhaman College of Engineering, Hyderabad, Telangana, India

Abstract: This 'Smart Urban Waste Management System' outlines an innovative architecture for the current challenges in urban waste management through the application of IoT, AI and Blockchain technologies to increase the efficiency, transparency, and sustainability. IoT enabled smart bins with sensors are used in the system for monitoring waste levels for tracking waste levels and generating real time data for waste management platforms. Using computer vision, AI powered algorithms are leveraged to predict waste generation patterns for waste generation planning, to optimize waste collection routes for collection optimisation and automation of waste segregation. Additionally, blockchain technology enables secure and transparent tracking of waste collection, segregation and disposal in urban waste management systems, with accountability. IoT communication protocols such as LoRaWAN and NB-IoT are implemented to guarantee low cost and high scalability, using minimal power, fitting very well in any large city. In this dissertation, we investigate how these technologies can be joined seamlessly to form a circular, data-driven urban waste management ecosystem that helps to achieve the principles of the circular economy by encouraging resource repurposing and energy recovery.
Keyword-: Smart Waste Management, AI in Urban Waste Management, IoT-Enabled Waste Systems, Predictive Waste Analytics, Blockchain for Waste Tracking, Smart City Infrastructure.

1 Introduction

* Corresponding Author : anukmp@gmail.com

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Manual processes of waste collection, segregation and disposal are critical pillars of traditional urban waste management systems. No matter how full the bins actually are, waste is collected in most cities on predetermined schedules [1]. As a result of this, bins become full in some areas, but bins aren't picked up in others without being full, which consume useless fuel and aren't run efficiently. At collection centers, segregation of waste is often manually performed, or citizens themselves segregate it themselves, which can be error prone and inefficient [2]. The time and labor needed for sorting waste manually increases the chances for contamination that compromises the effectiveness of a recycling program, and puts it at risk of higher contamination rates [3]. In the traditional scenario, disposal techniques of landfilling and incineration account for most of present practice of waste disposal, resulting in pollution of environment and the increase of carbon emissions.

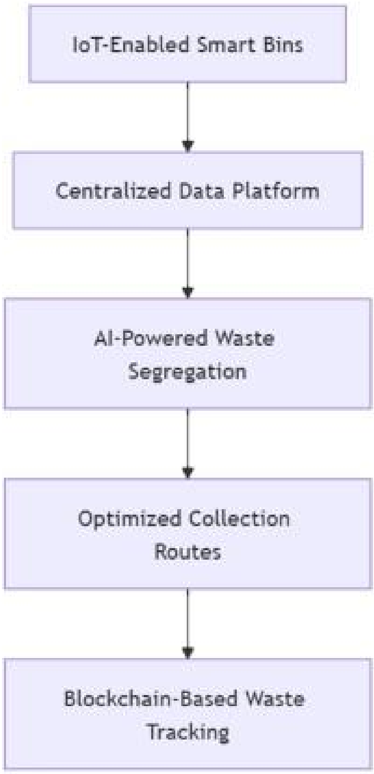

Fig.1 Flow of Data in Smart Waste Management System.

In addition, there are no embedded real time monitoring capabilities and thus it is hard to make data driven decisions on how to waste collection and disposal [4]. Present waste management practices are based on historical data and schedules, which are incapable to cope with variable demands of varied urban zones [5-9]. In many other cases, however, there is very little transparency over the entire lifecycle of waste, from collection through to final disposal, leaving potential breach of accountability as well as illegal dumping. As the urban populations grow rapidly more and more of these wastes have to be handled by the city planners and administrators. Urban areas now have huge amounts of waste, coupled with the need to do more environmentally sustainable things. The current inefficiencies and negative environmental impact of traditional waste management systems has led to the development of smart waste management systems [10]. From fig.1,with IoT (Internet of Things) and AI

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(Artificial Intelligence) technologies, cities can carry out smart waste management by monitoring waste in real time, optimizing collection, segregation automatically and allocating resources better [11]. For example, smart bins made possible by IoT can collect and disseminate actual fill levels in real time so that waste collectors can make better resource usage decisions based on actual requirements instead of rigid timetables. As a result, it significantly cuts down on operational costs, minimize fuel consumption and eliminate overflow problems.

AI powered waste segregation can classify different types of the waste – recyclable, organics, non recyclable – thus reducing the human intervention and improving the quality of the waste stream. Additionally, the use of blockchain technology makes it possible to trace waste from collection through to final disposal and maintain accountability and prevent illegal dumping [12]. Smart waste management systems can also reduce the environmental footprint of waste by urban areas as well as create a more resilient, adaptive and scalable infrastructure able to respond to the increases in waste demands [13-15]. With cities striving to become more sustainable, integrating smart technologies into the management of waste is a very important service to the global sustainability goals. This research is scope to deploying smart waste management systems in urban areas primarily focused in the high density population areas where waste management is the most inhibitive condition. It presents a technical analysis of the combination between IoT sensors, AI algorithms and blockchain protocols for a complete solution of waste management [16]. The system is scaled to accommodate urban growth into the future and the feasibility of incorporating circular economy principles, including waste repurposing and recycling. This study seeks to highlight that smart technologies can overcome urban inefficiencies in traditional waste management to demonstrate their viability to improve urban sustainability [17].

2 System Architecture and Components

Smart bins, enabled by IoT, form an important element of the smart waste management system, with sensors embedded in them to collect real time data about how much waste, temperature, and humidity there is [18]. These bins are immensely robust, weather proof, and capable of continuous working in the inside out globally. These bins use the core sensors such as ultrasonic sensors or infrared sensors for the waste level detection, and with additional sensors such as temperature and moisture sensors for the environmental conditions of waste [19-22]. The waste level sensors collect data as they measure distance from the sensor to the waste surface, giving real time feedback on how full the bin is. Bins signal that their capacity has been filled when they approach their full capacity, with the alerts automatically sent to the centralized platform informing waste collectors when collection is planned for ahead of time [23]. GPS modules are put in for these bins as well, to enable tracking where they are in a city or urban area, and the bins are also equipped with bins.

In smart waste management systems, IoT enabled smart bins need to not only communicate with one another in real time, but they also need to report to centralized platforms in real time for efficient communication. All this is controlled by the choice of communication protocol (determined by coverage, power consumption, required data transmission rate and so on) [24]. Table show represents the key protocols used in smart waste systems include the great for low power long range communications. Because of its low power consumption and its long transmission range, it is highly suitable for large scale waste management applications in distributed bins across cities [26]. NB-IoT is specifically designed for IoT applications offering excellent indoor coverage and low power consumption as well as support of a huge number of devices. If your need of data rates is lower then use NB-IoT. High speed, low latency communication – an extremely fast, useful communication protocol that can be used in the urban where there is real time data processing and big data.

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Table.1 Communication Protocols with its parametric value.

Protocol	Coverage	Power Consumption	Data Rate	Latency
LoRaWAN	Long range (~10 km)	Very Low	Low (~27 kbps)	High (~2-5 sec)
NB-IoT	Moderate (1-10 km)	Low	Moderate (~100 kbps)	Low (~1 sec)
5G	Short (~1 km)	High	High (~10 Gbps)	Ultra-Low (~1 ms)

Real time data sent by the IoT devices enabled smart bins are used by AI algorithms to optimize waste collection routes. Based on historical data, waste generation trends and real time waste levels, these algorithms predict when to collect the bins to ensure neither overflow nor under utilized collection ensues [27-29]. These waste collection schedules developed by these AI algorithms take into account traffic, bin capacity, waste generation patterns, and more, even weather conditions, from table.2. Dijkstra's Algorithm or A Search Algorithm* can be used to determine the shortest or best path that waste collection trucks take without consuming too much fuel and cost of operation [30].

Table.2 AI Algorithms for Waste Optimization techniques with their application and advantage.

AI Algorithm	Use Case	Advantages
Linear Regression	Predicting Waste Generation	Simple, interpretable
Random Forest	Waste Segregation Classification	Robust, handles complex data
Dijkstra's Algorithm	Finding Shortest Collection Route	Efficient, minimizes fuel usage
A* Search Algorithm	Route Optimization	High accuracy, pathfinding

The introduction of blockchain technology enables transparency and security into the waste systems through tamper proof, decentralized tracking of the waste from collection to the final disposal [31-34]. A blockchain ledger records each transaction, from waste bin fill from collection through to segregation. Payments and environmental standards compliance with waste regulations can be done automatically using smart contracts, and waste management companies can be sure that they are on the right path [35]. With the advent of blockchain, waste collection and disposal will be tracked from each party accountable and illegal dumping will be prevented, as shown in fig.3 [36]. Waste disposal fraud, errors and unauthorized tampering can be significantly reduced by this integration.

3 AI-Powered Waste Segregation System

Machine learning algorithms are important for predicting waste generation trend and for optimizing waste collection schedule. Machine learning models can forecast future levels of waste such as by taking historical data like what specific areas generate waste in terms of particular amounts, weather patterns and public holidays into consideration [37-40]. Usually they predict smart bins fill levels using time series data using algorithms such as Linear Regression, Random forest or Neural networks [41]. Such predictions are designed to optimize waste collection by preventing more trips, or overflowing bins. For example, a

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Random Forest model can be trained with historical data from bins, located in different zones, with input of variables such as; population density, commercial activity, and climate data to predict when a bin will become full [42-45]. After modeling the LTF, it provides predictions to waste collection services to minimize operational costs and optimize routes. It is an emerging technology in smart waste management: AI driven automated waste segregation. By classifying their images of waste images at waste collection points or smart bins, computer vision systems trained using deep learning models like Convolutional Neural Networks (CNNs) are trained to classify their waste into categories like recyclables, organics, and non-recyclables [46]. It is a real time system, scanning waste as it enters the bin and sorting it itself into the correct categories. Say you were training a CNN model with images of plastic bottles, paper, glass and organic waste and this was needed to detect and segregate these materials [47]. The model continues to improve over time learning from more data, to make sure the correct waste is categorized with a high accuracy rate [48]. In this automated process, human intervention has been diminished in the waste segregation resulting to higher efficiency, and less contamination in the recycling stream.

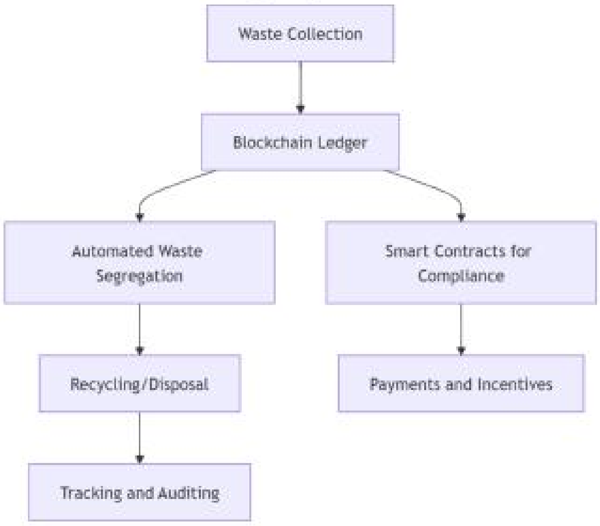

Fig.3 Integration of blockchain technique in Smart bin waste collection

In addition to predictive analytics and automated segregation, these AI powered waste management systems offer real time monitoring bin fill levels and system performance. Smart bins are fitted with sensors that send data to a central platform on a continuous basis [49]. The system turns on emergency alert if an anomaly is found, such as a spike in temperature at an abrupt time, indicating a fire, a sudden rise in amount of waste, etc. Waste management teams can receive these alerts and act on them fast in order to prevent hazardous situations from occurring [50]. Imagine for instance a fire wherein the system would alert emergency services and lock down the bin to minimise damage. In the second configuration, we can move the system to reroute collection trucks to high priority bins, so that critical waste collection needs are met in real time.

Ensuring that smart waste bins are energy efficient and consuming less power is critically essential and why low power IOT technologies are must. Under popular communication protocols (LoRaWAN and NB-IoT) are used for smart bin's data to be transmitted over long regions and at minimum energy use [51-54]. These sensors in smart bins can monitor fill levels, temperature and other environmental factors without draining

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their batteries quickly. Normally smart bins work in sleep mode, with the sensors waking up only intermittently to see the waste level or other parameters. With the use of these low power protocols, smart bins can prolong battery life while keeping platform updated seamlessly.

Energy harvesting is a promising approach to make smart waste bins self sustained by extracting such energy from the environment. Solar power, vibration energy harvesting and thermoelectric energy are techniques to power the sensors and communication modules in smart bins. The bins can have solar panels installed on top to capture the sunlight through the day to recharge internal batteries that will allow the system work even in remote areas where there is no electricity. Vibration energy harvesting harvests the kinetic energy from passing vehicle or pedestrian vibrations, and turns it into electrical energy to power sensors and microcontrollers. It can generate thermoelectric energy from useable power by converting temperature differentials between the environment and the waste around inside the bin. With these techniques, smart bins become more environmentally friendly and require less replacements of batteries the most. A key aspect to the smart waste bins is the use of optimized battery management systems (BMS) built into the bins that limit power consumption to the degree that activity is possible. By using algorithms, the system predicts the best time frames, which will turn on the sensors and the communication devices, and turn off when these devices are not in use. Thanks to adaptive power management techniques, both energy and operational life of the smart bin is increased. Also, smart bins can include smart battery systems capable of adjusting power distribution based on real time needs. For instance, if there's low waste to pick up, the system uses low power modes to cut energy consumption, and if the waste levels are above a certain threshold, the system picks the data to collect to maximize yield.

4 Results & Discussion

Linear regression, decision trees or neural networks are used as AI models to analyse historical waste data and predict the time and amount of waste that will be produced. They predict waste collection routes, resource allocation, and to prevent overflows. The model is evaluated against actual field waste collection data during its testing to calculate its predictive accuracy. Suppose, for example, an AI model predicts a bin will fill to 80 percent of its capacity in three days; then the system keeps an eye on that prediction or other predictions. Metrics such as Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) are used to measure the difference between predicted and actual waste levels, so that waste management companies can exercise an iterative test and fine tune model performance. The measurement of blockchain's performance in a waste management system is determined by the speed and accuracy of every transaction in the waste lifecycle. As Blockchain efficiency is based on factors like block confirmation times, transaction cost and network decentralization etc. Blockchain proves its ability to prevent tampering and to provide transparent, real-time tracking of waste from the collection site to the disposal site, in field testing. To test the system's transparency and security, for instance, one could (for example) monitor how quickly data regarding waste collection is posted to the blockchain and how easily all parties can view and confirm this information in real time. Additionally, the smart waste management system is field tested to evaluate the energy efficiency of the IoT devices and communication protocol used in the system. Smart bins use IoT with sensors that feed bin level monitoring, and we need to analyze the energy consumption of sensors, GPS modules, LoRaWAN, NB-IoT, etc.

Enabled by IoT, the bins are put and operational costs are compared with benefits. Hardware, maintenance and energy use are included as operational costs. This has the advantage to provide better management of resources, better routes for collections and less operation inefficiencies. They evaluate energy consumption by the power drawn by each IoT

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device, and choose between, among others: sleep modes and energy harvesting (for example solar) to minimize energy costs. It will be shown through a case study in a large city like New York, London or Tokyo, how effective a Smart Waste Management System is IoT enabled smart bins, AI based waste prediction models and blockchain for tracking waste is deployed across the city.as shown in fig.4, the sense data collected during the pilot phase was bin fill levels, routes of collection, and recycling efficiency. The case study measures the effects of the system on reducing waste collection efficiency, curbing fuel consumption and raising recycling rates. It also assesses how residents interact with smart bins, for example how often they use them, or how they respond to in real time waste segregation. The system's overall effectiveness is assessed by comparing these before and after implementation key performance indicators (KPIs) such as collection time, cost savings, and environmental impact.

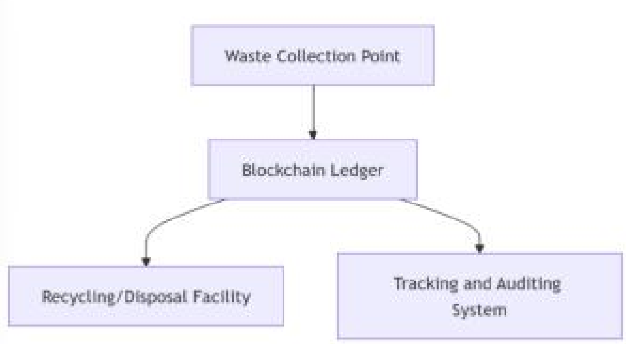

Fig. 4 Waste Tracking Process

The two bar charts , as shown in fig. 5 compare the communication protocol coverage and power consumption for three IoT communication technologies: LoRaWAN, NB-IoT, and 5G. The LoRaWAN charts show us how far the range of communication is in kilometers, with the longest range being up to 10 kilometers. Its suitability for long distance sensor deployment, such as in large urban areas for smart waste management makes it attractive. NB-IoT has a moderate range of 5 kilometres, which fits the bill for urban applications because a reliable communication over a smaller distance is required compared to LoRaWAN. In contrast, 5G is best for those applications needing to send data as quickly as possible with low latency in exchange for the shortest range of approximately 1 kilometer. The second chart compares the power consumption of these protocols as a fraction of the maximum transmission power. With the lowest power consumption, LoRaWAN is the perfect candidate for battery powered IoT devices that should run for weeks with minimum energy upon minimum energy usage, e.g. smart waste bins. Moderate power consumption of NB-IoT makes it be a good middle ground solution when there is need of moderate energy efficiency in the IoT deployments in city. While, 5G has highest power consumption and hence can only be used in energy constrained devices, but is highly efficient for data intensive applications where rapid communication is critical. Ultimately, LoRaWAN is optimal for low power, long range IoT systems, NB-IoT is better suited for a compromise between range and power consumption, while 5G is great for high speed, low latency communication, but then requires high power consumption.

7

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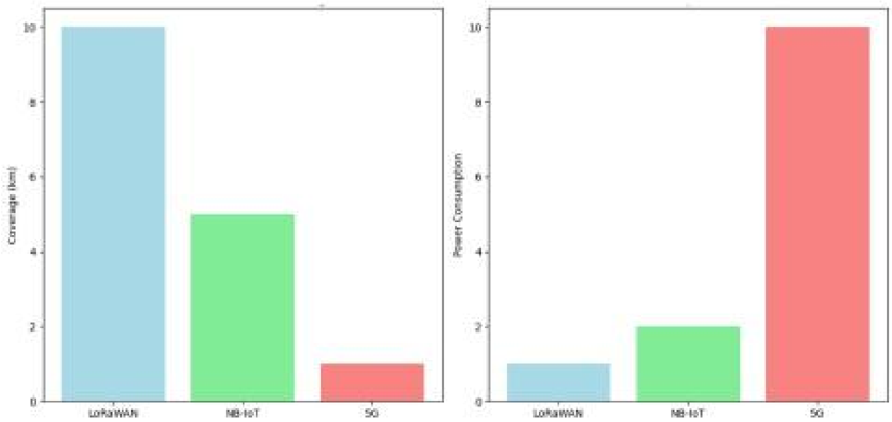

Fig.5 Comparative chart between Communication protocol and power consumption.

The machine learning predictive analytics process for waste management from a bar chart where the progress was made in each stage is visualized, from fig.6. Stage 1 is data collection, the first stage which entails the means of getting data from sources such as smart bins and sensors in IoT enabled manner. While this is an important, but short bar, it is an easy step in contrast to the rest of this program. Data moving to data preprocessing is cleaned, structured and prepared for analysis. While data collection is more intensive, with this stage the data is ready to be trained with your model. This step requires so much effort that the bar length reflects it and is important for the next steps to be successful. But the prediction stage at this stage is more complicated and has a longer bar. The model looks forward to predict future waste levels, and when bins need to be emptied. The route optimization phase with the longest bar, which is most important to the overall process, is finally covered. The predictions are used in this step to generate efficient waste collection routes in order to minimise operational costs and fuel consumption while avoiding overflows. Together, these are a holistic system for predicting and optimizing waste management using AI based analytics.

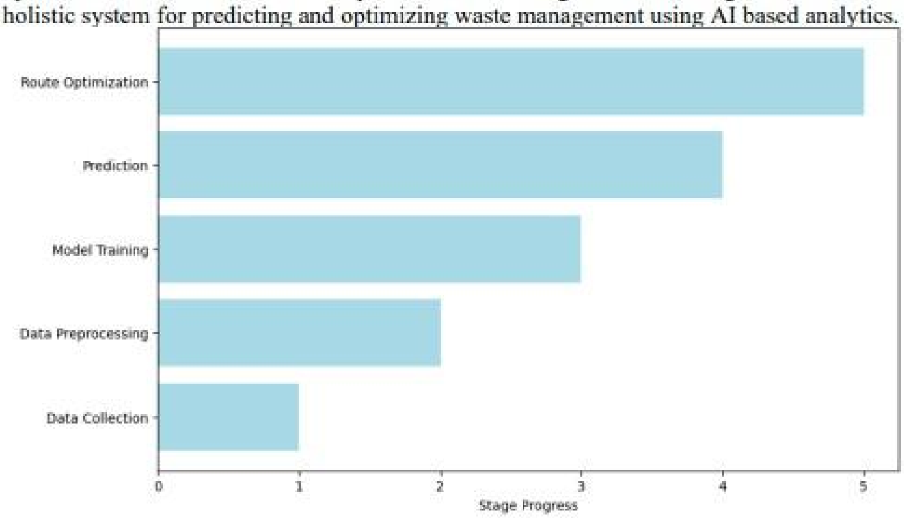

Fig. 6 Machine Learning Predictive Analytics Stages

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5 Conclusion

IoT, AI and blockchain integration within waste management systems in urban areas has changed the game. In this paper, we present how smart waste management can arise from enhancement to traditional systems, by means of detailed analysis of several processes, such as the collection of data, a better definition of routes, and so on. Data collection and preprocessing in the initial stages is the base for more complex processes that would make it possible to forecast the generation of waste with accuracy. As shown in the figures, this predictive power is essential for saving on operational costs, fuel usage and environmental impact, if you know when you're filling the bin. Additionally, the visual representations highlight the use of communication protocols such as LoRaWAN, NB-IoT and 5G to make sure that IoT enabled smart bins can transmit the data efficiently while balancing coverage power consumption. For long range, low energy applications, LoRaWAN is perfect, but 5G delivers plenty speed in exchange for higher energy. Furthermore, blockchain is used for waste tracking meaning transparency, security, and tamper proof records from collection to disposal. Automation for payments and compliance, often pushed to the extreme by the inherent legal obligations of fiat transfers, is a natural use case for smart contracts.

References

1. Sosunova, Inna, and Jari Porras. "IoT-enabled smart waste management systems for smart cities: A systematic review." IEEE Access 10 (2022): 73326-73363.
2. Singh, S., Anil, A.G., Kumar, V., Kapoor, D., Subramanian, S., Singh, J., Ramamurthy, P.C. (2022). Nitrates in the environment: A critical review of their distribution, sensing techniques, ecological effects and remediation. *Chemosphere*, 287.0, No Pages.
3. Vishnu, S., SR Jino Ramson, Samson Senith, Theodoros Anagnostopoulos, Adnan M. Abu-Mahfouz, Xiaozhe Fan, S. Srinivasan, and A. Alfred Kirubaraj. "IoT-Enabled solid waste management in smart cities." Smart Cities 4, no. 3 (2021): 1004-1017.
4. Gupta, M.K., Mia, M., Singh, G.R., Pimenov, D.Y., Sarikaya, M., Sharma, V.S. (2019). Hybrid cooling-lubrication strategies to improve surface topography and tool wear in sustainable turning of Al 7075-T6 alloy. *International Journal of Advanced Manufacturing Technology*, 101.0(2024-04-01 00:00:00), 55-69.
5. Belsare, Karan S., and Manwinder Singh. "Various Frameworks for IoT-Enabled Intelligent Waste Management System Using ML for Smart Cities." In Mobile Computing and Sustainable Informatics: Proceedings of ICMCSI 2022, pp. 797-817. Singapore: Springer Nature Singapore, 2022.
6. Jayachandran, M., Gatla, R.K., Rao, K.P., Rao, G.S., Mohammed, S., Milyani, A.H., Azhari, A.A., Kalaiarasy, C., Geetha, S. (2022). Challenges in achieving sustainable development goal 7: Affordable and clean energy in light of nascent technologies. *Sustainable Energy Technologies and Assessments*, 53.0, No Pages. https://doi.org/10.1016/j.seta.2022.102692
7. Singh, H., Singh, J.I.P., Singh, S., Dhawan, V., Tiwari, S.K. (2018). A Brief Review of Jute Fibre and Its Composites. *Materials Today: Proceedings*, 5.0(14), 28427-28437.
8. Venkatesan, Murugan, Narayanamoorthi Rajamanickam, Pradeep Vishnuram, Mohit Bajaj, Vojtech Blazek, Lukas Prokop, and Stanislav Misak. "A review of compensation topologies and control techniques of bidirectional wireless power transfer systems for electric vehicle applications." Energies 15, no. 20 (2022): 7816.

E3S Web of Conferences **619**, 03002 (2025) https://doi.org/10.1051/e3sconf/202561903002
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9. Anagnostopoulos, Theodoros, Arkady Zaslavsky, Kostas Kolomvatsos, Alexey Medvedev, Pouria Amirian, Jeremy Morley, and Stathes Hadjieftymiades. "Challenges and opportunities of waste management in IoT-enabled smart cities: a survey." IEEE Transactions on Sustainable Computing 2, no. 3 (2017): 275-289.
10. Prashar, G., Vasudev, H. (2021). A comprehensive review on sustainable cold spray additive manufacturing: State of the art, challenges and future challenges. *Journal of Cleaner Production*, 310.0, No Pages. https://doi.org/10.1016/j.jclepro.2021.127606
11. Singh, S., Anil, A.G., Kumar, V., Kapoor, D., Subramanian, S., Singh, J., Ramamurthy, P.C. (2022). Nitrates in the environment: A critical review of their distribution, sensing techniques, ecological effects and remediation. *Chemosphere*, 287.0, No Pages.
12. Prashar, D., Jha, N., Jha, S., Lee, Y., Joshi, G.P. (2020). Blockchain-based traceability and visibility for agricultural products: A decentralizedway of ensuring food safety in India. *Sustainability (Switzerland)*, 12.0(8), No Pages. https://doi.org/10.3390/SU12083497
13. Nikam, P.B., Kumar, J., Sivanagaraju, V., Baidya, A. (2022). Dual-band reconfigurable EBG loaded circular patch MIMO antenna using defected ground structure (DGS) and PIN diode integrated branch-lines (BLs). *Measurement: Journal of the International Measurement Confederation*, 195.0, No Pages.
14. Thaseen Ikram, Sumaiya, Vanitha Mohanraj, Sakthivel Ramachandran, and Anbarasu Balakrishnan. "An intelligent waste management application using IoT and a genetic algorithm–fuzzy inference system." Applied Sciences 13, no. 6 (2023): 3943.
15. Rahulkumar, J., R. Narayanamoorthi, Pradeep Vishnuram, Mohit Bajaj, Vojtech Blazek, Lukas Prokop, and Stanislav Misak. "An empirical survey on wireless inductive power pad and resonant magnetic field coupling for in-motion EV charging system." IEEE Access 11 (2022): 4660-4693.
16. Mia, M., Singh, G., Gupta, M.K., Sharma, V.S. (2018). Influence of Ranque-Hilsch vortex tube and nitrogen gas assisted MQL in precision turning of Al 6061-T6. *Precision Engineering*, 53.0, 289-299.
17. William, P., Jaikumar M. Patil, Sunita Panda, Anita Venugopal, Pellakuri Vidyullatha, Nellore Manoj Kumar, and Aman Jandwani. "An optimized framework for implementation of smart waste collection and management system in smart cities using IoT based deep learning approach." International Journal of Information Technology (2024): 1-8.
18. Khursheed, R., Singh, S.K., Wadhwa, S., Kapoor, B., Gulati, M., Kumar, R., Ramanunny, A.K., Awasthi, A., Dua, K. (2019). Treatment strategies against diabetes: Success so far and challenges ahead. *European Journal of Pharmacology*, 862.0, No Pages. https://doi.org/10.1016/j.ejphar.2019.172625
19. Nijaguna, G.S., Manjunath, D.R., Abouhawwash, M., Askar, S.S., Basha, D.K., Sengupta, J. (2023). Deep Learning-Based Improved WCM Technique for Soil Moisture Retrieval with Satellite Images. *Remote Sensing*, 15.0(8.0), No Pages. https://doi.org/10.3390/rs15082005
20. Masud, M., Gaba, G.S., Choudhary, K., Hossain, M.S., Alhamid, M.F., Muhammad, G. (2022). Lightweight and Anonymity-Preserving User Authentication Scheme for IoT-Based Healthcare. *IEEE Internet of Things Journal*, 9.0(4), 2649-2656.
21. Arputharaj, J. Vijay, Joanna Mariam Varkey, Rishi Vagadia, and Ramesh Kumar Ayyasamy. "Leveraging Intelligent Systems and the AIoT/IIoT for Enhanced Waste Management and Recycling Efficiency." In Intelligent Systems and Industrial

Appendix

1. Publications:

International Conference on Next-Gen Quantum and Advanced Computing: Algorithms, Security, and Beyond : Submission (294) has been created. Inbox ×

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Hello,

The following submission has been created.

Track Name: NQComp2026

Paper ID: 294

Paper Title: SMART WASTE MANAGEMENT, DISPOSAL AND SANITIZATION MONITORING AI SYSTEM

Abstract:
This presents the design and development of a smart, technology-driven waste management system that integrates waste segregation, disposal, and sanitization monitoring. The system leverages artificial intelligence (AI), machine learning, and web technologies to address inefficiencies in urban and campus waste handling. Using the system distinguishes between organic, recyclable, and hazardous waste while enabling real-time tracking of collection and sanitization activities. This approach enhances accountability, improves public participation, and ensures sustainable waste management practices.
The rapid expansion of city dwellers has made the situation of waste management more challenging and, thus, intensified the problems of inefficiencies, missed collections, and poor post-disposal sanitization. In order to tackle these challenges, the current research proposes an AI-based integrated ted system for smart waste management, disposal, and sanitization monitoring that merges web technologies and analytics to improve transparency, accountability, and the overall efficiency of waste management. The solution enables the monitoring of disposal in real-time, verification of sanitization, prediction of analytical support for collection-based scheduling, and citizen involvement through a reporting module. Special dashboards for each role allow the administrator, workers, and the public to jointly observe the activities related to waste, the trustworthiness of the data being handled being guaranteed by the secure backend services. The experimental evaluation carried out in a controlled setting shows that there is better accuracy in logging, increased community participation, and smoother workflow.
Rapid population growth and shifting consumption patterns are making the growing amount of waste in urban environments problematic. Due to inadequate waste management, resources.

Keywords-Smart Waste Management, AI, Sanitization Monitoring.

2. Project Report- Similarity Report

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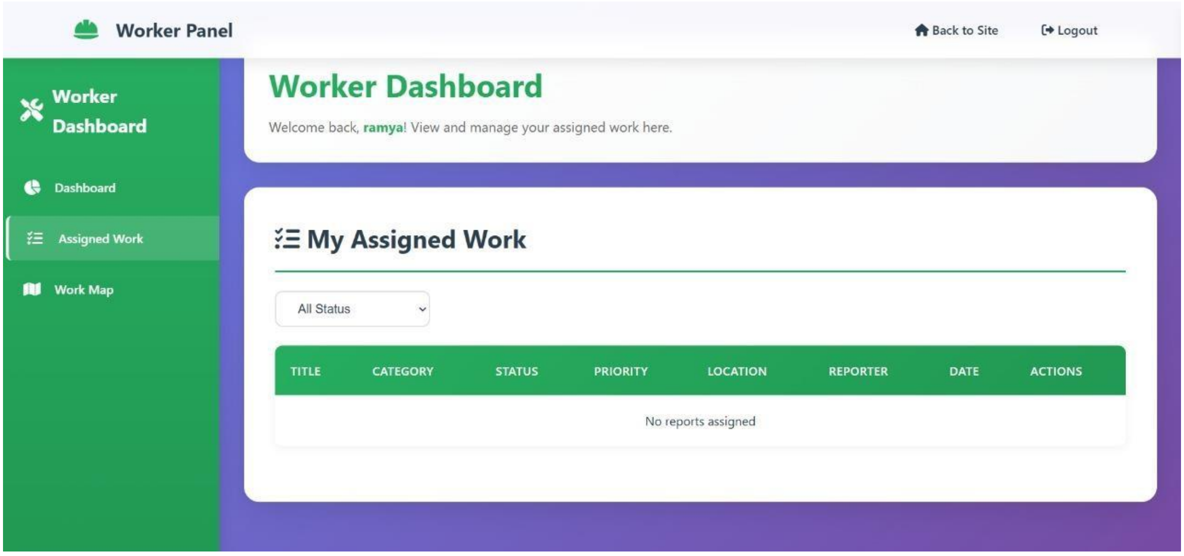

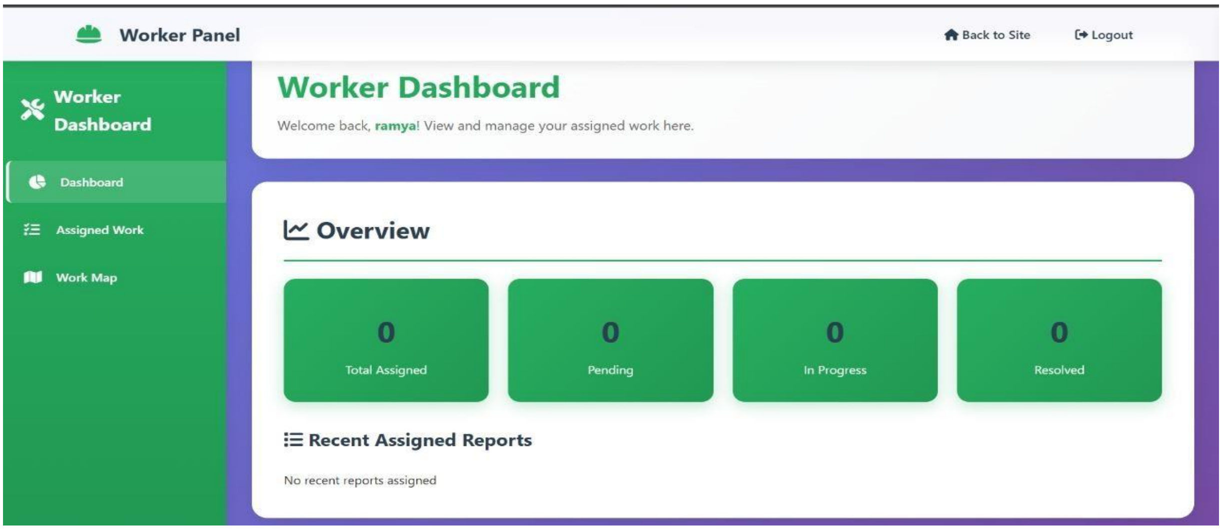

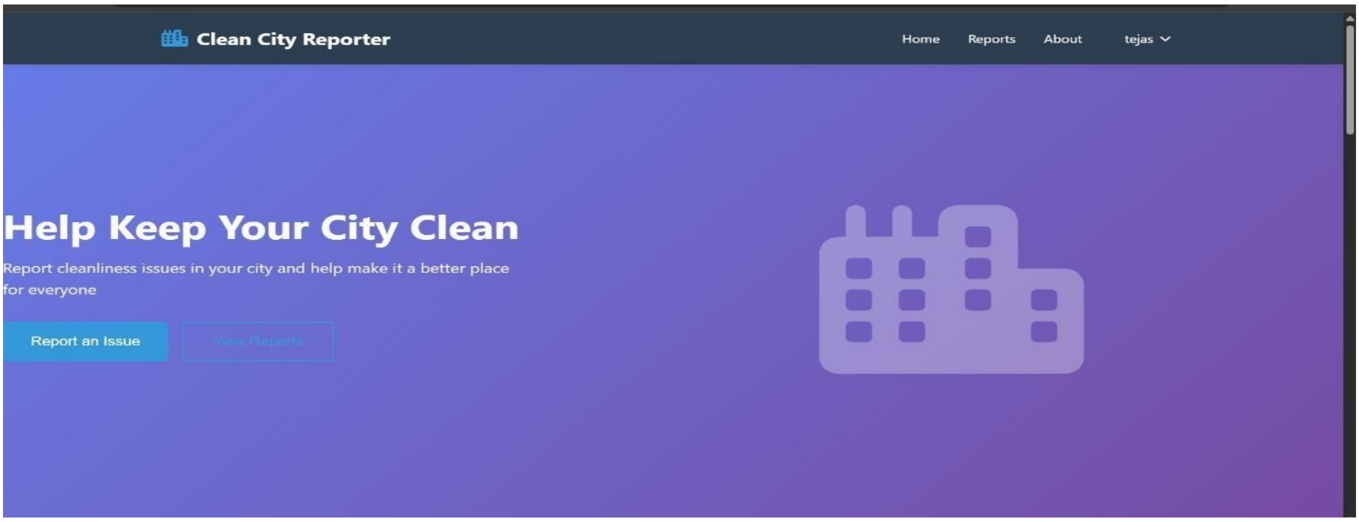

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