Department of Computer Science and Engineering
T.K.M College of Engineering, Kollam
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IOT BASED WASTE MANAGEMENT SYSTEM

Mini Project Report

Submitted By

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to

APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of
B.Tech Degree in Computer Science and Engineering

DECLARATION

We undersigned hereby declare that the project report on “Iot Based Waste Management System”, submitted as part of our curriculum, Mini Project under APJ Abdul Kalam University, Kerala is a bonafide work done by us under supervision of Prof. Muhammed Siyad B, Assistant Professor, TKMCE .

This submission represents our ideas in our own words and from other sources that have been adequately and accurately cited and referenced. We also declare that we have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in our submission.

We understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

Place: Kollam
Date: 15/05/2024

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T.K.M COLLEGE OF ENGINEERING, KOLLAM

CERTIFICATE

This is to certify that the report titled "**IOT Based WasteManagement System**" submitted by **Aisha Thameem**, **TKM21CS012**; **Bhagya A Jai**, **TKM21CS041**; **Fathima A**, **TKM21CS053**; **Uthara Sabu**, **TKM21CS138** to the APJ Abdul Kalam Technological University in completion of the requirements for the award of Bachelor of Technology Degree in Computer Science and Engineering during 2023 – 2024 is a bonafide record of the **Mini Project** work carried out by them under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Project Coordinators   Head of the Department

External Examiner

ACKNOWLEDGEMENT

We take this opportunity to express my deep sense of gratitude to the Almighty and sincere thanks to all who helped me to complete the project successfully.

We express our sincere gratitude to **Dr. T. A. Shahul Hameed**, Principal, TKMCE, for providing us with all the necessary facilities and support for doing the project.

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We extend our immense gratitude to all Faculties and Technical Staffs in the Department of Computer Science and Engineering, for their help and necessary facilities to complete the project. Our humble gratitude and heartiest thanks also go to our parents and friends, who have supported and helped me on the course of this work.

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ABSTRACT

To make the cities greener, safer, and more efficient, the Internet of Things (IoT) can play an important role. Improvement in safety and quality of life can be achieved by connecting devices, vehicles and infrastructure all around in a city. Best technological solutions can be achieved in smart cities by making different stakeholders work together . System integrators, network operators and technology providers have a role to play in working with governments to enable smart solutions. But, building such solutions on an open, standards-based communications platform that can be continuously used is a challenge.

We present a waste collection management solution based on providing intelligence to waste bins, using an IoT prototype with sensors and providing an optimized route for waste collection. The bin can read, collect, and transmit a huge volume of data over the Internet. Such data, when put into a spatio-temporal context and processed by intelligent and optimized algorithms, can be used to dynamically manage waste collection mechanisms. Simulations for several cases are carried out to investigate the benefits of such a system over a traditional system.Also Route optimization is achieved by leveraging IoT devices to detect the fill level of bins and signal when they are full.

Keywords : Internet of Things (Iot), Route Optimization, Smart bin, Smart cities, Waste management, Sensor technology, Sustainability

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ABBREVIATIONS

UI - User Interface
GUI - Graphical User Interface
HTTPS - Hypertext Transfer Protocol Secure
SDLC - Software Development Life Cycle
API - Application Programming Interface
RDBMS - Relational Database Management System
SQL - Structured Query Language
ER - Entity Relation
UML - Unified Modeling Language
JS - JavaScript
POS - Program Outcomes
IDE - Integrated Development Environment
SRS - Software Requirement Specification Document
SDD - Software Design Document
PHP - Hypertext Preprocessor
MCU - Microcontroller Unit
IOT - Internet of Things
ORS - Open Route Service

CHAPTER 1

INTRODUCTION

1.1. Introduction to Project

In today's ever-evolving urban landscape, the urgency of efficient waste management cannot be overstated. We introduce a Smart waste management system embedded with IoT technology aimed at revolutionizing how cities handle waste. With a deep understanding of the health and environmental challenges posed by inadequate waste management practices, IoT based waste management offers real-time monitoring and route optimization functionalities . By harnessing the power of IoT sensors, our platform empowers municipalities to collect and analyze data, enabling proactive decision-making and resource allocation. Thus we can create cleaner, healthier, and more sustainable cities for all.

1.2. Motivation

The primary motivation behind our project is to address the environmental crisis threatening ecosystems and biodiversity by revolutionizing waste management practices through IoT technology. Our platform aims to mitigate health risks associated with inefficient waste management, while also reducing resource wastage and promoting sustainable urban development. By tackling issues such as overflowing waste bins and increased operational costs, our solution seeks to enhance the aesthetic appeal of cities and improve overall quality of life. Furthermore, we recognize the growing trend of urbanization and aim to provide cities with the tools they need to effectively manage waste in the face of rapid population growth.

1.3. Objectives

Our primary objective with this project is to revolutionize waste management practices through the implementation of IoT technology, focusing on real-time monitoring and route optimization. By utilizing ultrasonic or infrared sensors, we can collect and transmit data in real-time to our waste management software, enabling timely and informed decision-making. Integration with GPS technology allows for dynamic route optimization based on fill levels, ensuring efficient collection routes that minimize operational costs and time.

Furthermore, our solution aims to enhance sustainability by incorporating eco-friendly practices within the Waste Management System. Through predictive analytics powered by machine learning algorithms, we can analyze historical data to predict future waste generation patterns. By leveraging these insights, municipalities and waste management authorities can proactively plan and allocate resources, ultimately contributing to a more sustainable and environmentally conscious waste management approach.

CHAPTER 2

LITERATURE REVIEW

In recent years, the application of Internet of Things (IoT) technology in waste management systems has received significant attention due to its potential to optimize waste collection, disposal, and recycling processes. Various studies have highlighted both the advantages and challenges associated with IoT-based waste management systems.

One common issue identified in the literature is the lack of comprehensive discussion on economic feasibility, scalability, maintenance, data security, and adaptive capacity of IoT-enabled waste management systems. These factors are crucial for ensuring the long-term sustainability and effectiveness of such systems.

Our project aims to provide a range of innovative features through our IoT-based waste management system, geared towards optimizing waste collection, disposal, and recycling processes. At its core, our system offers real-time monitoring and data collection capabilities facilitated by IoT devices like Sensors and Microcontroller units. These devices enable the continuous tracking of fill levels in waste bins, allowing for precise and efficient route optimization for collection vehicles. By leveraging this real-time data, our system ensures timely waste collection while minimizing unnecessary trips, thereby reducing fuel consumption and environmental impact.

Overall, the implementation of an IoT-based waste management system offers significant societal benefits, ranging from environmental sustainability and public health to economic growth and technological innovation. By leveraging advanced technology to address pressing waste management challenges, such systems contribute to building cleaner, healthier, and more prosperous communities.

- Tejashree Kadus presented a research paper on waste management system featuring Smart Netbin, WiFi facilities with a reward system, load sensors, IR sensors, and a mechanical shredder, along with collaborators Pawankumar Nirmal and Kartikee Kulkarni.

  https://www.researchgate.net/publication/341870789_Smart_Waste_Management_System_using_IOT

- In 2021, P. Ranjana, Varsha.S, and Sherin Eliyas presented a paper on IoT-based smart garbage collection, incorporating RFID tags for value points, gas sensors to detect odors and toxic gases, humidity sensors, IR sensors, and GPS for location tracking.

  https://iopscience.iop.org/article/10.1088/1742-6596/1818/1/012225/pdf

CHAPTER 3

REQUIREMENT ANALYSIS

3.1. Requirement Gathering Methodologies

- **Public opinion survey**:

We circulated a google form to all our friends and relatives and to their friends enquiring about their field of study, categories in which they are interested to do jobs and specifying the type of jobs in selected categories.

- **Brainstorming**

A dynamic and collaborative approach to generate innovative ideas for designing a job providing website. By engaging stakeholders and team members in a brainstorming session, diverse perspectives and insights are collected, fostering creativity and enabling comprehensive requirements gathering for developing a user-centric job platform.

3.2. Functional Requirements

3.2.1 User Functionalities:

- Register/Login: Users should be able to create an account and log in to access the system.
- Request Pickup: Users can request waste pickup for their location if a bin is full or needs attention.
- Track Requests: Users can track the status of their pickup requests and receive notifications when completed.
- Update Profile: Users can update their personal information, notification preferences, and address details.
- Feedback: Users can provide feedback on the waste collection service, including reporting issues or suggesting improvements.

3.2.2 Admin Functionalities:

- Dashboard: Admins have access to a dashboard for monitoring system status, bin fill levels, and collection activities.
- Manage Bins: Admins can add, remove, or update information for waste bins, including location details and sensor data.
- Route Optimization: Admins can optimize waste collection routes based on real-time data and historical analysis.
- User Management: Admins can manage user accounts, including registration, authentication, and permissions.
- Reporting: Admins can generate reports on system performance, route efficiency, and waste management metrics.
- Alerts and Notifications: Admins receive alerts for critical system events, such as bin overflows or sensor failures, and can send notifications to users and drivers.

3.2.3 Driver Functionalities:

- Route Navigation: Drivers can access optimized routes for waste collection and navigation assistance using ORS Services.
- View Pickup Requests: Drivers can view pending pickup requests, including location details and urgency.
- Update Status: Drivers can update the status of pickups, including completion status and any issues encountered.
- Communicate with Admin: Drivers can communicate with admin for route adjustments, emergencies, or other issues.
- Submit Reports: Drivers can submit reports on bin conditions, collection challenges, or maintenance requirements.
- Optimized Routing: Bins contribute to route optimization by providing real-time data on fill levels and collection needs.

3.2.4 Waste Bin Functionalities:

- Sensor Integration: Bins are equipped with sensors to detect fill levels and other relevant parameters.
- Data Transmission: Bins transmit data on fill levels and status to the central server or database.
- Alerts: Bins send alerts when reaching capacity or encountering maintenance issues.
- Self-Diagnostics: Bins perform self-diagnostics to detect sensor malfunctions or communication errors.

3.3.Non Functional Requirements

3.3.1 Performance Requirements:

The IoT-based waste management system should efficiently handle a high volume of data from sensors and users, ensuring real-time monitoring and route optimization. Data processing and analysis should be performed swiftly, with responses to queries and alerts generated within a reasonable timeframe, such as less than one minute.

3.3.2 Security Requirements:

The system must implement robust security measures to safeguard data integrity, confidentiality, and availability. This includes encryption of sensor data during transmission, secure authentication mechanisms for authorized access, and regular security audits to identify and mitigate potential vulnerabilities.

3.3.3 Software Quality Attributes:

- Usability: The system should feature user-friendly interfaces for administrators and stakeholders to easily configure settings, monitor performance metrics, and generate reports. Intuitive dashboards and visualization tools should facilitate data interpretation and decision-making.
- Reliability: The system should operate reliably under varying environmental conditions and network disruptions, ensuring continuous data collection and processing. Redundancy measures and failover mechanisms should be in place to minimize downtime and ensure uninterrupted service.
- Performance: The system should demonstrate high responsiveness and low latency in data transmission and processing, enabling timely decision-making and action. Real-time monitoring capabilities should provide instant insights into waste levels and collection activities.
- Security: The system should adhere to industry best practices for data security, implementing encryption protocols, access controls, and intrusion detection systems to protect against unauthorized access and cyber threats. Regular security audits and updates should be conducted to maintain system integrity.
- Maintainability: The system should be designed with modular components and well-documented code, facilitating ease of maintenance, troubleshooting, and future upgrades. Version control and change management processes should be implemented to track system modifications and ensure system stability.
- Scalability: The system architecture should be scalable to accommodate growth in data volume and user base over time. Horizontal and vertical scaling options should be available to support increased sensor deployments and user interactions without compromising performance.
- Compatibility: The system should be compatible with a variety of IoT devices, sensors, and communication protocols, ensuring interoperability and seamless integration with existing infrastructure. Cross-platform support for web and mobile interfaces should be provided to enable access from different devices and operating systems.

CHAPTER 4

PROPOSED SYSTEM DESIGN

4.1.Software Development Life Cycle(SDLC)

A system development life cycle is essentially a project management model. It defines different stages that are necessary to bring a project from its initial idea all the way to deployment and later maintenance all according to the end user's demands . There are various software development approaches defined and designed which are used during the development process of software, these approaches are also referred as “Software Development Process Models” (e.g., Waterfall model, incremental model, V-model, iterative model, etc.). Each process model follows a particular life cycle in order to ensure success in the process of software development.

Figure 1: The SDLC

4.2. System Development

Life cycle model describes the phases of the software cycle and the order in which those phases are executed. Each phase produces deliverables required by the next phase in the life cycle. Requirements are translated into design. Code is produced according to the design which is called the development phase. After coding and development, the testing verifies the deliverable of the implementation phase against requirements. A software development process is the process of dividing software development work into smaller and distinct phases to improve design, product management, and project management. It is also known as a software development life cycle. The methodology may include the pre-definition of specific deliverables and artifacts that are created and completed by a project team to develop or maintain an application.

Most modern development processes can be vaguely described as agile. Other methodologies include waterfall, prototyping, iterative and incremental development, spiral development, rapid application development, and extreme programming.Some people consider a life-cycle "model" a more general term for a category of methodologies and a software development "process" is a more specific term to refer to a specific process chosen by a specific organization. The field is often considered a subset of the systems development life cycle. The model used in the creation of “ Iot Based Waste Management System “ is Agile Methodology in which new ideas are included in the website at each stage.

4.3. System Architecture Design

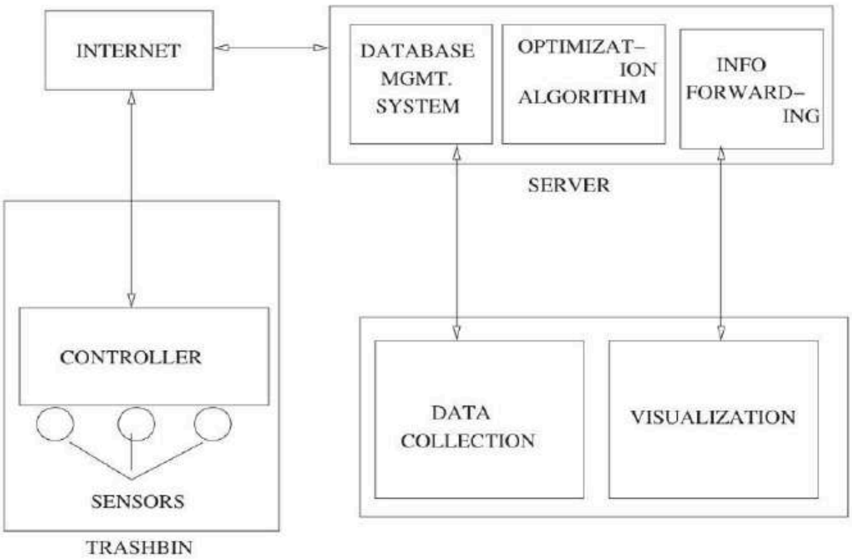


Figure 2: System Architecture

The proposed system is a web-based application using cloud-based technology. The system architecture is designed as a multi-tier architecture, consisting of distinct layers for efficient management and interaction.

At the base lies the physical layer, housing tangible hardware components like NodeMCU. These devices are equipped with various sensors such as ultrasonic sensors, display enabling real-time data collection and monitoring.Above the physical layer is the process layer, responsible for orchestrating waste management services through sensor-based processes. It facilitates seamless integration with existing systems, ensuring smooth data mapping, formatting, and interaction with databases.

The data access layer utilizes a Relational Database Management System (RDBMS) alongside applications tailored for waste management service providers. These applications enable the creation of sensor "events" and utilize Google Firebase as an IoT platform, ensuring robust data management and accessibility.

Lastly, the user interface layer provides an intuitive graphical interface, accessible through both web and mobile applications. This layer ensures a uniform and user-friendly experience, allowing stakeholders to interact with sensors effortlessly and manage waste efficiently.

4.4. Data Design

Data Storage:

To effectively manage the data generated and utilized by our IoT-based waste management system, we have selected MySQL as the relational database management system (RDBMS) for its reliability, performance, and scalability. The MySQL database will include the following tables:

- SensorData: This table will store real-time data collected from IoT sensors, including bin fill levels, temperature, humidity, and other relevant sensor readings. Each record will contain timestamped data entries for accurate monitoring and analysis.

- RouteOptimization: This table will store data related to route optimization, including optimized collection routes, vehicle assignments, and route performance metrics. It will facilitate efficient waste collection by ensuring optimal route planning based on real-time data.

- MaintenanceLogs: This table will record maintenance activities for waste management equipment, such as maintenance schedules, service records, and equipment status updates. It will help ensure the reliability and longevity of the equipment through timely maintenance interventions.

- UserAccounts: This table will store user account information, including usernames, passwords, and other relevant details for authentication and authorization purposes. It will ensure secure access to the system and protect user data from unauthorized access.

- Notifications: This table will store notification preferences and settings for users and administrators. It will facilitate timely communication and alerting regarding critical events, such as bin overflow or equipment malfunction.

- By leveraging MySQL as the underlying database management system, our IoT-based waste management system will benefit from robust data storage capabilities, efficient querying, and reliable data management, ensuring optimal performance and scalability to meet the evolving needs of waste management operations.

4.5. ER Diagram

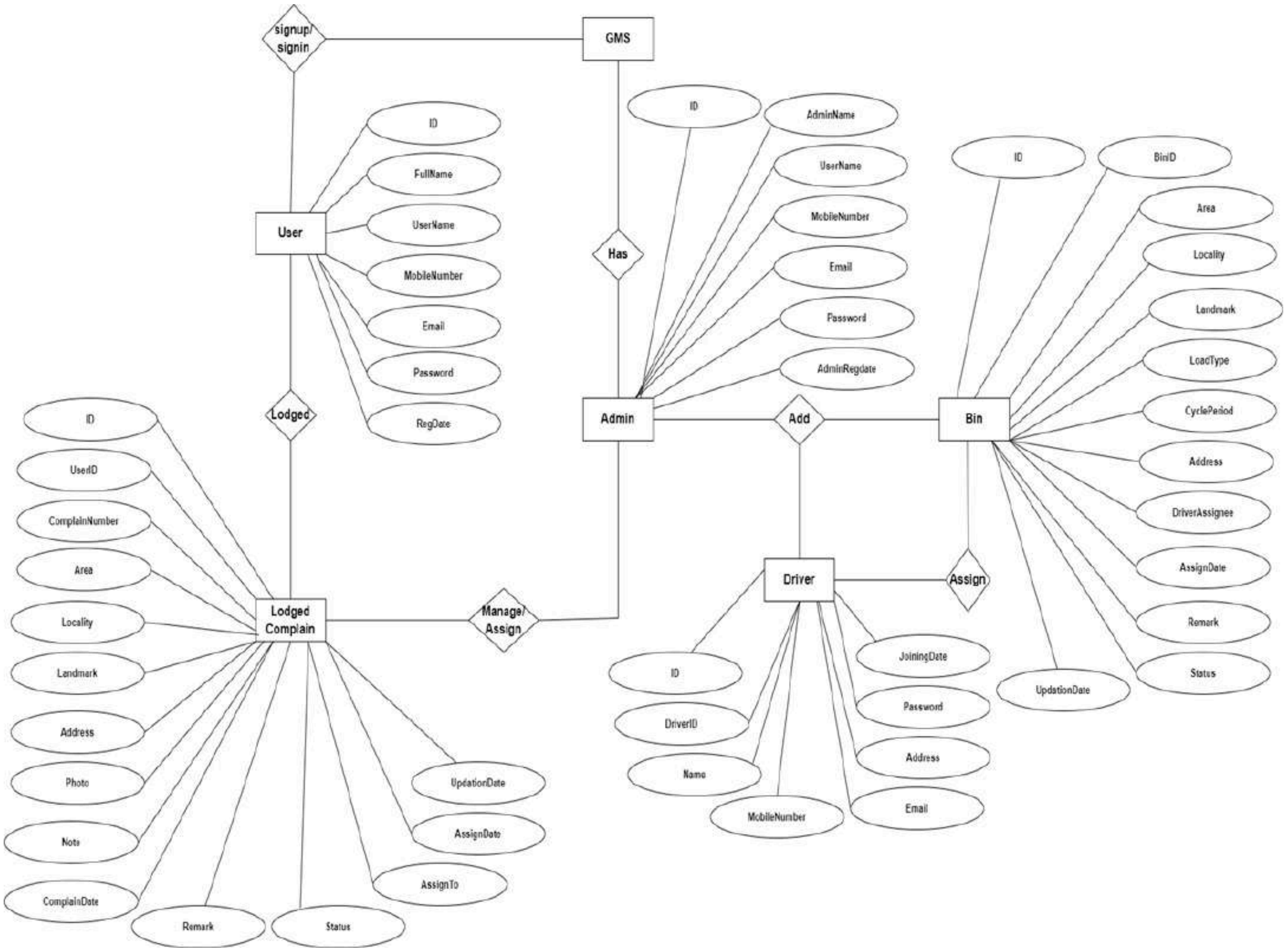


Figure 3: ER Diagram

4.6. UML Class Diagram

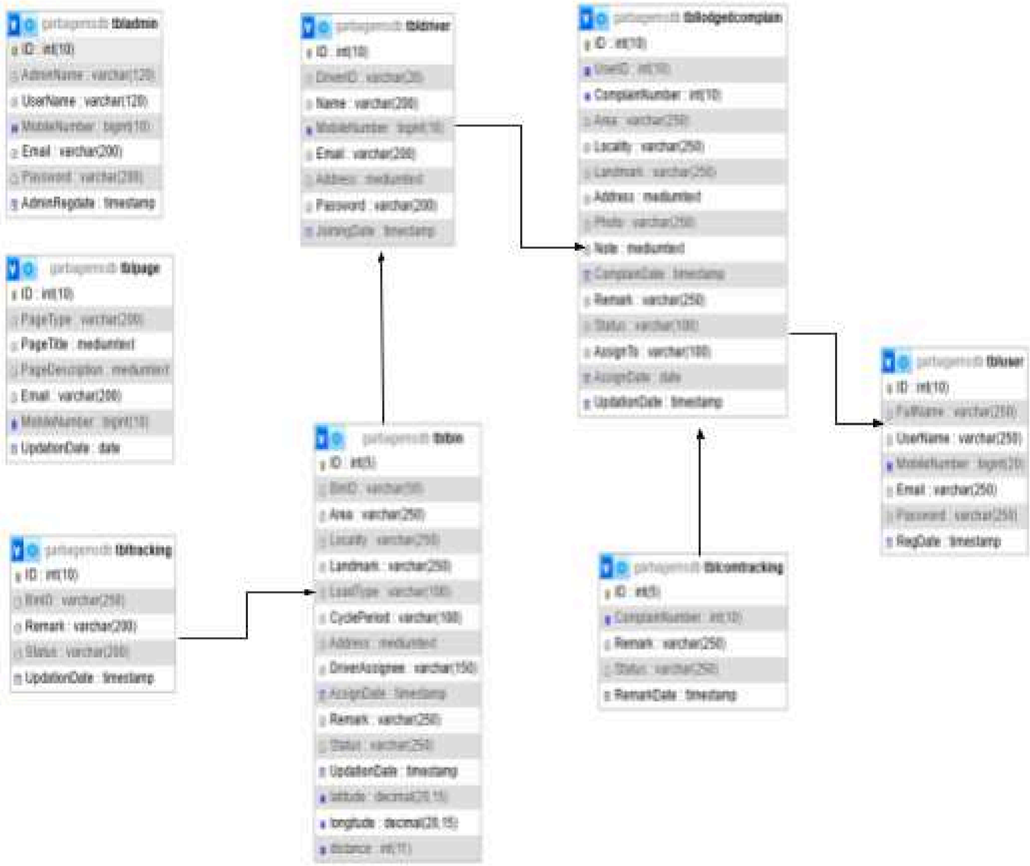
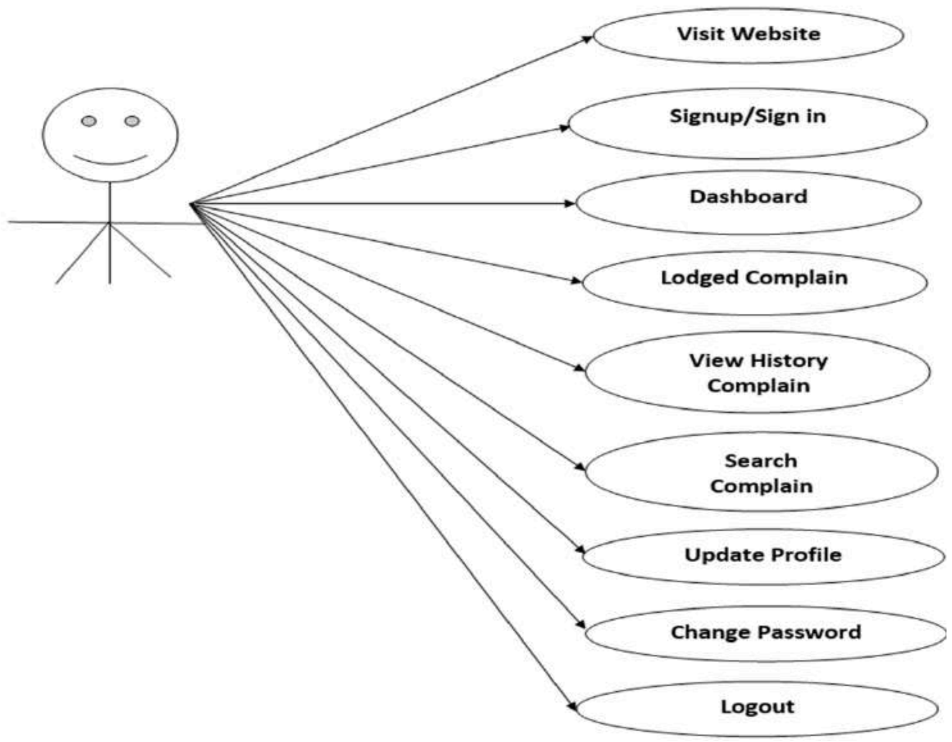


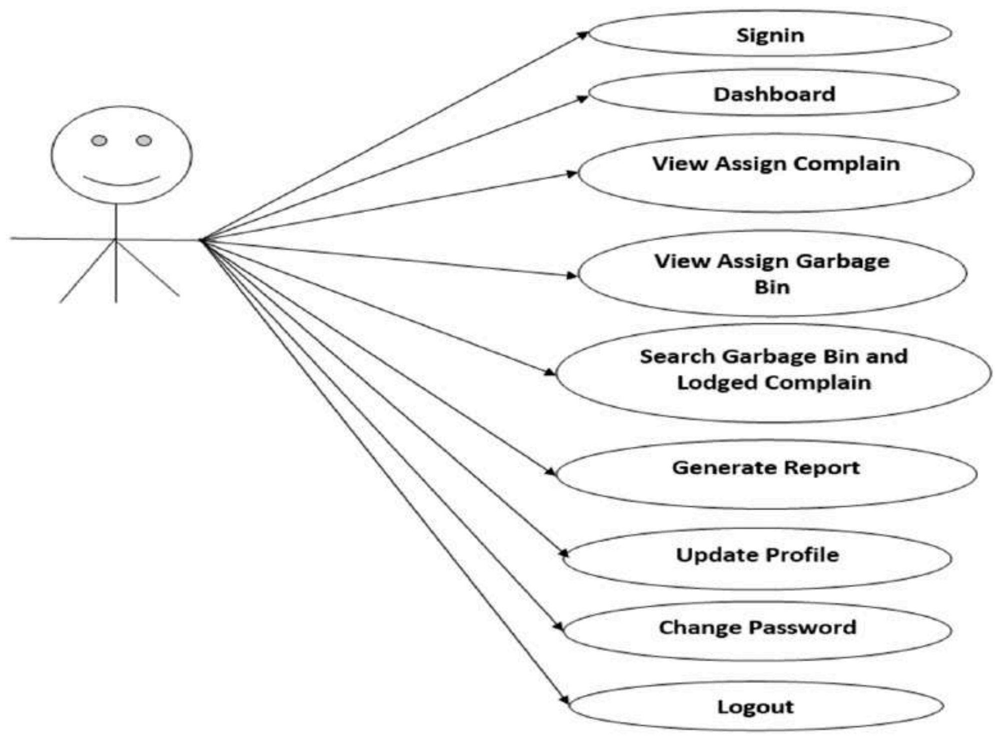
Figure 4: Class Diagram

4.7. Use Case Diagram

1) Use Case Diagrams of User



2) Use Case Diagrams Of Driver



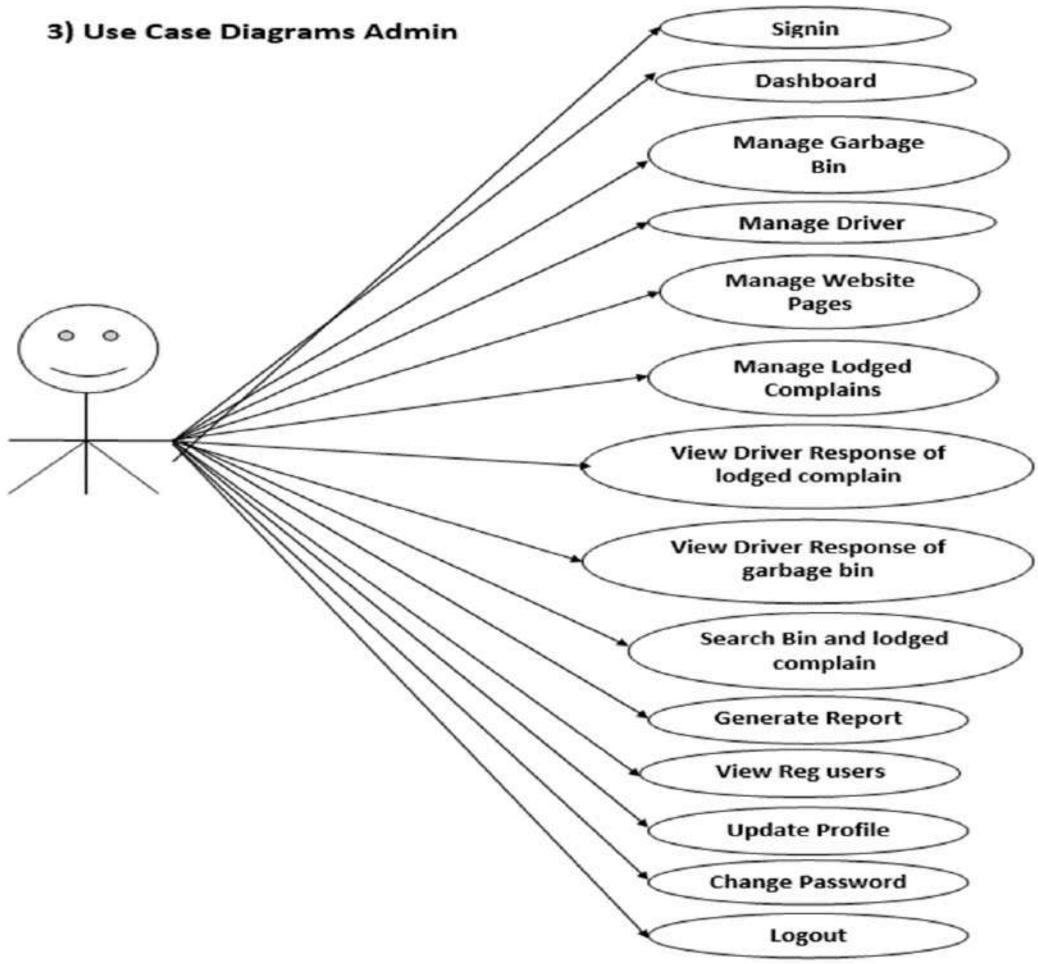


Figure 5: Use Case Diagrams

CHAPTER 5

IMPLEMENTATION

5.1. Technology Stack

5.1.1 PHPMyAdmin: It is a PHP-based web application used for managing MySQL and MariaDB databases through a browser interface. It simplifies tasks like database management, data manipulation, and user account administration. As an open-source tool, it's popular among developers, webmasters, and system administrators for database management in various environments.

Table: tbladmin

←T→	ID	AdminName	UserName	MobileNumber	Email	Password	AdminRegdate
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Check all With selected: Edit Copy Delete Export

Table: tblbin

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Edit Copy Delete	2	B-234	Kundara	Kollam		High	Daily	Kundara	vams123	2024-05-01 16:36:27	High Density area	Completed	2024-05-01 23:53:20	8.910830932812395	76.618318937623020	10
Edit Copy Delete	3	B-345	Anchalinmoodu	Kollam	Near Bridge	High	Daily	Anchalinmoodu	vams123	2024-05-01 17:03:00	Road Construction	Ongoing	2024-05-14 13:34:06	9.036499829429918	76.521172550706070	15
Edit Copy Delete	4	B-456	Kollam	Chinnakada	Clock Tower	High	Daily	Kollam	vams123	2024-05-01 17:10:48	Traffic Congestion	Ongoing	2024-05-14 13:34:06	8.904750177496260	76.585298267385040	7
Edit Copy Delete	7	btest	kerala	karicode	tkmce	High	Alternate	karicode	vams123	2024-05-01 17:15:52	Parking Restriction	Ongoing	2024-05-14 13:33:36	8.936369420777636	76.588830680490260	14

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Table: tblcomtracking

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Edit Copy Delete	2	526529361	Driver is on the way	On the way	2024-05-06 22:27:34
Edit Copy Delete	3	526529361	On the way	On the way	2024-05-07 17:36:36
Edit Copy Delete	4	526529361	Completed	Completed	2024-05-07 21:40:31
Edit Copy Delete	5	699612318	your complain hass been approved	Approved	2024-05-08 16:12:01
Edit Copy Delete	6	699612318	On the way for collecting the garbage	On the way	2024-05-08 11:48:28
Edit Copy Delete	7	792381847	Assign to driver	Approved	2024-05-09 17:51:18
Edit Copy Delete	8	792381847	On the way for pickup garbage	On the way	2024-05-10 17:52:54
Edit Copy Delete	9	792381847	Completed	Completed	2024-05-10 20:53:12

Check all With selected: Edit Copy Delete Export

Table: tbldriver

←T→	ID	DriverID	Name	MobileNumber	Email	Address	Password	JoiningDate
Edit Copy Delete	1	vams123	TEST	4654654654	rahul123@gmail.com	J-234, near reliance mayur vihar new delhi	f925916e2754e5e03f75dd58a5733251	2024-05-02 13:09:35
Edit Copy Delete	2	vams124	Test	9879879879	kai@gmail.com	H-987, Hari Nagar Delhi	202cb962ac59075b964b07152d234b70	2024-05-02 13:12:39
Edit Copy Delete	4	vams125	Mahesh Kumar	9879789799	mahesh@gmail.com	hkjhjkhkjhuyifhkjwehfk jkljkljrkawteae5t	202cb962ac59075b964b07152d234b70	2024-05-02 14:40:20
Edit Copy Delete	6	test123	John Dore	1234567890	johndoe@gmail.com	New Delhi 110001	f925916e2754e5e03f75dd58a5733251	2024-05-02 16:40:20

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Table: tbllodgedcomplaint

←T→	ID	UserID	ComplainNumber	Area	Locality	Landmark	Address	Photo	Note	ComplainDate	Remark	Status	AssignTo	AssignDate	UpdationDate
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Edit Copy Delete	2	2	699612318	Kalyanpuri	jgjhghjgjhg	nera oppulent mall	K-0890, fghy, uytu,New Delhi	photo2.jpg	There is more than one week no one come to pic thi...	2024-05-04 17:20:44	On the way for collecting the garbage	On the way	vams123	2024-05-06	2024-05-14 14:05:43
Edit Copy Delete	3	2	526529312	Mayur Vihar Phase 3	Hari Kunj	near relaince fresh	Urvarshi Apartment J&J-806 mayur vihar ph-3	photo3.jpg	NULL	2024-05-05 18:00:45	Completed	Completed	vams123	2024-05-07	2024-05-14 14:05:43
Edit Copy Delete	4	3	792381847	XYZ Street	ABC Locality	NA	A1232 Secor 5 Noida	photo4.png	NA	2024-08-08 17:49:45	Completed	Completed	vams123	2024-05-09	2024-05-14 14:05:43

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Table: tblpage

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Edit Copy Delete	2	contactus	Contact Us	TKM College Of Engineering, Karicode, Kollam India...	aisha_bhagya_fathima _uthara@gmail.com	7896541236	2024-05-01

Check all With selected: Edit Copy Delete Export

Table: tbltracking

←T→	ID	BinID	Remark	Status	UpdationDate
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Edit Copy Delete	2	Bin-123	Garbage collected	Completed	2024-05-07 17:20:44
Edit Copy Delete	3	B-123	otw	On The Way	2024-05-08 16:13:16
Edit Copy Delete	4	B-123	completed	Completed	2024-05-14 13:15:13

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Table: tbluser

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Edit Copy Delete	2	test	test123	7946547897	test@gmail.com	202cb962ac59075b964b07152d234b70	2024-05-02 18:04:42
Edit Copy Delete	3	Joh Doe	Johndoe123	1231231230	johndoe@gmail.com	f925916e2754e5e03f75dd58a5733251	2024-05-03 17:48:44

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Figure 6: PHPMyAdmin Tables

5.1.2 XAMPP: It is an integrated web server solution package developed by Apache Friends. It includes Apache, MySQL or MariaDB, PHP, and Perl, providing a comprehensive environment for running web applications locally. With easy installation and portability, XAMPP simplifies the setup and management of local development environments, making it ideal for web developers, designers, and students.

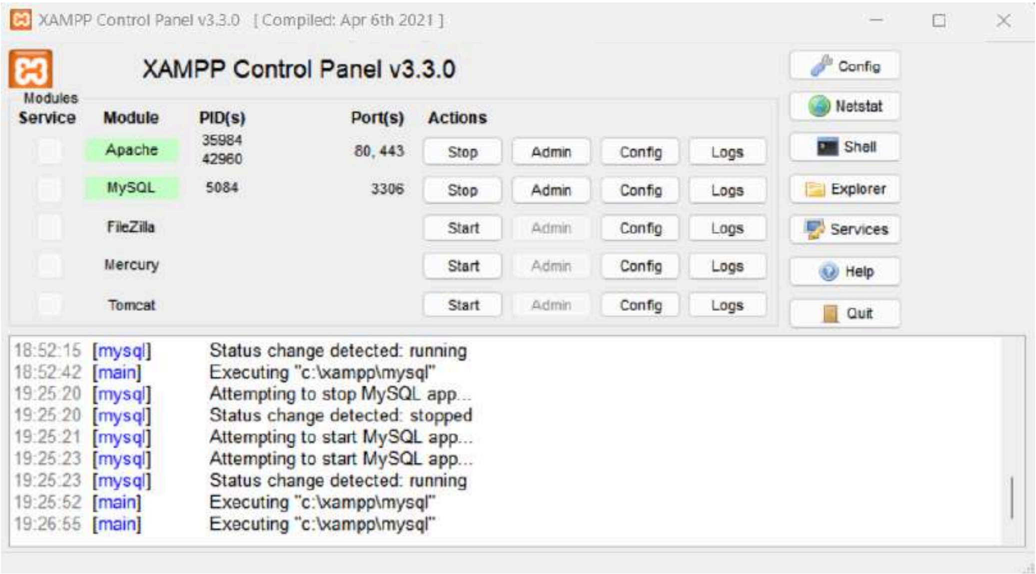

Figure 7: XAMPP Control Panel

5.2. Graphical user Interface

5.2.1 Homepage:

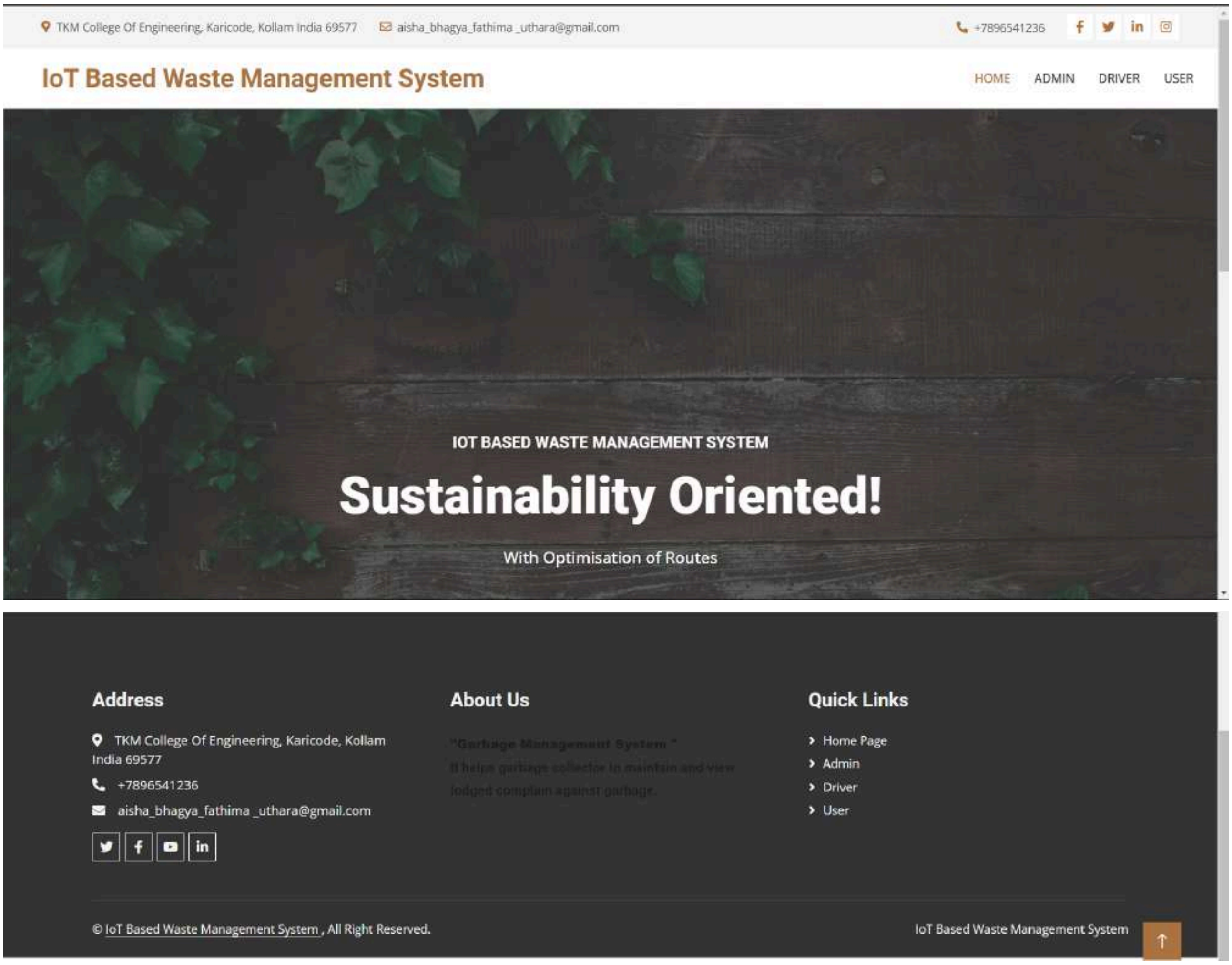

Figure 8: Homepage GUI

5.2.2 Login Page:

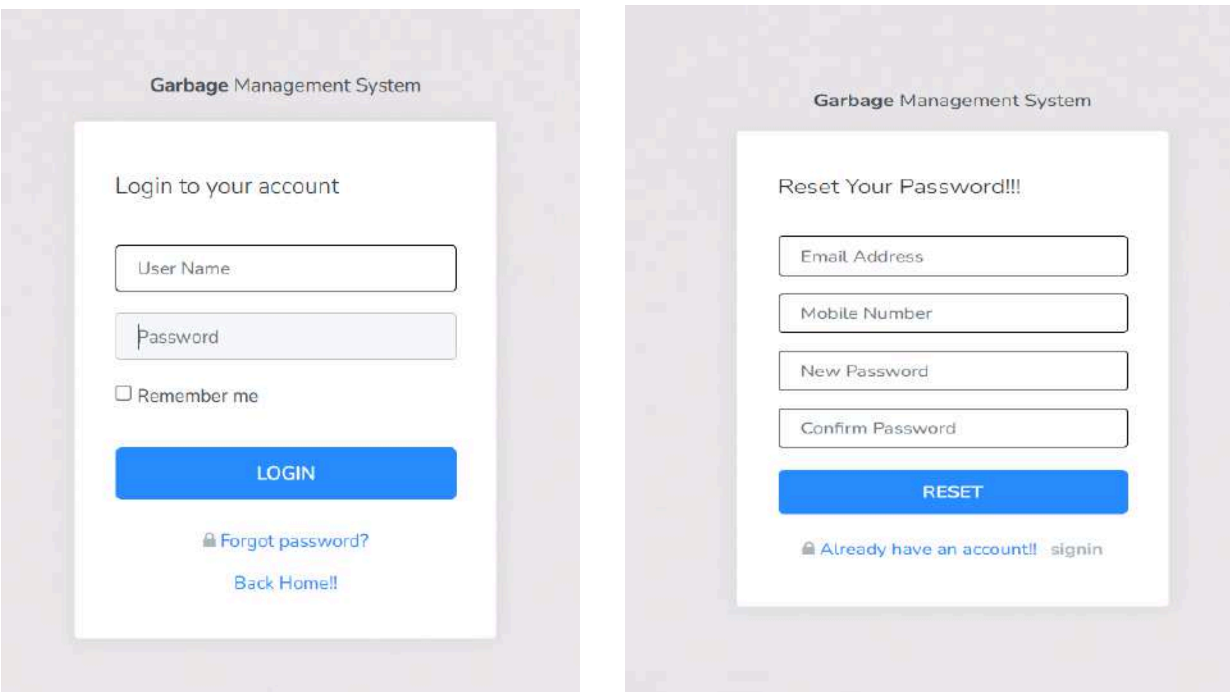

Figure 9: Login Page

5.2.3 Admin:

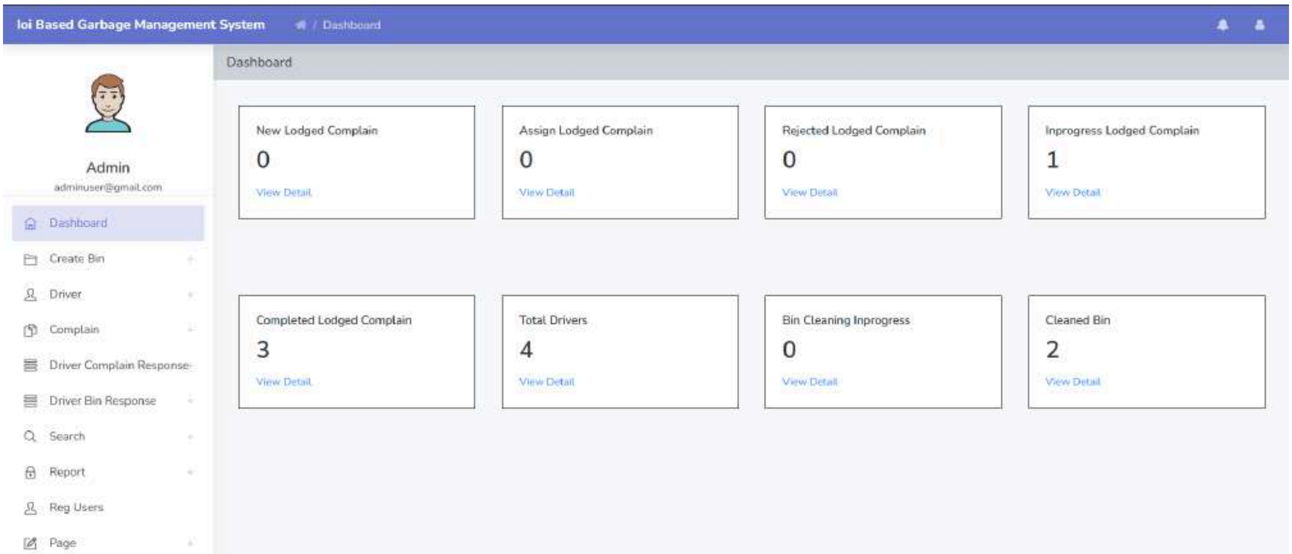

Figure 10: Admin Dashboard Screen

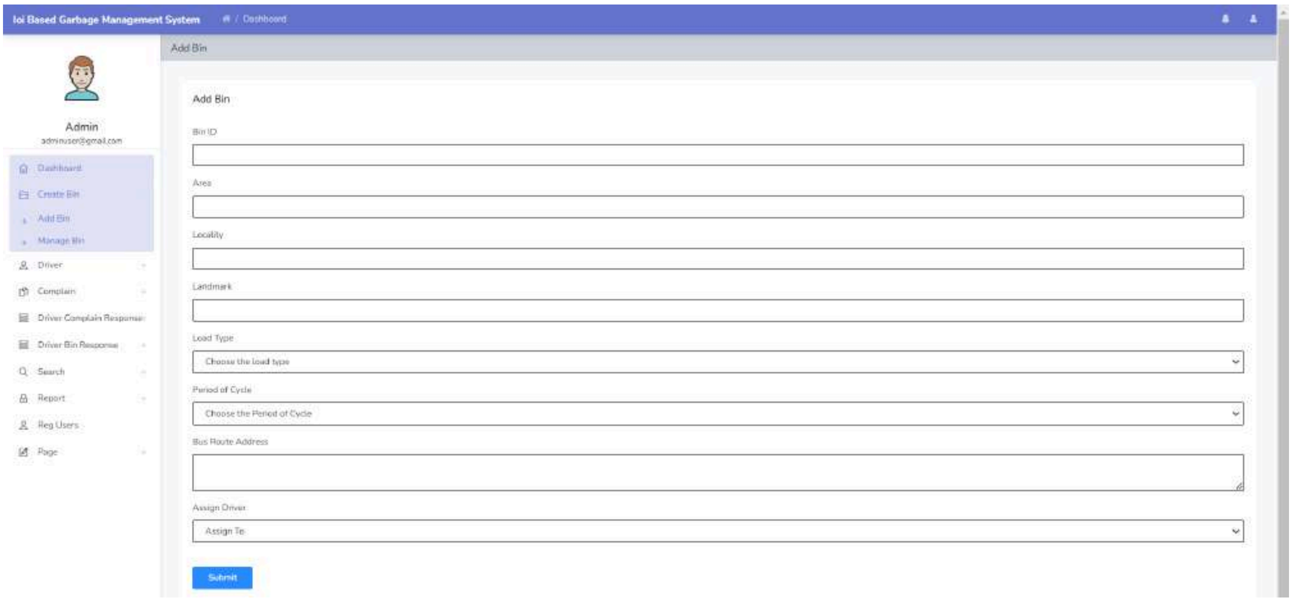

Figure 10.1: Admin Add Bin Screen

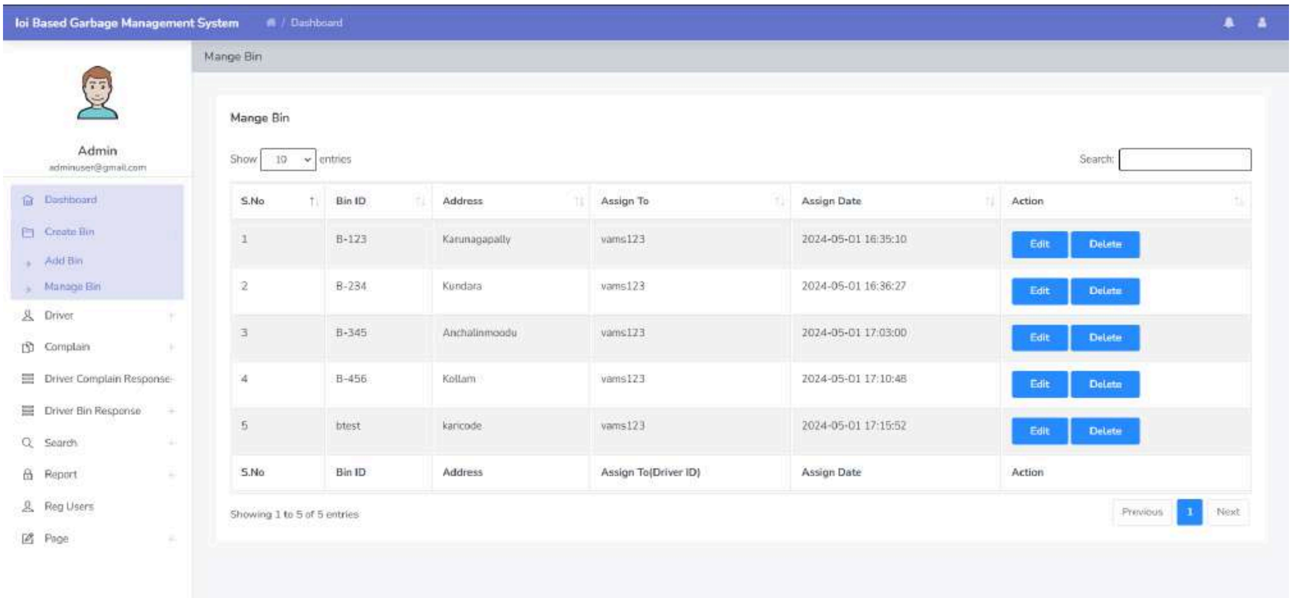

Figure 10.2: Admin Manage Bin Screen

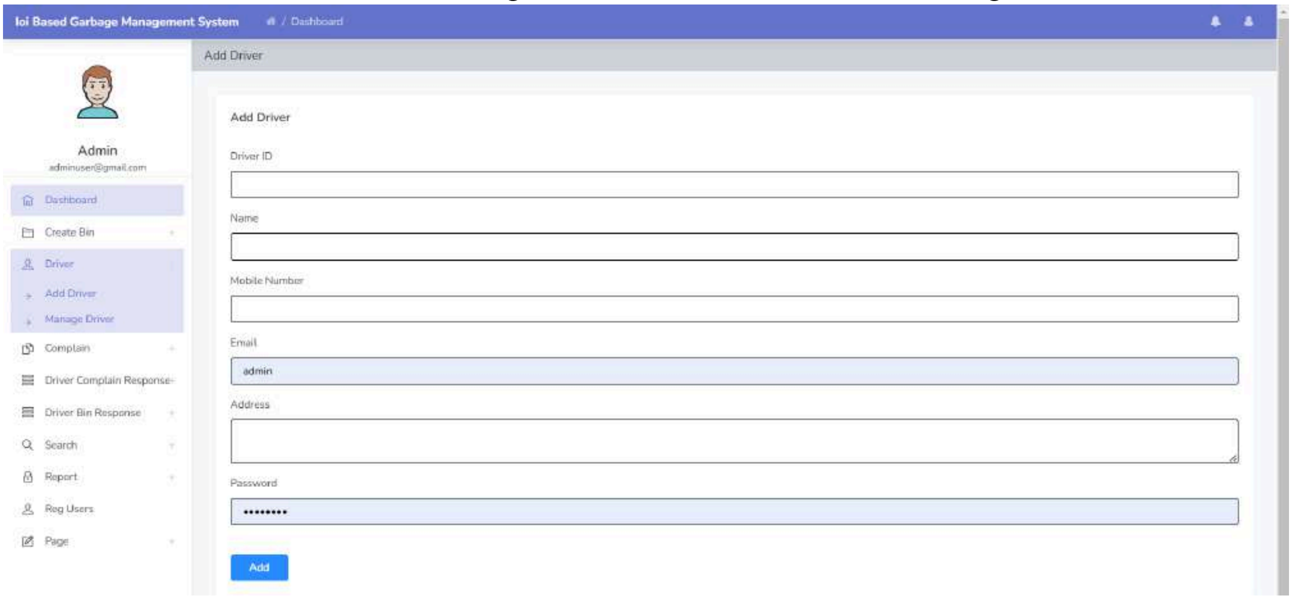

Figure 10.3: Admin Add Driver Screen

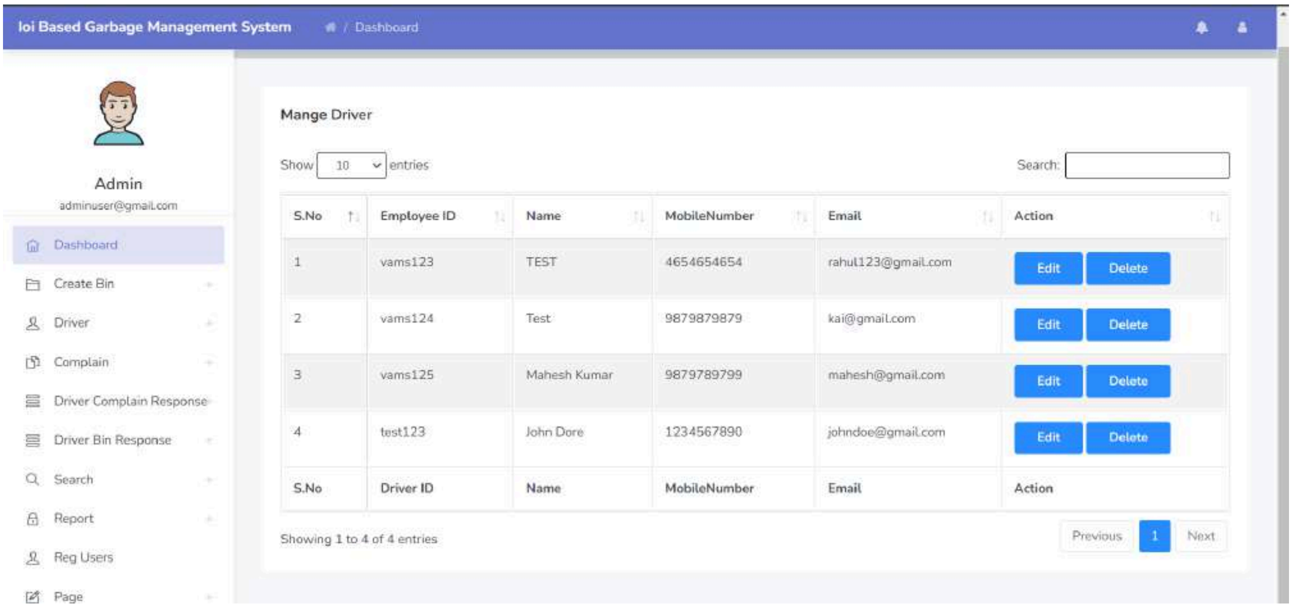

Figure 10.4: Admin Manage Driver Screen

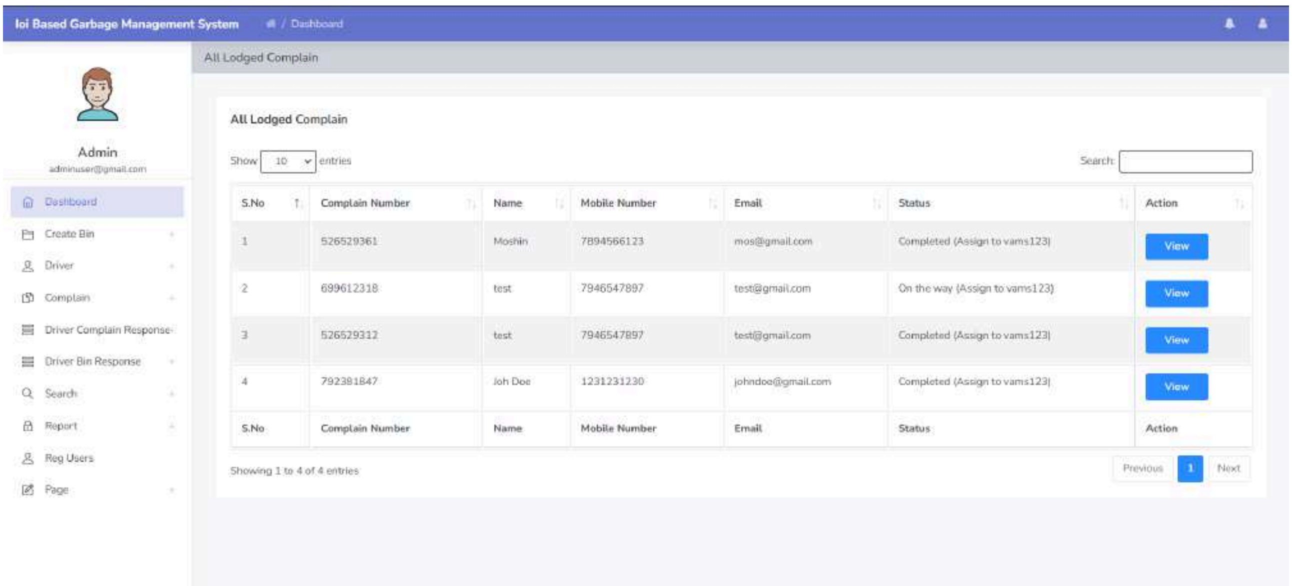

Figure 10.5: Admin Lodged Complaint Screen

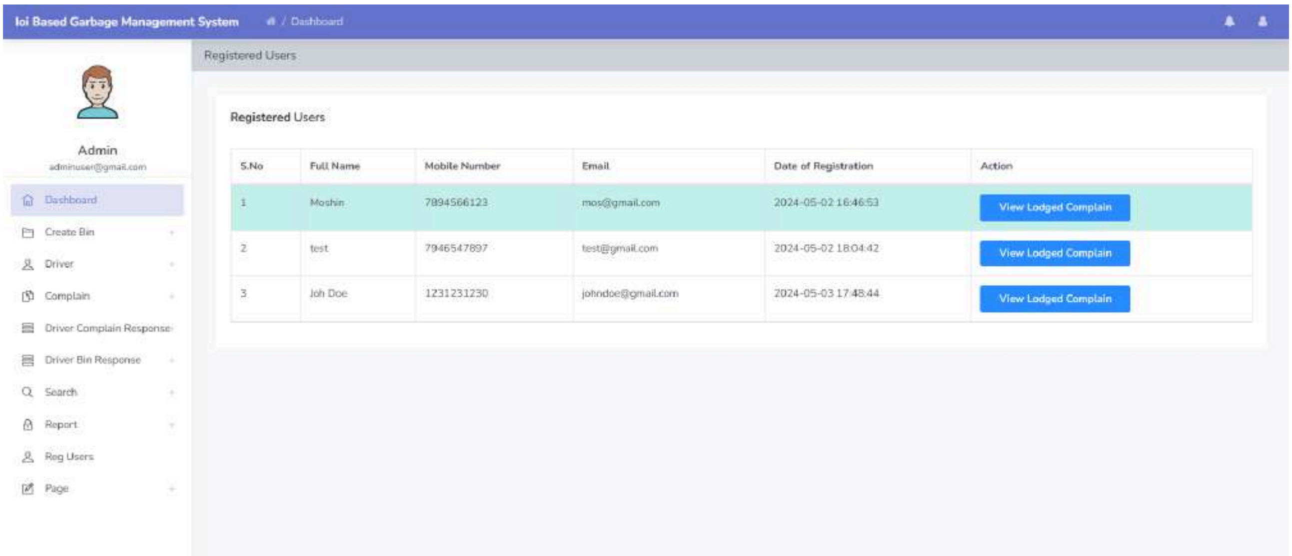

Figure 10.6: Admin View Registered User Screen

5.2.4 Driver:

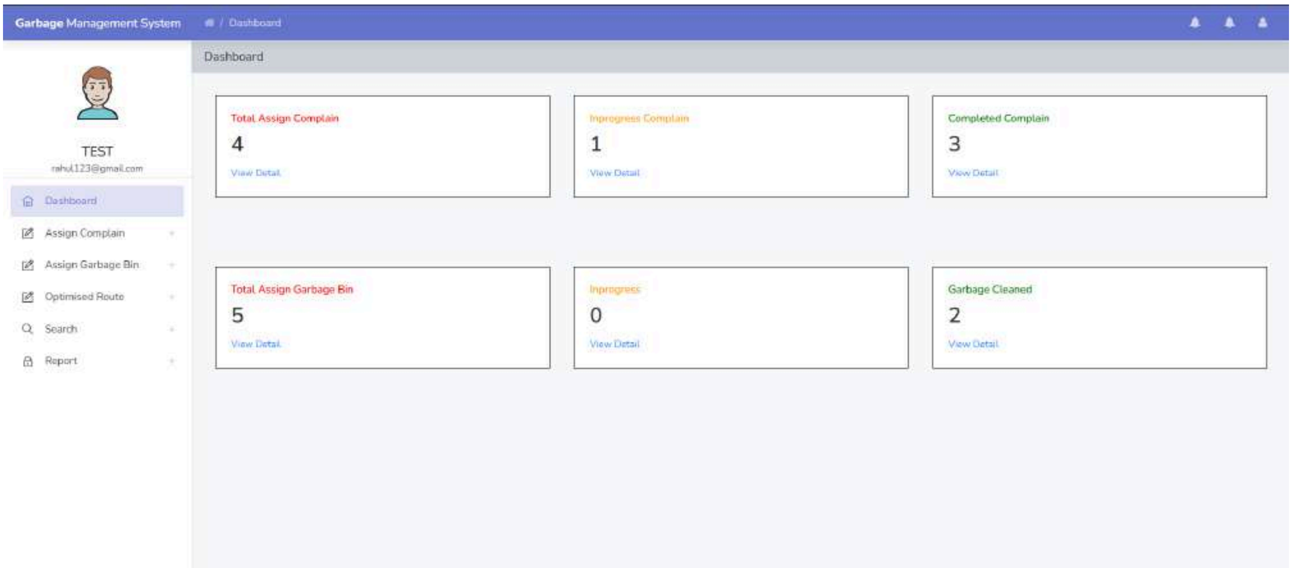

Figure 11: Driver Dashboard Screen

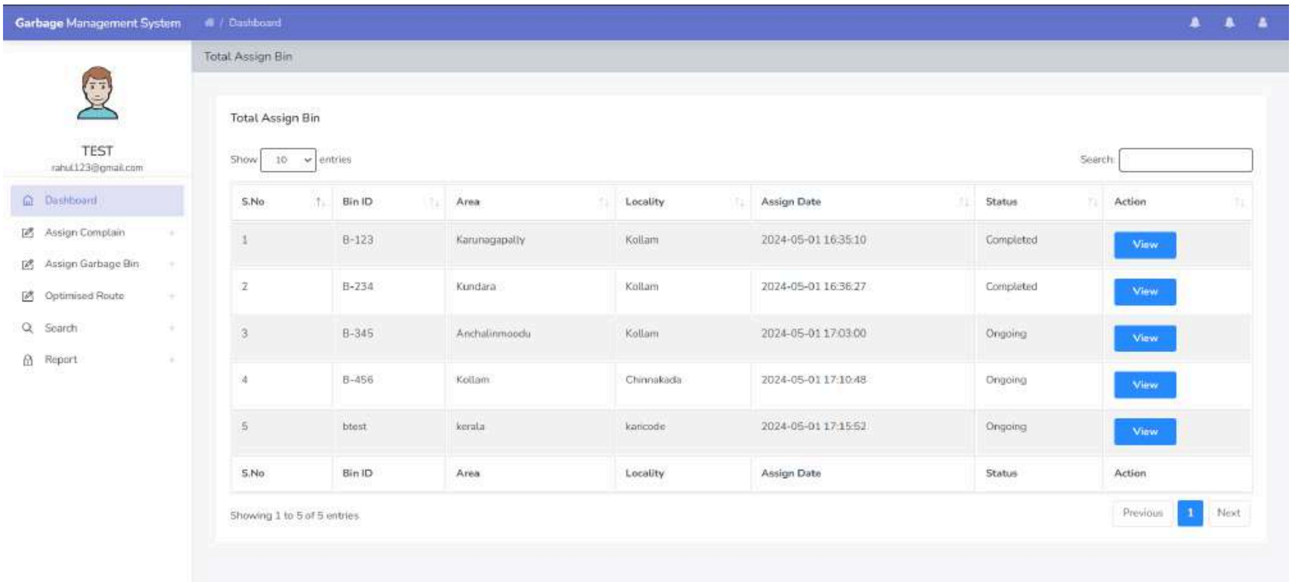

Figure 11.1: Driver Assigned Bin Screen

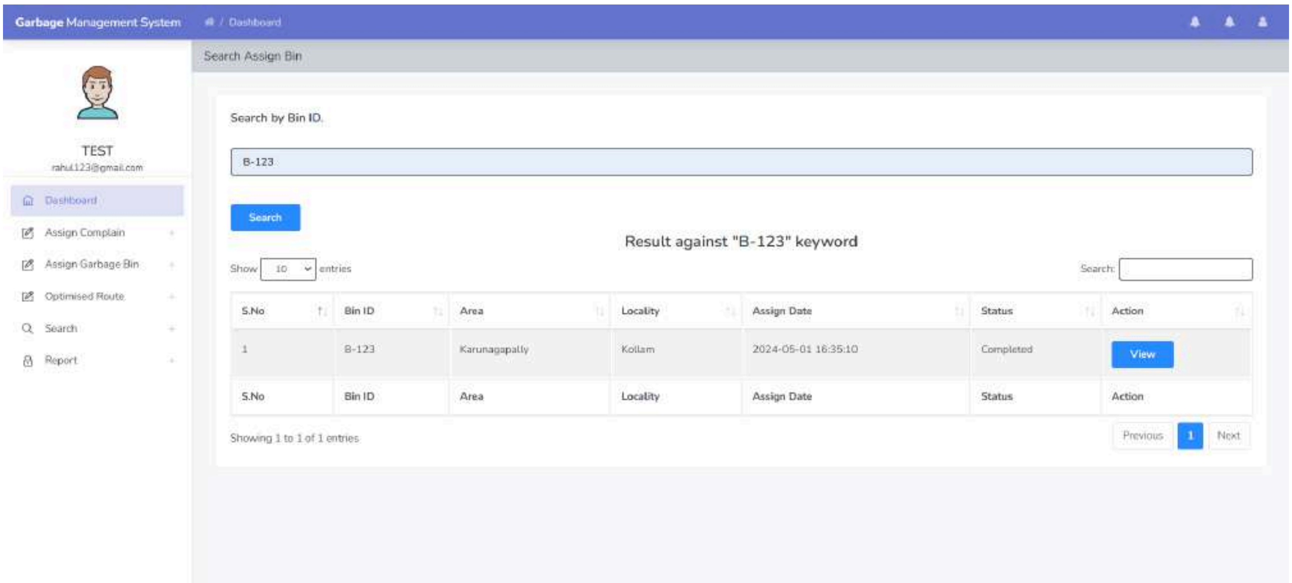

Figure 11.2: Driver Assigned Bin Screen

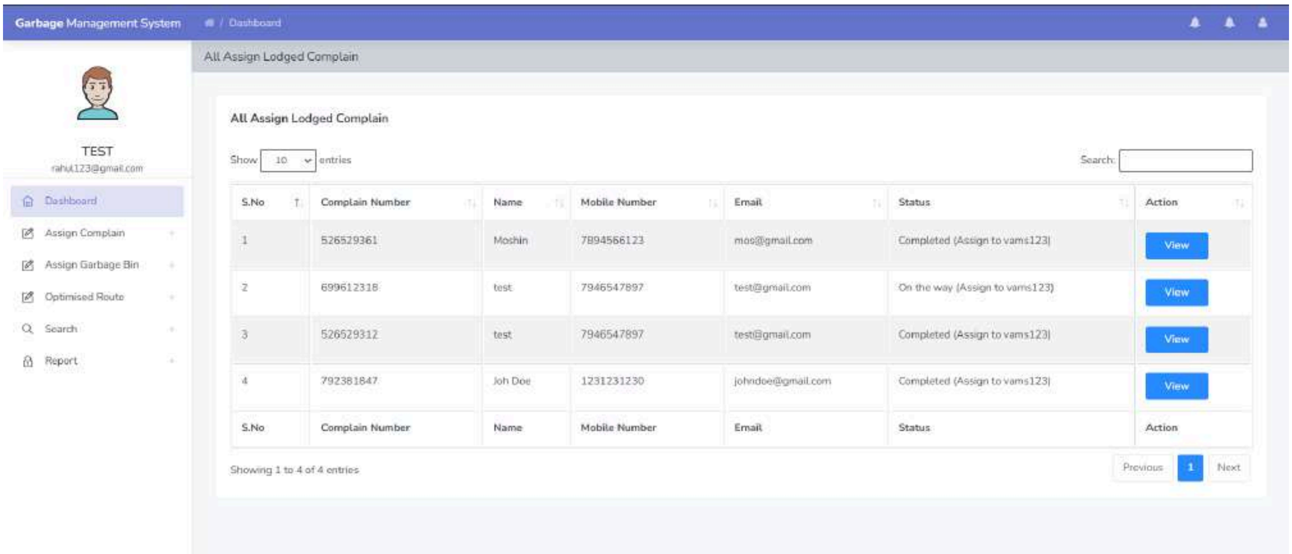

Figure 11.3: Driver View Lodged Complaints Screen

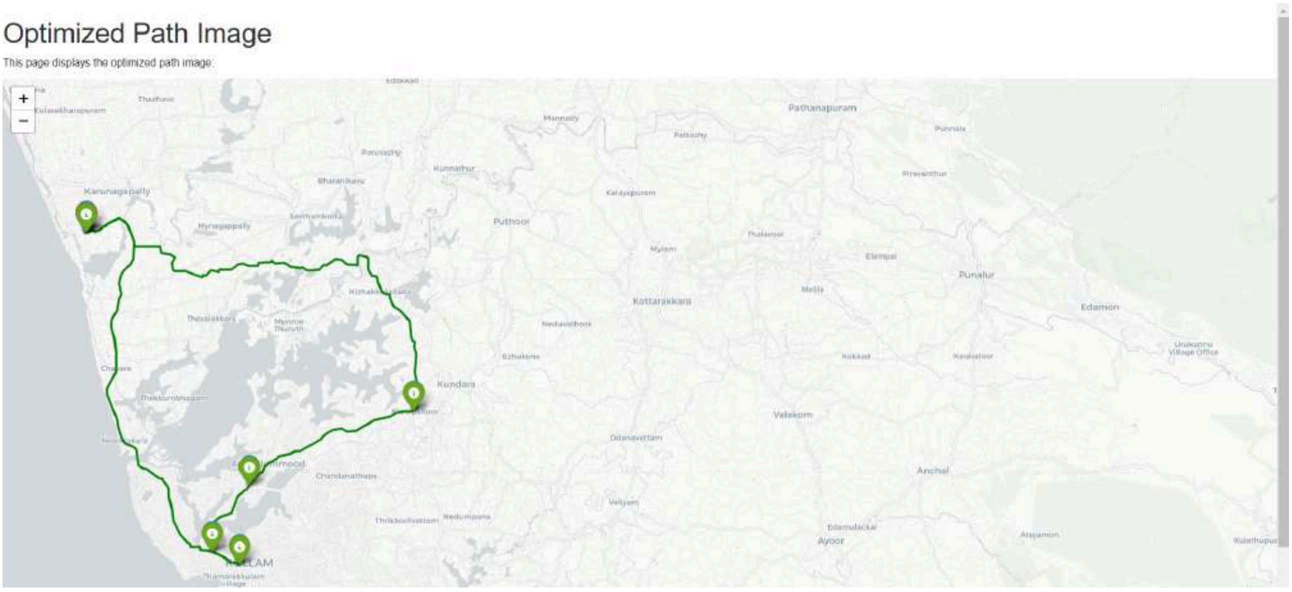

Figure 12: Driver Optimized Route Screen

5.2.5 User:

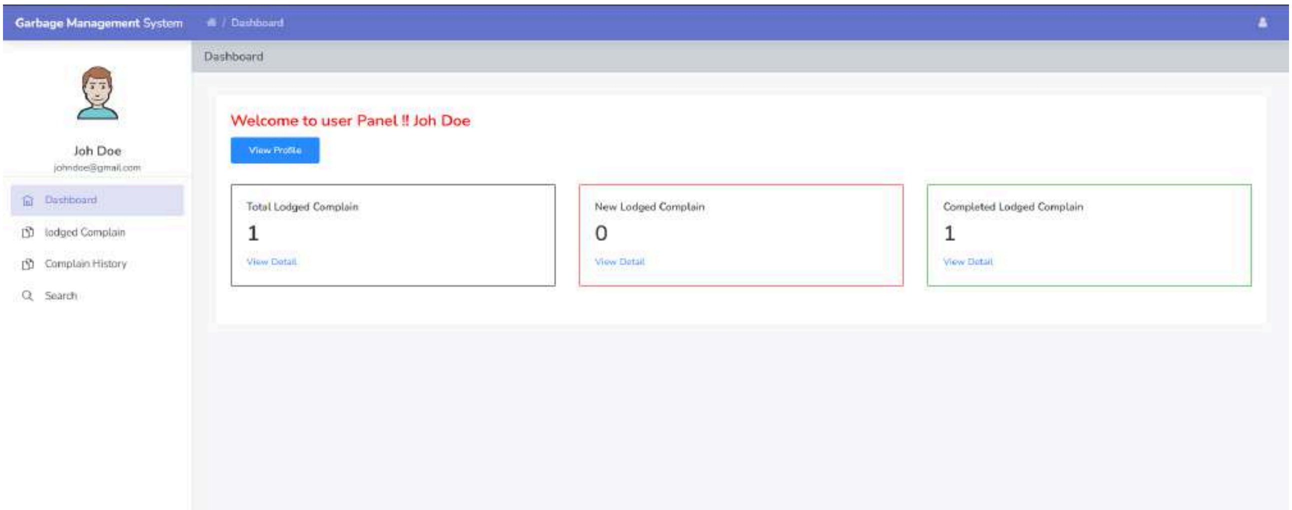

Figure 13: User Dashboard Screen

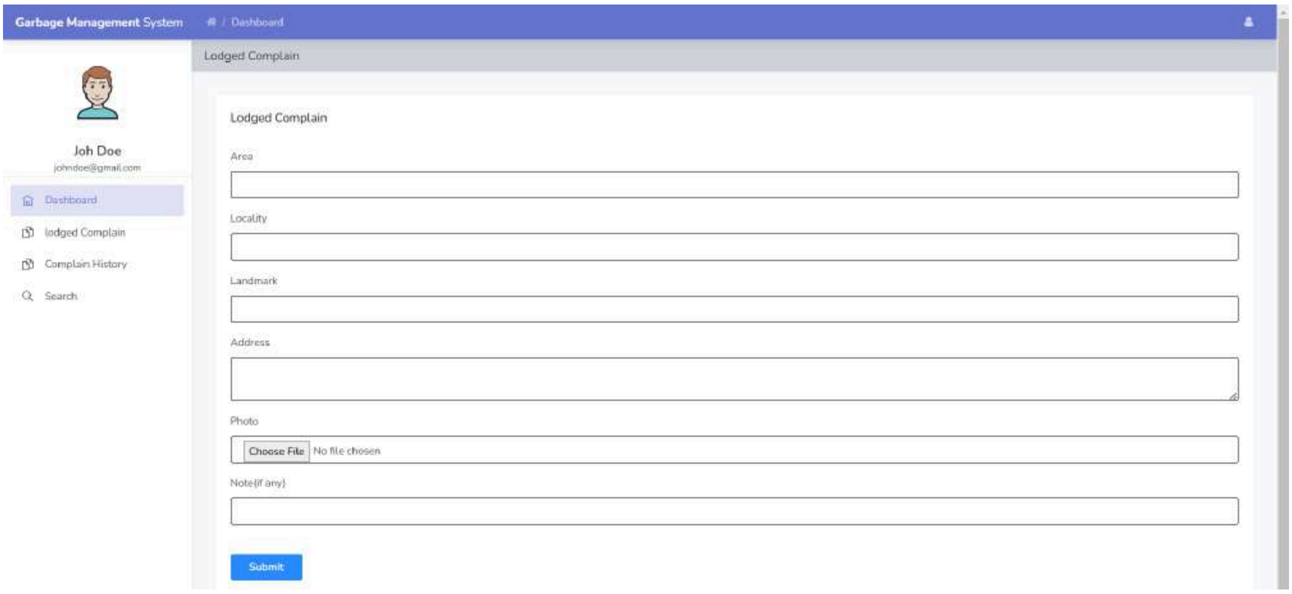

Figure 13.1: User Register Complaint Screen

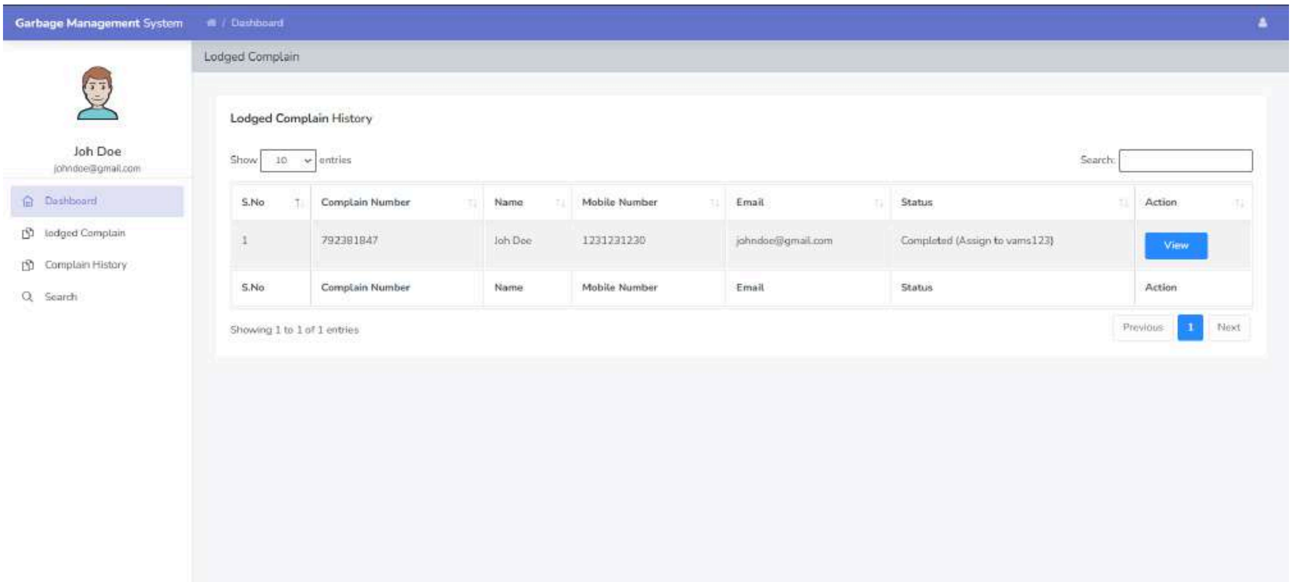

Figure 13.2: User Lodged Complaint History Screen

CHAPTER 6

CONCLUSION & FUTURE SCOPE

Our IoT-based waste management system represents a significant step forward in addressing the environmental and operational challenges faced by municipalities and waste management authorities. Through the implementation of hardware connections, sensor data processing, and route optimization algorithms, we have demonstrated the feasibility and effectiveness of our solution in optimizing waste collection processes and promoting sustainability.

Through hardware integration of ultrasonic sensors and NodeMCU ESP8266, coupled with Arduino IDE code for distance measurement, our IoT-based waste management system achieves real-time waste monitoring. The creation of a comprehensive website interface facilitates interaction among drivers, administrators, and users, enhancing system accessibility. Additionally, dynamic route optimization based on bin fill levels optimizes resource allocation, reducing operational costs and environmental impact. In summary, our system marks a significant advancement in waste management, promising a greener, more efficient future.

To further enhance the capabilities and impact of our system, we envision several avenues for future development and expansion. Firstly, we aim to scale up our solution by deploying it in additional cities and regions, leveraging the successful implementation in our initial pilot location. This expansion will allow us to reach a wider audience and address the waste management needs of diverse urban environments.

Furthermore, we plan to enhance the user experience and functionality of our system by incorporating additional features and integrations. This includes the development of a comprehensive web-based interface for drivers, administrators, and users to interact with the system seamlessly. Additionally, we will explore the integration of real-time communication tools, such as chat functionality, to facilitate collaboration and coordination among stakeholders.

In terms of technical enhancements, we will continue to refine our hardware and software components to improve accuracy, reliability, and scalability. This includes exploring advanced sensor technologies, optimizing data processing algorithms, and integrating predictive analytics capabilities to anticipate waste generation trends and optimize resource allocation proactively.

Overall, we are committed to advancing the capabilities of our IoT-based waste management system to address the evolving needs of urban waste management and contribute to building cleaner, more sustainable cities for future generations.

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APPENDIX - I FULFILLMENT OF PROGRAM OUTCOMES

No.	Program Outcomes	Explain how attained through mini project
1	Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	Applied knowledge of software engineering is required to plan and build functioning software and databases for the project.
2	Problem analysis: Identify, form, date, review research literature, and analyze complex engineering problems reaching substantiated conclusions using principles of mathematics, natural sciences, and engineering sciences.	A problem from the daily lives of students have been identified, analyzed and an approach to solve the problem has been formulated using the principles of computer science.
3	Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	The needs for the solution have been specified in the SRS document and the appropriate design details have been documented.

4	Modern tool usage: Create, select and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations	Modern software tools such as IDE, GitHub, ReactJS, Django, PostgreSQL, etc. have been used during the course of the project.
5	The engineer and the society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.	Our platform contributes to promoting economic growth, and fostering skill development for students and our platform respects cultural diversity.
6	Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental context and demonstrate the knowledge of, and need for sustainable development.	The project was tested to be efficient such that it will not consume too much power. It has support for older devices, so that it does not encourage people to buy new devices.
7	Ethics: Apply ethical principles and commit professional ethics and responsibilities and norms of the engineering practice.	During the project we have cited all the references from where we have acquired materials and guidelines.
8	Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.	All the members of the team have contributed effectively to the project.
9	Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large,such as, being able to comprehend and write effective reports and design documentation, make effective presentations and give and receive clear instructions.	Effective group communication and communication with the supervisors have been maintained throughout the project. Regular project presentations were held. Design and requirements documents were scrutinized regularly by the supervisors and improvements were constantly made to the same.
10	Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.	Members in the project choose the infrastructure in accordance with the budget of the project.
11	Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.	Members were able to refer to various resources from the internet and research new technologies to solve problems.