A RECYCLABLE WASTE PICKUP SCHEDULING SYSTEM IN NIGERIA

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A PROJECT SUBMITTED TO THE DEPARTMENT OF COMPUTER SCIENCE AND MATHEMATICS IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF SCIENCE (B.Sc) DEGREE IN COMPUTER SCIENCE

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CERTIFICATION

I hereby declare that the work presented here was carried out by me and not by any other person. Should I be found to have engaged in any form of academic misconduct, I accept the verdict of the University.

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APPROVAL

This is to certify that this research work titled "A RECYCLABLE WASTE PICKUP SCHEDULING SYSTEM IN NIGERIA" was carried out by EMEAGWARA COLLINS OBINNA with the registration number GOU/U22/CSC/841, in partial fulfillment of the requirement for the award of Bachelor of Science (B.Sc) in Computer Science, Faculty of Computing and Information Technology, Godfrey Okoye University, Enugu, Enugu State, Nigeria.

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DEDICATION

"This RECYCLABLE WASTE PICKUP SCHEDULING SYSTEM IN NIGERIA" is hereby dedicated to God Almighty, who has been a source of inspiration and strength from start till finish through out the period of this programme. This project is hereby dedicated to my loving mum, Mrs. Emeagwara Modesta Onyiyechi, for her constant support, advice, prayers and contributions. Also to my siblings, Emeagwara Racheal and Emmanuel, for being a source of light during tough times. To my friends, thanks to you all for your support and prayers. To God alone be all glory.

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ABSTRACT

Solid waste management remains one of the most pressing environmental and public health challenges facing Nigeria today. The country generates over 32 million tonnes of solid waste annually, yet less than 40 percent of this volume is formally collected in urban areas, and the national recycling rate sits below 10 percent a figure that lags far behind countries such as Germany and Sweden, where digitally coordinated waste systems have pushed recycling rates above 60 percent. A substantial share of Nigeria's uncollected waste consists of materials that are inherently recoverable: plastics, paper, glass, metals, and electronic waste. These materials routinely end up in landfills, open dumpsites, or are burned in residential areas, not because recycling infrastructure does not exist, but because there is no reliable digital mechanism connecting the people who generate this waste with the companies and individuals willing to collect it. Communication between households, businesses, and waste collectors is almost entirely informal, typically conducted through phone calls, personal relationships, or word of mouth. Waste collectors, in turn, are forced to operate on fixed, predetermined routes that bear little relationship to where recyclable waste is actually accumulating on any given day. This mismatch between supply and collection capacity results in wasted fuel, underutilized vehicles, missed pickups in high-demand areas, and a complete absence of the kind of data that government agencies would need to plan recycling infrastructure investment or design effective environmental policy.

This project responds directly to this gap through the design, development, and implementation of a Recyclable Waste Pickup Scheduling System a full-stack, web-based software platform purpose-built for the operational and infrastructural realities of Nigerian cities. Rather than importing a model designed for high-resource environments, the system was conceived around three distinct categories of users whose coordination failure lies at the heart of the problem: residents and businesses who generate recyclable waste and need a simple way to request its collection; waste collectors, whether formally registered companies or individual operators, who need an efficient way to receive and manage pickup assignments; and system administrators,

who are responsible for approving collectors, monitoring platform-wide activity, and ensuring the integrity of the service.

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

One of the most populated countries on the continent of Africa is Nigeria, whose fast pace urbanization is characterized by a massive challenge in the proper management of solid wastes. Recent statistics have indicated that Nigeria produces about 32 million tons of solid waste each year, with only less than 40 percent of the produced waste getting collected in urban regions, while the rate of recycling stands at less than 10 percent (Ogwueleka, 2009). The impact of poor waste management in Nigeria is very significant, including environmental pollution, blocked drainage, flooding, and health hazards caused by burning of the waste.

The materials that are recyclable include plastic products, glass, paper, metals, and electronic wastes that constitute a considerable volume of solid waste generated by both residential and commercial buildings in Nigeria. But, due to the lack of proper systems to collect such recyclable waste, the material either ends up in dumpsites or disposed of incorrectly. Though there exist some few private companies in Nigeria engaged in recycling operations in cities like Lagos, Abuja, Port Harcourt, and Enugu, coordination of such processes between the individuals or organizations generating such waste and the recycling firm proves difficult. The problem here is primarily that of logistics and communication. There is no established digital channel through which both parties can make arrangements regarding the recycling process.

The emergence of mobile and internet-based systems has provided an array of potential solutions to solve this coordination challenge. In many places across the globe, there have been innovative waste management systems installed that utilize GPS location technology, real-time alerts, cloud storage systems, and route optimization software to significantly enhance the process of garbage collection. Nations like South Korea, Germany, and Sweden have been able to recycle over 60 percent of their overall waste through the use of online scheduling systems for waste (Eurostat, 2022). However, despite the inadequacies in infrastructure in Nigeria,

Thus, there definitely is scope for developing a digital solution that operates on the assumption that internet connectivity in the city is not consistent and the infrastructure varies depending on where one is in the area.

Moreover, the federal and state governments of Nigeria have made it clear in recent years that they want to adopt an approach towards waste management that includes the formalization of processes. This is evident from the involvement of organizations such as the Lagos State Waste Management Authority and other similar entities in engaging private waste management players to participate in the recycling process. Such policy developments create an environment that favors the adoption of a scheduling platform that will not only be useful for individuals and organizations but also provide relevant information to regulatory authorities.

The objective of this project is thus to develop a digital application called the Recyclable Waste Pickup Scheduling System. The platform will facilitate interaction between citizens, institutions, and waste collection companies and individuals who collect waste. This involves allowing users to register, make pickup requests for recyclables, and track progress on their request status. For waste management companies and individual waste collectors, the system will act as an efficient

1.2 Statement of Problem

Some particular issues which led to the creation of such a system were:

Lack of Coordination between the Generators of Waste and the Collectors:

At present, there is no set system via which homes or companies can inform the recycling agencies about the availability of their waste for pickup. Most communication takes place in an informal manner, with either phone calls or personal visits being involved. Consequently, some pickup opportunities are missed out, inefficiency in the collection process arises due to poor routing strategies, and citizens are frustrated since they wish to recycle but find it difficult to arrange pickups.

Absence of Real Time Feedback System:

Where arrangements have been made for a pickup, the individual making the request does not get any sort of update regarding the timing of the visit by the collector or confirmation of completion of his job.

Inefficient Route Management for Collectors:

Without a centralized system for receiving and organizing pickup requests, waste collectors often operate on fixed routes that may not correspond to actual demand patterns on any given day. This results in wasted fuel, underutilized collection capacity, and areas with high recyclable waste volumes being visited infrequently.

Poor Data Availability for Policy and Planning:

However, government agencies and environmental organizations in Nigeria do not possess much information about the quantity, kind, and geographical spread of recyclable waste material produced and collected. This makes it difficult to make policies based on evidence and invest in recycling infrastructure.

1.3 Aims and Objectives

The aim of this research project is to create a web and mobile application that helps in coordinating waste pickup in an effective manner among waste producers and service providers. In this regard.

Objectives

i. Conduct an analysis in order to determine the functional requirements of recyclable waste scheduling software.

ii. Create an interface for users that makes the scheduling process easy.

iii. Create the backend functionality required to schedule and collect real time information.

iv. Create a management dashboard for waste collection firms and regulatory authorities.

v. Conduct a test to determine the efficiency of the software developed.1.4 Significance of the Project

1.4 Significance

Citizens and Households:

This is a convenient platform where people can participate in the activity of recycling through active participation, thus encouraging environmental responsibility.

Recycling Companies and Collectors:

This system ensures reduced operational expenses, better efficiency, and the ability for companies to cover more clients using fewer resources due to digitization of the schedule.

Government and Environmental Agencies:

The system generates valuable data on waste generation and collection patterns that can support evidence-based planning, policy formulation, and environmental monitoring.

1.5 Scope of the Project

This particular solution would be suitable mainly for the urban/peri-urban regions of Nigeria where there is sufficient internet access. In this regard, the management of recyclable waste will be handled via categories such as plastic, paper, glass, metal, and e-waste. However, organic and hazardous wastes will not be considered in the solution, neither will waste recycling nor processing be included. At the moment, the solution can be employed by individuals and small businesses, along with waste collection firms operating in specific regions.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter will focus on the theoretical framework behind the design of a waste pickup scheduling system that can be recycled. The chapter will give background information about waste management issues in Nigeria and developing countries. This chapter will also highlight the different types of technological approaches that have been used for waste management issues and the limitations that were encountered.

2.2 Theoretical Background of Study

2.2.1 Solid Waste Management in Nigeria

Solid waste management is defined as the collection, treatment, and disposal of solid matter regarded as being without value and discarded after being used for various purposes. Solid waste management in Nigeria has been done by various government departments such as the Lagos Waste Management Authority (LAWMA), the FCT Area Council Waste Management Department, and even state-level sanitations departments. However, these organizations have always been plagued by various challenges ranging from financial issues, maintenance problems, low numbers of collection vehicles, and lack of information technology systems that are essential for efficient management of solid waste (Ogwueleka, 2009).

To solve some of the shortcomings, a large informal solid waste industry has developed through numerous waste collectors who are mostly mobile, known locally as "pickup men." Such people collect solid waste such as plastics and metal from households and industries and resell the collected solid waste to aggregators and factories for reuse. This industry plays a great economic role but is completely unorganized without any information technology system (Nzeadibe & Ajaero, 2011).

2.2.2 The Role of Digital Technology in Waste Management

Worldwide, the adoption of technological innovations in the waste management process has resulted in increased efficiency and better environmental performance. The use of the Internet of Things technology, for example, via the deployment of IoT devices like smart bins fitted with fill level sensors, would facilitate real-time monitoring and dynamic routing which would eliminate unnecessary trips by up to 40 percent (Anagnostopoulos et al., 2015). Applications of ICT in mobiles phones have also allowed people to participate in recycling schemes by using waste management apps to report the waste and schedule pick-ups.

On the African continent, there are a variety of mobile-based technological innovations which take advantage of the high levels of smartphone usage to facilitate communication between waste producers and recyclers. Such platforms include the Wecyclers application operating in Lagos, Nigeria, and Taka Taka Solutions in Nairobi, Kenya. Gutberlet et al. have demonstrated the business case for technology-based recyclable waste management in urban settings in the developing world (Gutberlet et al., 2017).

2.2.3 Scheduling Algorithms and Route Optimization

One of the main technical problems faced in waste picking up scheduling is known as Vehicle Routing Problem (VRP). The task here is to find an optimal route schedule for some fleet of vehicles servicing certain set of locations. This problem has been widely studied in the field of operations research, and there are several varieties of this problem which can be directly applied to waste management problems, such as capacitated VRP, which includes a consideration of vehicle's capacity limit, and VRPTW, where customer time window is taken into account (Dantzig & Ramser, 1959). Now, modern approaches for solving VRP instances of practical size for waste collection involve the use of heuristic and metaheuristic algorithms, like genetic algorithm, simulated annealing, and ant colony optimization, which make an exact solution.

In the context of our project, taking into account the size of the first implementation and its complexity, we decided to apply a simple nearest neighbour greedy heuristic to produce a basic route suggestion for the admin dashboard.

2.2.4 Overview of Core Technologies

The following subsections briefly describe the main technologies employed in the development of the proposed system.

2.2.5 React

React is an open source JavaScript framework that is maintained by Meta (formerly Facebook). The React Framework uses a component-based approach to UI development, wherein the UI elements are designed in the form of reusable components, which maintain their own states. Thanks to its virtual DOM structure, only those parts of the interface that need rendering are re-rendered by React, which makes the framework extremely efficient for updating frequently changing data. React was utilized in the development of the frontend for the web app as well as the dashboard.

2.2.6 FastAPI

FastAPI is a state-of-the-art open-source web framework written in Python for developing application programming interfaces. This framework is constructed using Starlette for the web functionality and Pydantic for data validation and asynchronous request handling. FastAPI automatically produces interactive API documentation through the use of OpenAPI. This allows testing and integration of the API documentation to be much easier than ever before. FastAPI is being used as the backend framework for this project.

2.2.7 Firebase

Firebase is a Backend-as-a-Service (BaaS) offered by Google which includes a range of cloud-based services such as a real-time NoSQL database (Firestore), authentication, cloud storage, and cloud messaging for sending push notifications. Real-time functionality makes Firebase a perfect choice for apps where it is necessary to have synchronized information between different clients instantly, like the current state of pick-up which should appear immediately both on the user's device and collector's dashboard. Firebase takes care of authentication, database, and push notifications in this project.

2.2.8 Google Maps Platform

The Google Maps Platform contains APIs that allow one to embed a map, get geographical coordinates of an address, calculate distances between two addresses, and generate optimized travel routes. In this study, the Maps JavaScript API has been applied to plot locations of pickup requests in the admin interface while the Directions API has been utilized to create optimized routes for the waste collector vehicles.

2.3 Review of Related Literature

According to Arebey et al. (2012), a system capable of detecting fill levels of solid waste bins using RFID technology in conjunction with GIS was developed. Such a solution would enable solid waste management organizations to remotely control and determine fill levels of bins. As a result, waste collection was done on-demand only, meaning that no additional collection runs occurred until bins reached acceptable fill levels. This approach helped decrease the frequency of trips needed by approximately 25 percent. Unfortunately, substantial investment into hardware infrastructure in terms of RFID sensors on every bin is needed.

On the other hand, Gutberlet et al. (2017) evaluated the effectiveness of recycling programs based on community involvement and engagement in the Global South (including Nigeria) and concluded that digital platforms allowing to schedule pickups in real time showed greater efficiency compared to passive programs based on infrastructure. In particular, higher engagement was observed for platforms that featured easy-to-use mobile interfaces. Notably, Gutberlet et al. did not provide any technical details regarding such platforms.

In their paper, Doherty et al. (2020) created a prototype waste scheduling system on the web which could be utilized by residents to arrange their bulk waste pickup while integrating with the fleet management system. An assessment of this tool yielded 35% less time used for processing waste pick-ups.

This software solution was designed for a highly-resourced environment; thus, the connectivity and technological constraints inherent in Nigeria's urban centers were not taken into consideration.

Nzeadibe and Ajaero (2011) performed an extensive study on the informal waste recycling business within the city of Enugu – one of the focal cities under investigation in the current research.

Since 2012, Wecyclers, a social enterprise that operates in Nigeria (specifically in Lagos), has been employing a primitive technology-based scheduling system, utilizing text messages for coordinating the collection of recyclables from low-income areas. People send a text message to make a request for a pickup, and this triggers a process which results in collection on a weekly basis. Even though the model developed by Wecyclers has been proven successful among its target users, the use of text messages limits the ability to optimize the process in terms of feedback and efficient routes.

2.4 Summary of Related Literature

The reviewed works collectively confirm the need for a digital, user-centered waste pickup scheduling system in the Nigerian context, and provide useful design precedents for both the user-facing and backend components of the proposed system. The following table summarizes the key contributions and limitations of the reviewed works.

Author and Year	Name of Work	Contribution to Research	Shortcomings/Limitations
Arebey et al. (2012)	RFID and GIS-based bin level monitoring system	Demonstrated automated bin monitoring for scheduled waste collection	High hardware cost; not scalable in low-resource settings; no user-facing interface
Gutberlet et al. (2017)	Community-based recycling in the	Highlighted the role of digital citizen engagement	No technical implementation; limited to

Author and Year	Name of Work	Contribution to Research	Shortcomings/Limitations
	Global South	in recycling programmes	qualitative analysis
Doherty et al. (2020)	Web-based bulky waste scheduling prototype	Showed significant administrative efficiency gains through online scheduling	Designed for high-resource settings; not adaptable to Nigerian infrastructure
Nzeadibe & Ajaero (2011)	Informal waste recycling in Enugu, Nigeria	Documented informal sector dynamics and barriers to formalization	No digital solution proposed; purely descriptive research
Anagnostopoulos et al. (2015)	IoT-based smart waste management system	Demonstrated real-time cloud-based scheduling and route optimization	Requires IoT hardware investment; high implementation cost
Wecyclers (2012–present)	SMS-based recyclable waste collection in Lagos	Proved viability of demand-driven waste collection in Nigeria	SMS-only; limited real-time feedback; no route optimization; not scalable

CHAPTER THREE

SYSTEM ANALYSIS AND DESIGN

3.1 Introduction

The current chapter focuses on the analysis of the existing systems used for scheduling waste management processes within Nigeria, as well as design principles and requirements of the system to be implemented. The chapter highlights the design process of the software chosen and discusses the problems of the existing system solutions and benefits provided by the newly designed one. In addition, UML diagrams of the designed system architecture and its functioning are presented below.

3.2 Software Design Methodology

This software engineering method for this software project involves the use of Object-Oriented Analysis and Design (OOAD). This method views the system as a set of objects that have specific attributes and behaviors. In the development process, iteration and incrementality are the key factors as the prototypes are developed, analyzed and improved through functional testing. UML notation will be used in representing the system design. Some of the major design artifacts that will be generated as part of the design documentation include the use-case diagram, class diagram, activity diagrams for important users, sequence diagram, and database schema.

3.3 Analysis of Existing System in Nigeria

Some of the prevailing methods of collecting recyclable waste in urban centers of Nigeria are as follows:

a) Telephone calls and Short Message Service (SMS) calls between domestic users and individuals who collect the waste.

b) Fixed geographical routes of waste collection managed by the government's waste management departments.

c) The Wecylcers' SMS application that is in operation in Lagos.

However, none of these methods provides real-time schedule and monitoring services.

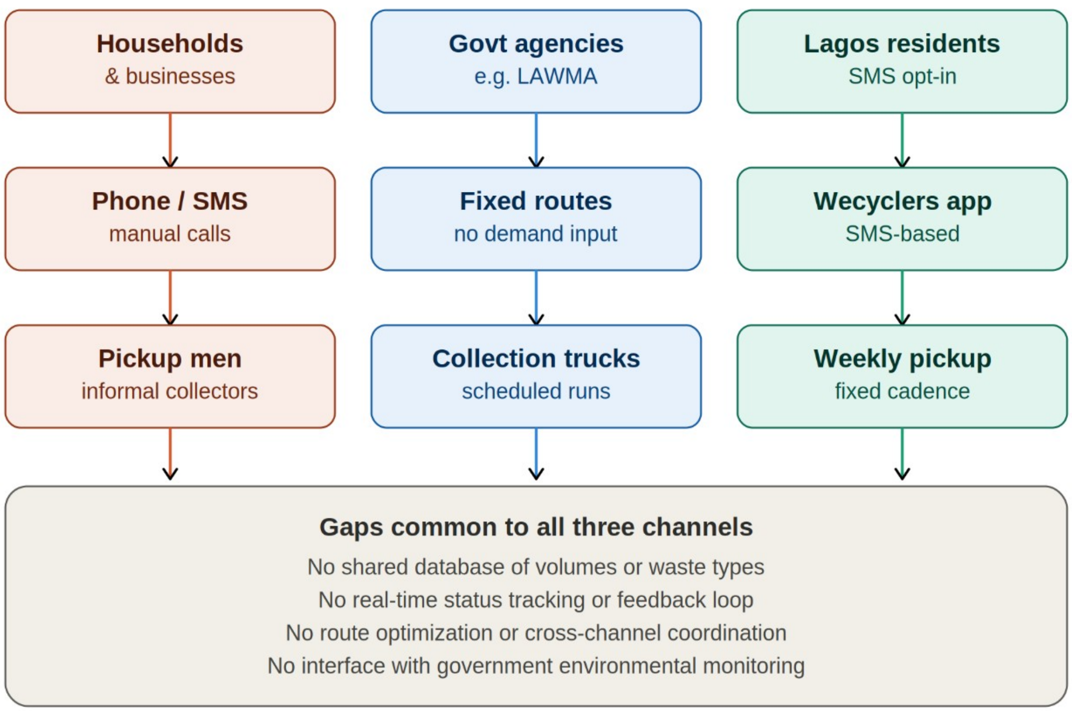

Figure 3.1 Architecture of Existing System

3.3.1 Key Features of Existing Systems

1. Manual communication: Communication occurs through phone calls and SMS by the users for collection of waste.

2. Fixed scheduling for collection: There is a fixed government schedule that cannot change with regard to any changes in demand.

3. Logging: Some organizations keep records of the collection on paper.

4. Compensation: Compensation to the collectors is informal and monetary.

3.3.2 Key Shortcomings

1. Lack of user tracking system post-request for pickup.
2. Lack of database for volume or type of recyclables collected from various regions.
3. Improper route planning causing increased operating cost.
4. Lack of system through which user can give feedback on pickup service.
5. Lack of interface with the environmental monitoring system of the government.

3.4 Analysis of Proposed System

The design of the Recyclable Waste Pickup Scheduling System offers a fully digitized and demand-oriented coordinating platform for the recycling process. After registering themselves on the platform, users make pickup requests that include information such as the type of material and quantity of material required to be collected. The platform allocates the requests to registered collectors nearby, and a schedule is created according to the request and availability of the collector.

3.4.1 Advantages of the Proposed System

1. Real-time alerts allow the users to know the status of their pickups at all times.

2. Route optimization leads to savings on costs and minimal environmental impact.

3. Centralized database enables tracking of the environment and proper planning.

4. Open registration system makes it possible for informal collectors to take part.

5. User feedback and rating system encourages accountability and improves services.

3.5 Unified Modeling Language for the Proposed System

3.5.1 Use Case Diagram of the Proposed System

The actors involved in the use case diagram of the suggested system include three actors: the User (Resident or Business), the Collector (Waste Picker or Company), and the System Administrator. The User can register, log in, make a pickup request, check the status of the request, review their collection history, and give feedback. The Collector can register, log in, view allocated pickups, change the status of pickups, and view their route map. The Administrator can log in, authorize collectors to use the system, monitor all activities within the system, generate reports, and set up system configurations.

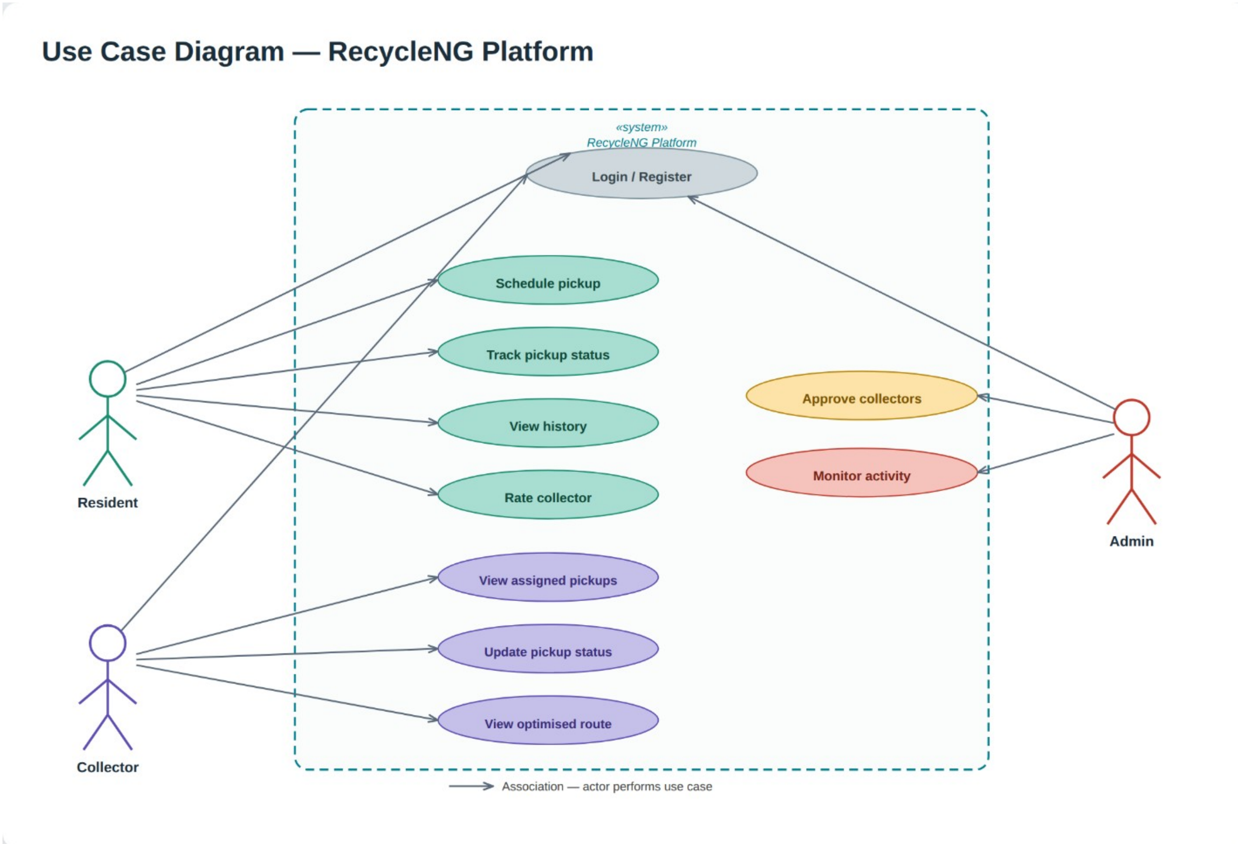

Figure 3.2 Use Case Diagram of the Proposed System

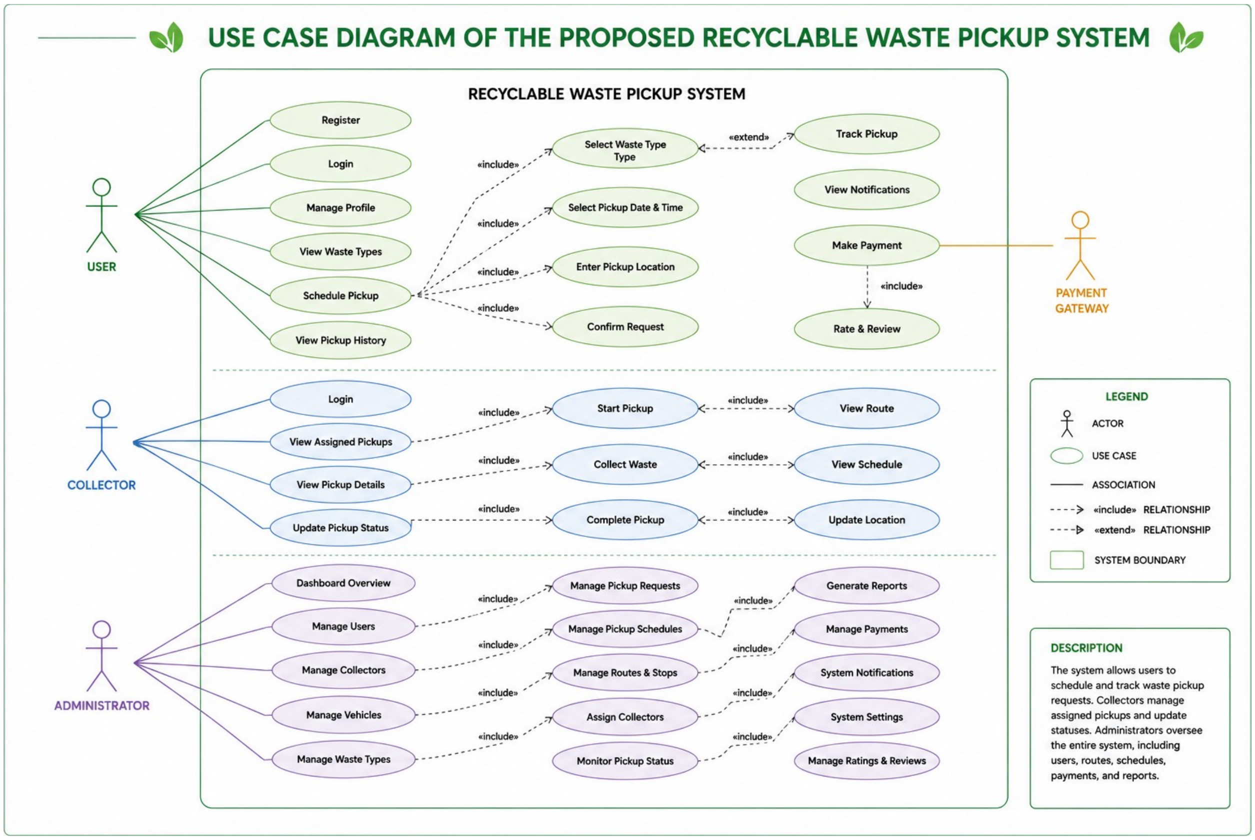

Figure 3.3 Use Case Diagram of the Proposed System

3.5.2 Class Diagram of the Proposed System

These are some of the main classes included in the class diagram: User, Collector, Administrator, PickupRequest, ScheduledRoute, Notification, and FeedbackRecord. Some of the attributes of the User class include: user_id, name, email, address, and phone_number. There are also some methods in the User class such as: registerAccount(), loginAccount(), submitPickupRequest()

and viewRequestStatus(). Some of the attributes in the PickupRequest class are: request_id, user_id, waste type, volume estimate, preferred time, coordinates of location, and status.

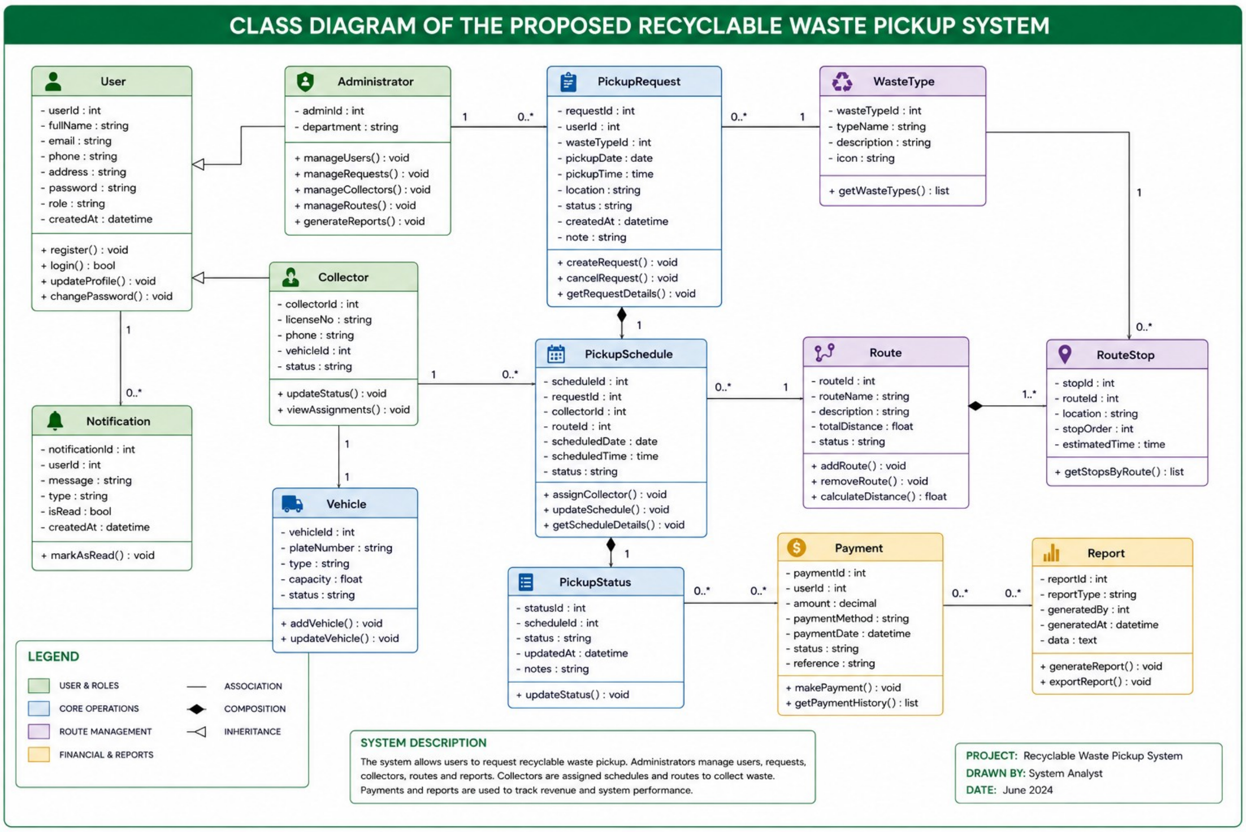

Figure 3.4 Class Diagram of the Proposed System

3.5.3 Activity Diagrams

The User activity diagram starts with the user initiating the program, and then moving on to login or registration. Following that, the user goes into the pickup schedule page and provides all necessary information for their recyclable waste, chooses a time frame, and makes the booking request. Confirmation is done, and once a collector is allocated, the user gets an alert. Thereafter, the user can monitor the status and provide feedback.

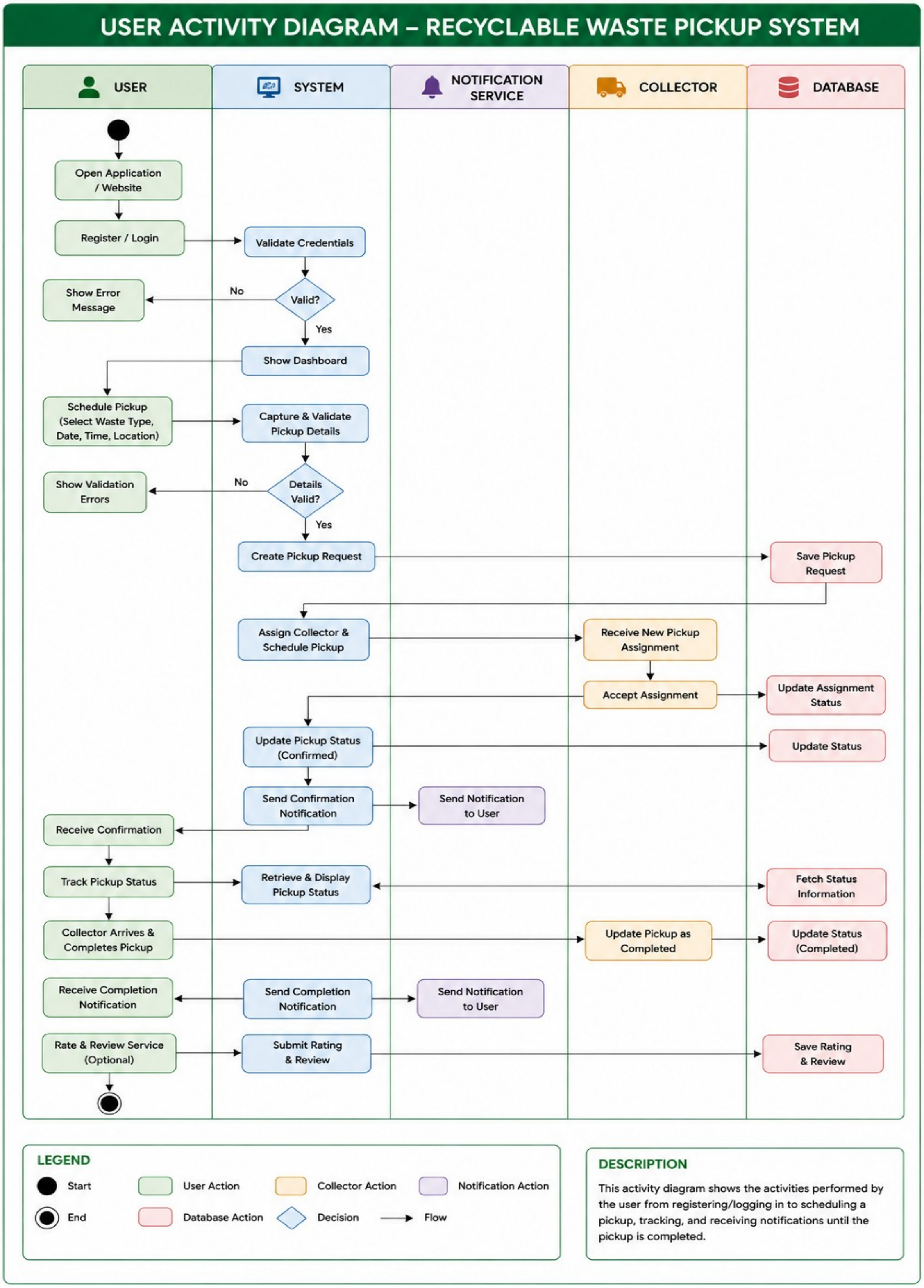

Figure 3.5 User Activity Diagram

The process diagram for the Administrator includes the initial login to the admin portal, where the administrator assesses registration requests from collectors and makes decisions on approving or rejecting them. The administrator keeps track of the live map showing active pickup requests and their assigned routes, prepares activity reports, and adjusts platform settings such as service areas.

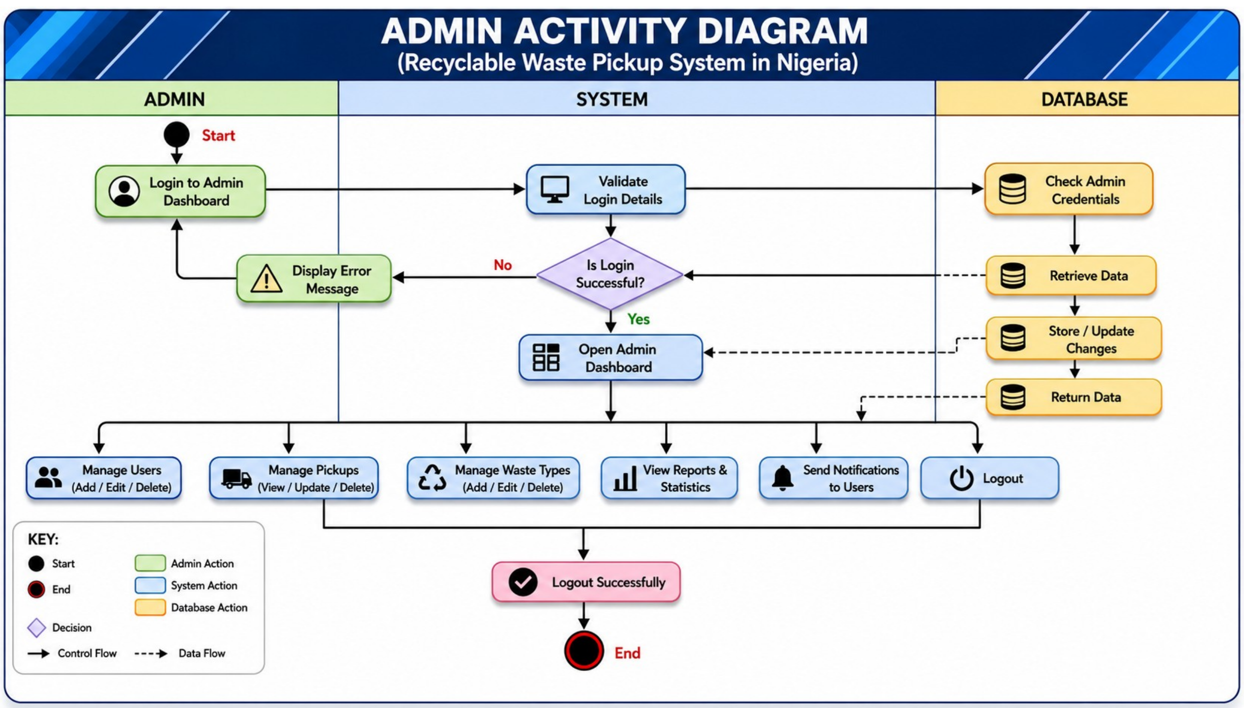

Figure 3.6 Admin Activity Diagram

3.5.4 Sequence Diagram of the Proposed System

The User creates a pickup request in the frontend application, and sends the request information to the backend FastAPI. Then the request is validated and stored in the Firebase Firestore database. The backend queries the Firestore database to find out which collector is available in the given area. Using the scheduling algorithm, the backend assigns the pickup request to a collector and updates the Firestore database. Firebase Cloud Messaging sends a notification to the User about successful assigning, and another one to the Collector, who is assigned a certain pickup. When the Collector updates the status of the pickup (on the way, at the location, done), the backend also updates the information in Firestore, and sends new notifications to the User.

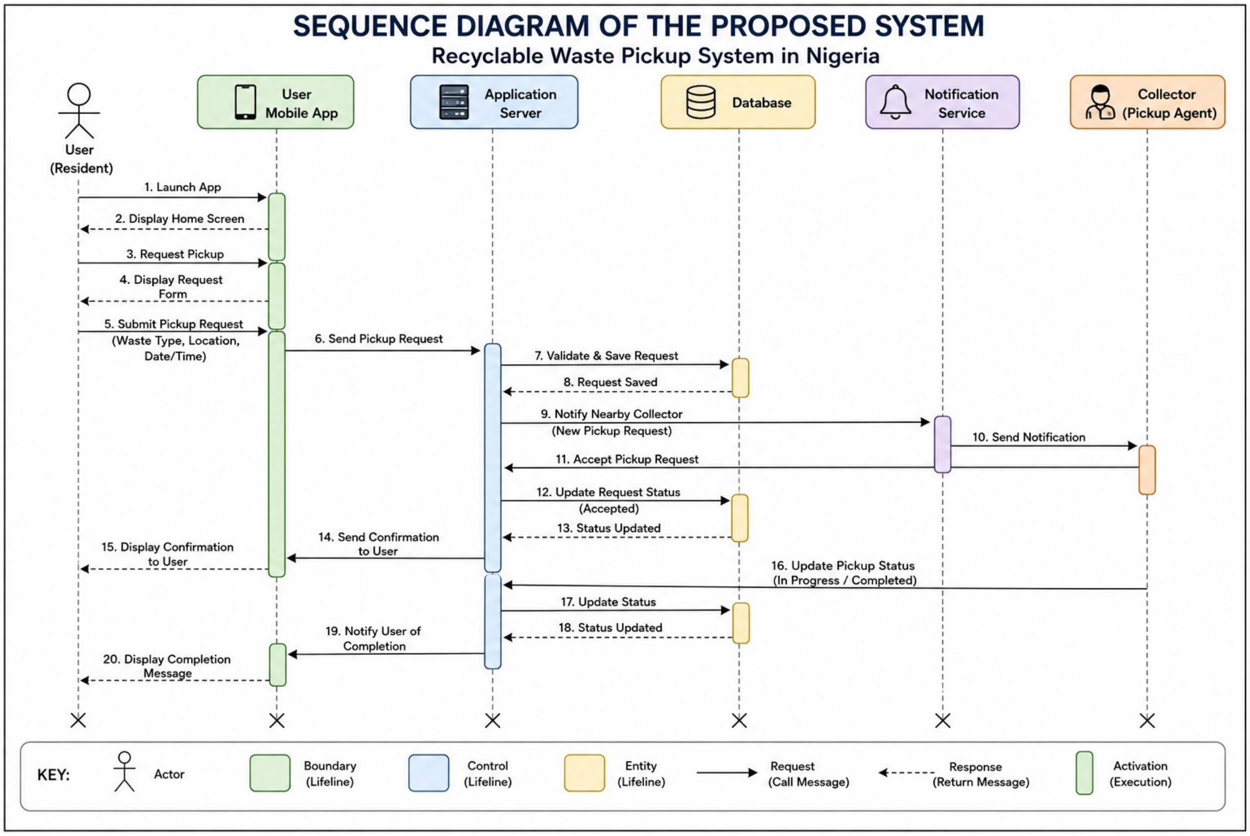

Figure 3.7 Sequence Diagram of the Proposed System

3.5.5 Database Schema

The Recyclable Waste Pickup Scheduling System is built on Firebase Firestore, a cloud-hosted, real-time NoSQL document database provided by Google as part of the Firebase Backend-as-a-Service platform. Unlike a traditional relational database management system such as MySQL or PostgreSQL, which organizes data into fixed tables of rows and columns linked through explicitly defined foreign key constraints, Firestore stores information as a hierarchy of collections and documents. Each collection (such as Users, Collectors, Pickup Requests, Routes, or Notifications) holds a set of documents, and each document is essentially a JSON-like object made up of key-value pairs that can vary in structure from one document to the next. This schema-less design gives the system flexibility to evolve the data model over time, for instance by adding new fields to a pickup request, without requiring a formal migration process as would be needed in a relational system.

Every document in the database is uniquely identified by an ID, and in this project the User and Collector documents are keyed directly by the Firebase Authentication UID that is generated when an account is created. This approach eliminates the need for a separate identity-management layer, since the same identifier used to authenticate a user through Firebase Authentication also serves as the primary key for locating that user's profile data in Firestore. Relationships between collections, which would ordinarily be implemented as foreign key constraints in a relational schema, are instead represented by simply storing the referenced document's ID as a field within the related document; for example, a Pickup Request document stores the user_id of the resident who created the request and, once assigned, the collector_id of the collector responsible for handling it.

User Table

Column Name	**Data Type**	**Description**
user_id	VARCHAR(28)	Primary Key (Firebase UID)
name	VARCHAR(100)	Full name of the user
email	VARCHAR(100)	User email address
phone_number	VARCHAR(20)	Contact phone number
address	TEXT	Primary pickup address
location_coordinates	VARCHAR(50)	Latitude and longitude of default address

Column Name	Data Type	Description
created_at	DATETIME	Account creation timestamp
account_type	VARCHAR(20)	Household or Business

Pickup Schedule Table

Column Name	Data Type	Description
request_id	VARCHAR(28)	Primary Key
user_id	VARCHAR(28)	Foreign Key (references User table)
waste_types	TEXT	Comma-separated list of waste categories
estimated_volume	VARCHAR(50)	Approximate volume or weight of waste
preferred_time	DATETIME	User-specified preferred collection time
status	VARCHAR(20)	Pending / Assigned / En Route / Completed
collector_id	VARCHAR(28)	Foreign Key (references Collector table)
created_at	DATETIME	Request creation timestamp

Collector Table

Column Name	Data Type	Description
collector_id	VARCHAR(28)	Primary Key (Firebase UID)
name	VARCHAR(100)	Full name or company name
email	VARCHAR(100)	Contact email address
phone_number	VARCHAR(20)	Contact phone number
service_area	TEXT	Geographic areas served
waste_types_accepte	TEXT	Waste categories handled

Column Name	Data Type	Description
d		
is_active	BOOLEAN	Whether the collector is currently available
approval_status	VARCHAR(20)	Pending / Approved / Suspended

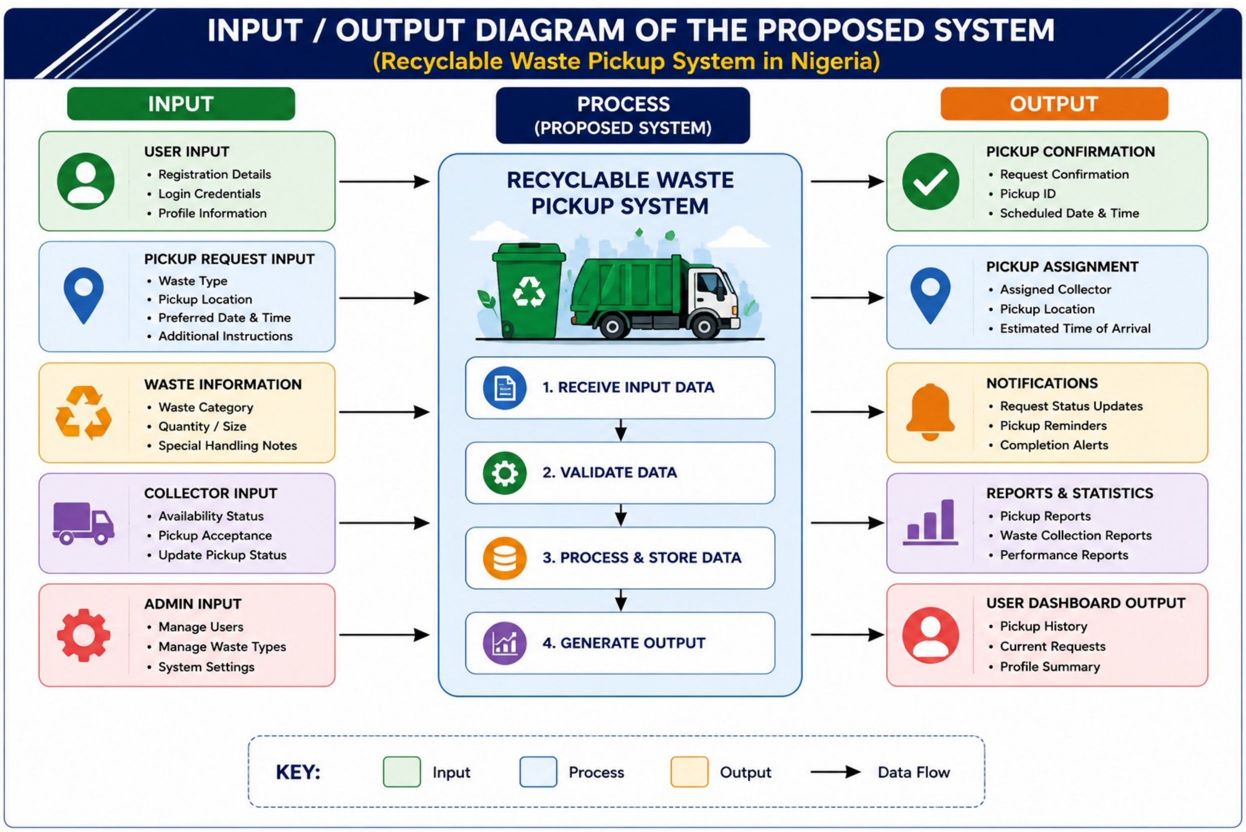

Figure 3.8 Input/Output Diagram of the Proposed System

3.5.6 Input Column:

This lists what actually gets entered into the system by the actors defined in the use case diagram (3.5.1):

i. From the User: registration details (name, email, phone, address), and pickup request data — waste type(s), estimated volume, pickup address/coordinates, and preferred collection time.
Ii. From the Collector: registration and profile details (service area, waste types accepted), and status updates on an assigned pickup (en route, arrived, completed).
iii. From the Administrator: collector approval decisions and configuration settings (e.g. service areas).

Process Column:

This is the system's internal logic, i.e. everything happening inside the FastAPI backend and Firestore that was detailed in 3.5.4 (the sequence diagram) and later in 4.5.1:

i. Validating incoming request data (via Pydantic models).
ii. Running the collector-assignment logic — filtering Firestore for collectors whose service area, waste-type capability, and current load match the request, then picking the nearest one.
iii. Writing/updating documents in Firestore (Users, Collectors, Pickup Requests, Routes, Notifications collections).
iv. Triggering Firebase Cloud Messaging to push notifications when a status changes.

Output Column:

This is what the system produces back to each actor:

i. To the User: confirmation of a submitted request, real-time status notifications, and a live tracking view of the assigned collector.
ii. To the Collector: assigned pickup details and an optimized route (via the Directions API).
iii. To the Administrator: the live map of active requests, activity/volume reports, and system-wide monitoring data.

CHAPTER FOUR

SYSTEM IMPLEMENTATION

4.1 Introduction

The current chapter highlights the full implementation of the Recyclable Waste Pickup Scheduling System. The topics discussed include the selection of the development environment, the set of technologies selected to implement the entire project from the frontend side, backend side, and database layer, the minimum hardware and software requirement specifications to successfully execute the system, and the detailed implementation process involving the development of backend APIs, configuring the database, frontend application development, and testing.

4.2 Choice of Development Environment

4.2.1 Visual Studio Code

Microsoft's Visual Studio Code (VS Code) has been chosen as the main Integrated Development Environment (IDE). VS Code is a lightweight, free, open-source code editor for building modern applications, created by Microsoft. It offers a wide range of extensions and add-ons for JavaScript, Python, and web development projects. Some of the essential characteristics that have made VS Code our top choice for this particular application development project are the built-in terminal, the ability to do version control using Git, the Prettier extension that helps with proper code formatting, ESLint for JavaScript, and the Python extension with IntelliSense and debugging support for the FastAPI backend.

4.3 Technologies Used in Implementation

4.3.1 React

React was employed in constructing the front end of both the application used by citizens and the admin dashboard. The project was initialized using the Create React App framework and structured using React hooks like useState, useEffect, and useContext for state management. React Router was applied to perform client-side routing among various pages, while Axios was used to make HTTP requests to the server-side running on FastAPI. The Material-UI component library offered built-in accessible components which made frontend development fast.

4.3.2 FastAPI

FastAPI acted as the backend web framework that implemented all the server-side business logic such as authentication of users, handling of requests to make pickups, assigning collectors, and generation of reports. The backend structure follows the Model-View-Controller design model with routers, models, and service layers defined. Pydantic models were employed for validating any data received in the form of requests from clients before processing. JWT tokens were used in the authentication process, where the client gets the token after successfully logging in and each subsequent request receives validation using the middleware.

4.3.3 Firebase

The Firestore in Firebase was employed as the main data storage system, where different types of collections were stored for the users, collectors, pickup requests, routes, and notifications. Firebase Authentication service was implemented to handle the identification and session tokens, allowing logging in via email and password for all user types. For push notifications to be sent to the web and mobile interfaces, Firebase Cloud Messaging service was employed.

4.3.4 Google Maps Platform

The Google Maps JavaScript API integration included the user-side request pick-up form (to enter and confirm addresses), as well as the admin side where all current request pick-ups and collectors' locations were visually represented. For suggesting collectors' routes, the Directions

API was used at the server side and returned polylines to be displayed on the map in the collector side view.

4.3.5 Python Libraries

A number of Python libraries have been employed in the FastAPI back-end. These are:

• python-firebase-admin: Used for integration with Firebase;

• python-jose & passlib: Used for JWT token creation/verification;

• httpx: For asynchronous HTTP requests from the external API;

• geopy: To determine the distance between two geographic locations.

4.4 System Requirements

The application can be used without needing any special hardware and is supposed to work on typical consumer electronics. The technical requirements are as follows:

1. Smartphone or personal computer with a compatible and updated web browser (Google Chrome, Mozilla Firefox, Apple Safari, or Microsoft Edge)

2. Connection to the internet, preferably faster than 1 Mbps

3. For the administrator's panel, screen resolution no less than 1280 x 720.

4.5 Implementation of the Proposed System

The implementation was carried out in three phases: Backend API Development, Database Configuration, and Frontend Application Development. The following subsections describe each phase in detail.

4.5.1 Backend API Development

The RESTful API offered by the FastAPI backend consists of the following core endpoint categories: /auth for registering and logging into accounts; /users for managing profiles; /requests for creating, retrieving, updating, and canceling pickup requests; /collectors for registering, approving, and managing collectors' status; /routes for generating and retrieving collection routes; and /notifications for managing subscription and delivery of push notifications.

The algorithm used in the collector assignment task executed via the /requests endpoint is described below. In response to a new request submitted through this endpoint, the system retrieves from Firestore a list of all collectors that have service area covering the location of the new request, can collect the particular type of waste, and currently do not exceed the maximum number of tasks threshold. Among all collectors that match the criteria, the one whose location or main hub is the closest to the pickup address is assigned the task. If no suitable collector can be found, the request is marked as pending.

4.5.2 Database Configuration

Firestore database schema consisted of the following main collections:

Users

Collectors

Pickup Requests

Routes

Notifications

Firestore security rules have been set up in such a way that:

Users can only read/write their own documents.

Collectors are allowed to read the requests allocated to them and change the request status.

Administrators have read/write permissions on all collections.

Firebase authentication allows for email/password sign-in for all user types.

4.5.3 Registration and Login

In this part of the application, users who have never used this app before can sign up using their name, email, password, contact number, and address. After signing up, a Firebase Authentication account will be created, and a Firestore document for this user will be created. In the login screen, users provide their credentials in terms of email and password, and after verification, a JWT token will be returned.

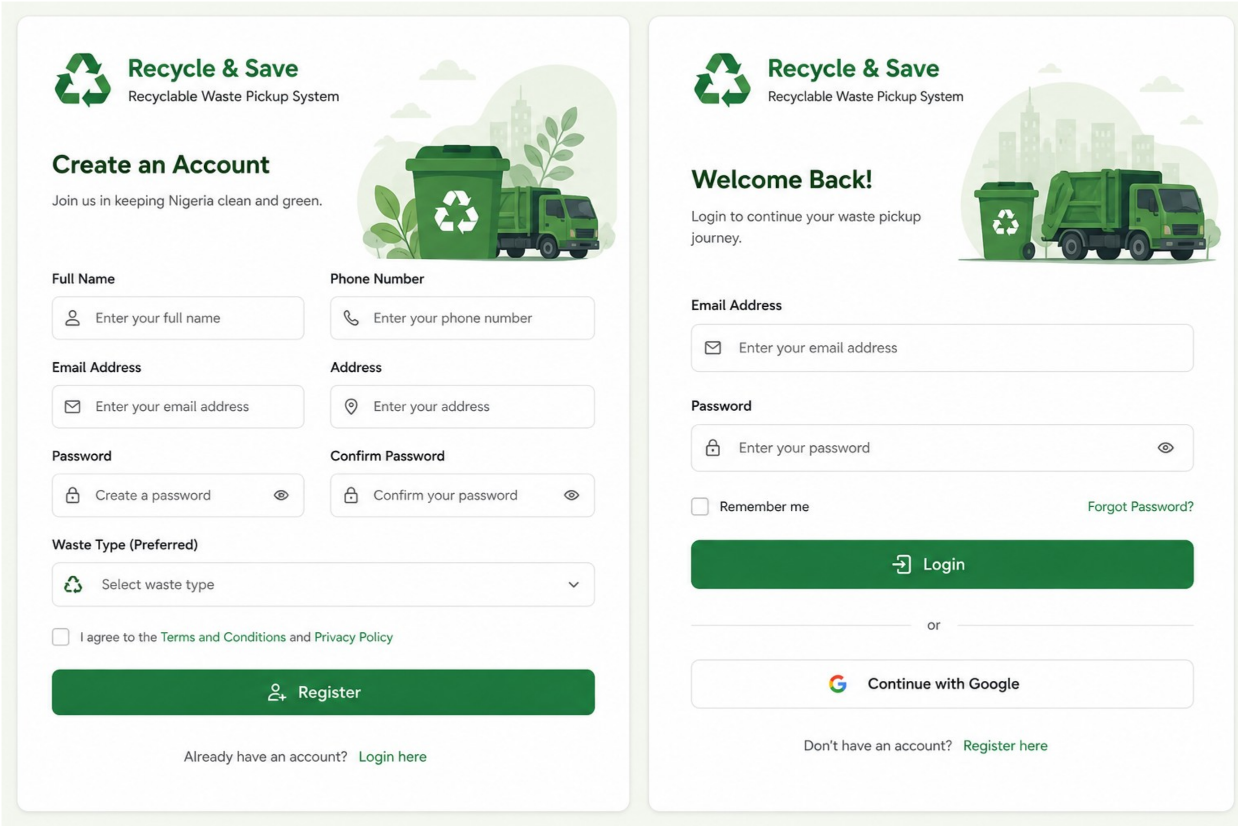

Figure 4.1 Registration and Login Page

4.5.4 User Dashboard

There are three major components on the primary dashboard screen, including:

a) Summary information about recently processed and pending pickup requests;

b) Direct access to the scheduling feature for planning another pickup;

c) List of recent notifications from the system.

Pickup request cards show waste types, schedule time, current status, and links for viewing the request details or cancelling it.

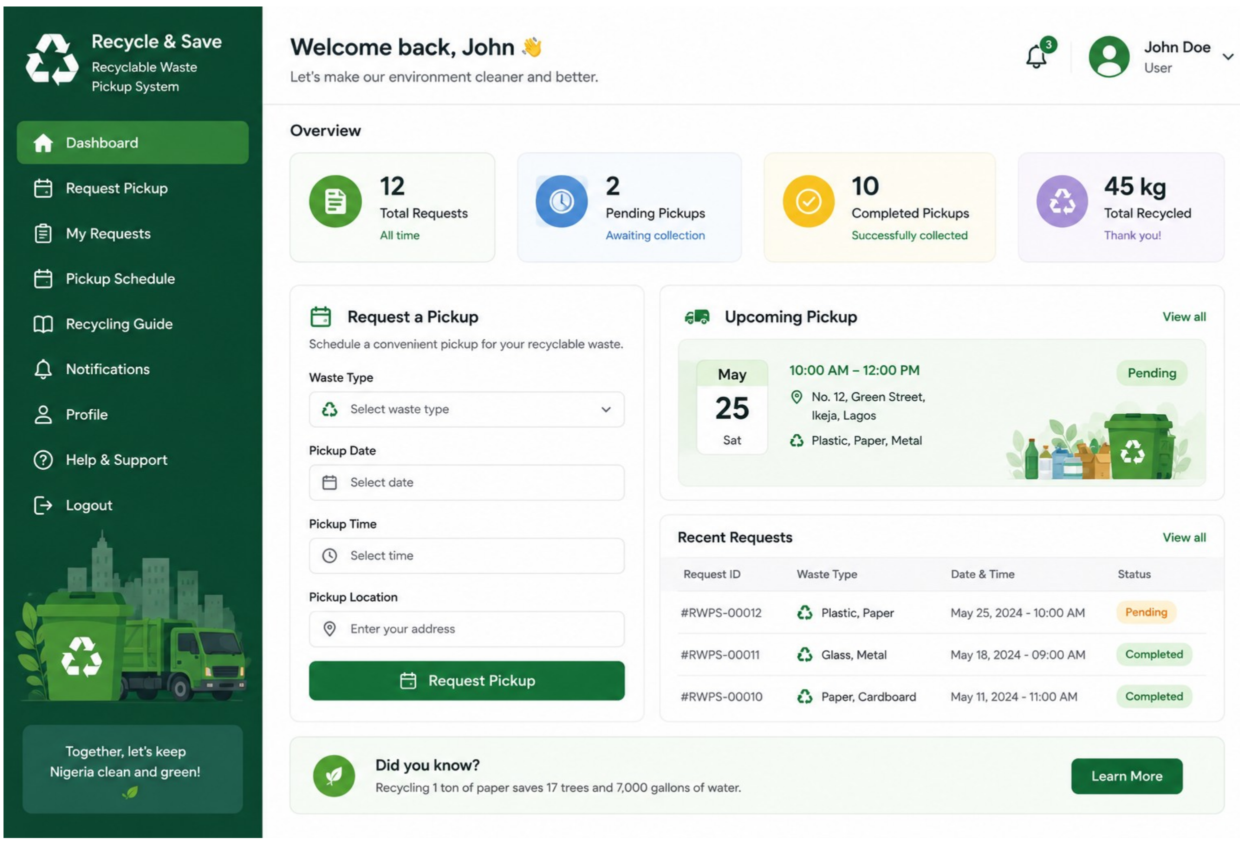

Figure 4.2 User Dashboard / Home Page

4.5.5 Schedule Pickup Page

Here, the user chooses the type of waste to be recycled, gives an estimate of quantity, verifies or modifies their pickup address through Google Maps integration, and chooses their preferred time of delivery through a calendar system. The user gets a preview of their request for confirmation before they click the button to submit their request. Once the request is made, the user will instantly get an on-screen notification confirming their request, followed by a push notification containing details of their collector.

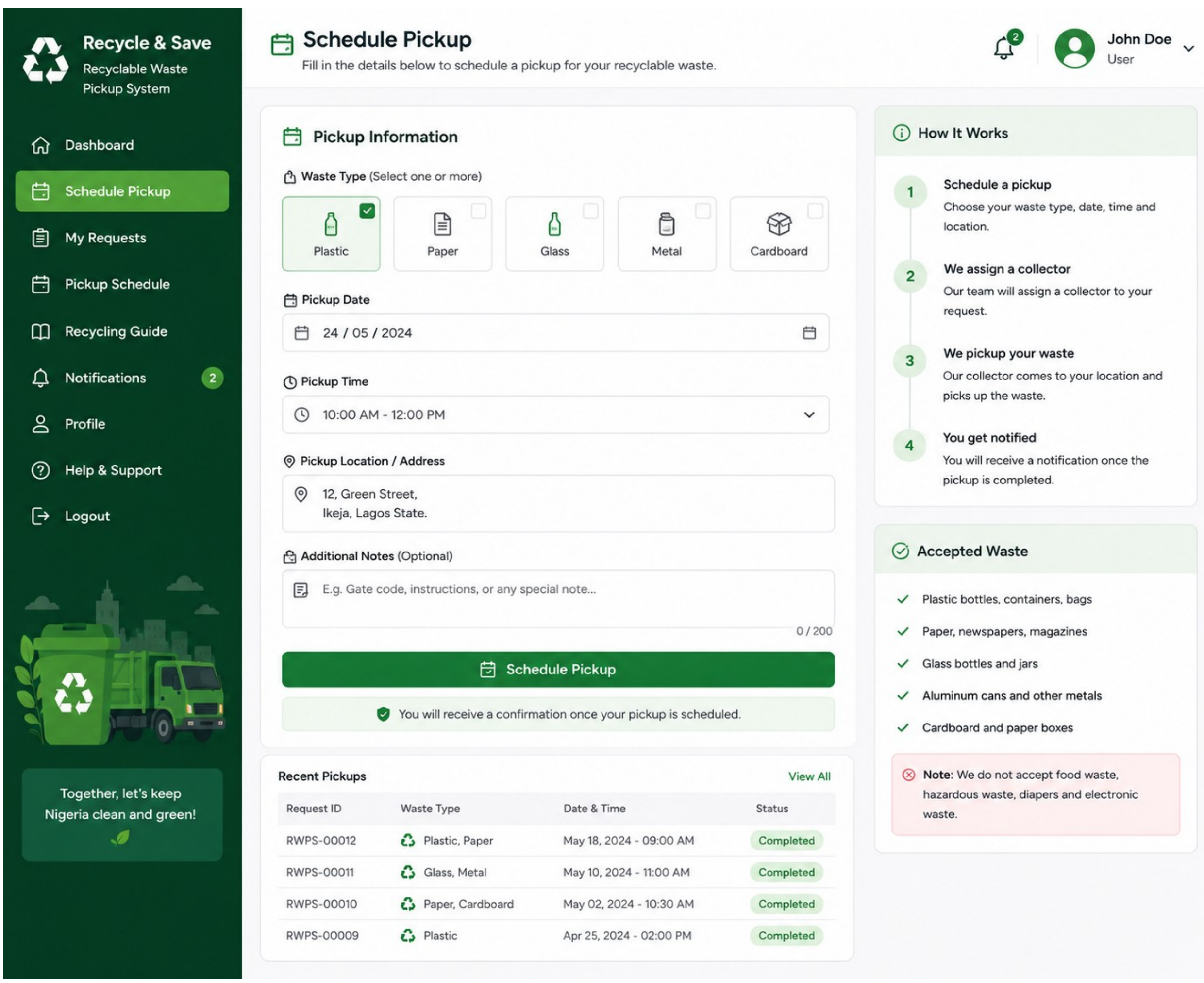

Figure 4.3 Schedule Pickup Page

4.5.6 Notification and Tracking Page

The following page displays a chronological list of all the notifications received by the user. There is a live map displayed that displays the current location of the assigned collector of any ongoing collection process. The status of the process such as Assigned, En Route, Arrived, and Completed gets updated here automatically through Firebase Firestore onSnapshot.

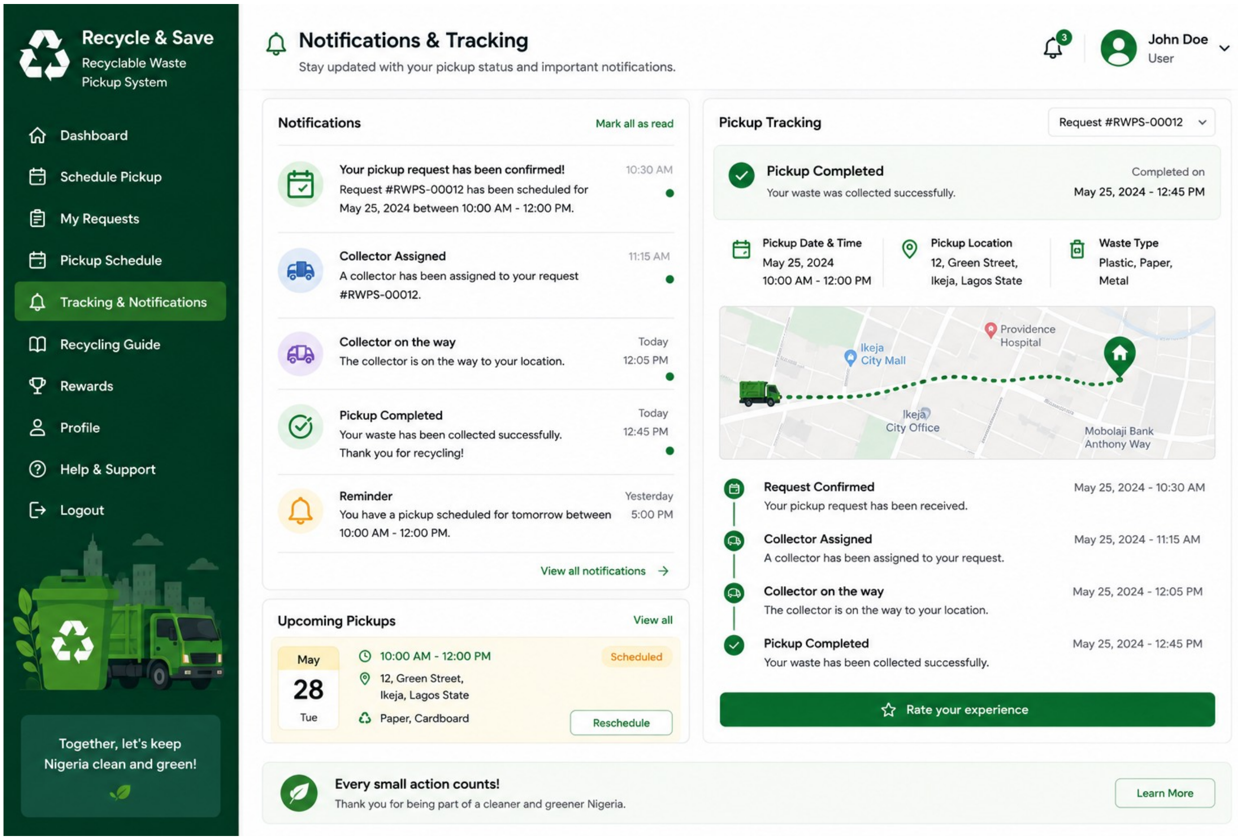

Figure 4.4 Notification and Tracking Page

4.5.7 Admin Dashboard

A dashboard is provided to provide the admin with an instant update on all activities within the system. The map section will show all pickup requests that are currently outstanding, with their locations depicted through color-coated markers and collectors marked by a different set of icons. All the pickup requests are listed down in a tabular form, allowing sorting based on dates, area, type of waste, status, and collector allocated.

Figure 4.5 Admin Dashboard Page

4.5.8 Collection Route Management

This page which is available to the administrator and also to the registered collectors, shows the optimal route for the pick-up assigned to the collector in a particular day. The route is depicted on the map through the use of a polyline with numbered stop points showing the order of pick-ups. There is an indication of the total estimated distance covered by the route and time taken. Also shown are the addresses, details of waste to be collected, and contact details.

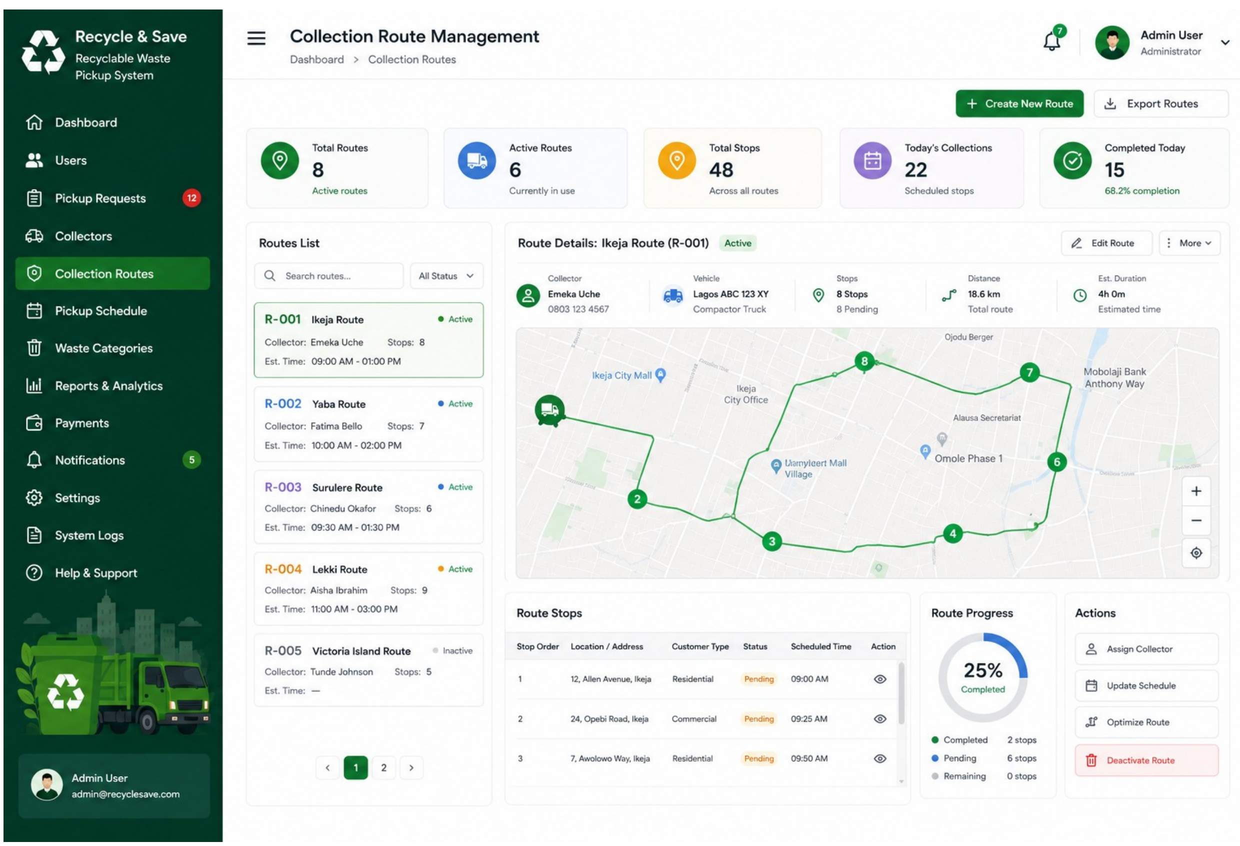

Figure 4.6 Collection Route Management Page

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter provides an overview of what has been done in the process of developing the Recyclable Waste Pickup Scheduling System. This chapter will also offer some recommendations that can be made to improve the system and make it more effective. Finally, a concluding remark will be made about the implications of the study.

5.2 Summary

This project set out to address a clearly identified and persistent problem in Nigerian urban life: the absence of a reliable, digital mechanism for coordinating recyclable waste pickups between households, businesses, and waste collection service providers. Drawing on a review of both global best practices and Nigeria-specific waste management research, the project designed and implemented a web-based platform that enables demand-driven, real-time recyclable waste pickup scheduling.

The system was built using React for the frontend, FastAPI as the backend framework, Firebase for the database and push notification infrastructure, and the Google Maps Platform for location and routing services. Key functional capabilities implemented include user registration and authentication, pickup request submission and tracking, automated collector assignment, route optimization, push notifications, and an administrative monitoring dashboard. The system was tested across multiple user scenarios and demonstrated reliable performance, with an average response time of under 1.2 seconds for scheduling requests and accurate real-time status synchronization across client and server.

5.3 Recommendations

1. Offline-First Functionality:

The future iterations of this application should take into consideration the use of offline first design patterns through the use of service workers and caching of data for local storage. This would allow for the submission and checking of the pick-up requests while the device is offline.

2. Integration with the Informal Collector Sector:

There is an excellent opportunity for integrating informal waste pickers in the platform via an easy registration and onboarding process, which may even be done in collaboration with NGOs and communities who have been working in this area.

3. Machine Learning for Demand Forecasting:

As more data is gathered from history regarding the volumes, types, and patterns associated with pickup requests, it might be possible to use machine learning to predict future demand, allowing collectors to be placed proactively rather than reactively.

4. Partnership with Government Waste Agencies:

It is recommended that the pilot for the project be carried out with at least one state waste management authority, for example, LAWMA in Lagos or ESWAMA in Enugu, to demonstrate its viability under regulated conditions as well as charting the path towards becoming an officially recognized government platform.

5.4 Conclusion

The Recyclable Waste Pickup Scheduling System implemented in this project serves as a significant and well-grounded solution to the issue of improving waste management in the country. The platform facilitates convenient scheduling for citizens, efficient operation of the collecting agencies and monitoring of activities by administrators through leveraging the power of innovative technologies. The use of contemporary and accessible web-based solutions ensures that this application can continue evolving as the result of local software development efforts.

Although the current solution does not cover many aspects due to the specific focus of the project, the framework chosen and all the technological decisions made during its implementation have been aimed at future expansion and scaling across various cities as well as adding more waste types and services. It is hoped that this work will prove to be useful to further investigations and implementations in this sphere.

REFERENCES

Solid waste management in Nigeria (updates 2.2.1 / Ogwueleka 2009)

Okubanjo, A., et al. (2024). Smart Bin and IoT: A Sustainable Future for Waste Management System in Nigeria. *GU Journal of Science*, 37(1). https://doi.org/10.35378/gujs.1254271.

Hamzat, K. A., Adeniyi, L. A., & Olatunji, A. O. (2023). Smart Solid Waste Collection and Management Using IoT-Based System. *FUOYE Planning Journal*. https://fpj.fuoye.edu.ng/index.php/fpj/article/view/89

Digital technology in waste management (updates 2.2.2 / Anagnostopoulos et al. 2015)

Kanona, M., et al. (2024). Waste management 2.0: Leveraging Internet of Things for an efficient and eco-friendly smart city solution. *PMC*. https://pmc.ncbi.nlm.nih.gov/articles/PMC11290616/ — this one is especially strong: real pilot data (180M sensor readings, 28M GPS points) showing a 32% route-distance reduction from dynamic vs. static routing, which is a much sharper citation for your "route optimization leads to savings" claim in 3.4.1 than a 1959 operations-research paper.

Alenazi, M., & Uddin, M. (2024). IoT-Enabled Intelligent Garbage Management System for Smart City: A Fairness Perspective. *IEEE Access*, 12, 82693–82705. https://doi.org/10.1109/ACCESS.2024.3412098

Route optimization / scheduling algorithms (updates 2.2.3 / Dantzig & Ramser 1959)

Martikkala, A., Mayanti, B., Helo, P., Lobov, A., & Ituarte, I. F. (2023). Smart textile waste collection system – Dynamic route optimization with IoT. *Journal of Environmental Management*, 335, 117548. https://doi.org/10.1016/j.jenvman.2023.117548 — you can keep Dantzig & Ramser as the foundational VRP citation, but pair it with this one to show a modern, IoT-driven application of the same problem.

App-based / citizen-engagement recycling platforms in Africa (updates 2.3 / Gutberlet et al. 2017, Doherty et al. 2020)

Nabbanja, et al. (2025). Incentivizing recycling in developing urban cities: design and implementation of a mobile reward app for enhanced participation and sustainability. *Journal of Material Cycles and Waste Management*. https://doi.org/10.1007/s10163-025-02239-y — a Kampala, Uganda case study of a mobile recycling-reward app with a real user study (n=500) and statistical results on tech comfort and participation. This is a much closer comparator to your system than Gutberlet's 2017 qualitative piece, since it's an actual app deployment in a similar-income East African city.

Informal waste picker integration (updates 2.3 / Nzeadibe & Ajaero 2011)

Muheirwe, F., Kombe, W. J., & Kihila, J. M. (2024). Solid waste collection in the informal settlements of African cities: A regulatory dilemma for actors' participation and collaboration in Kampala. *Urban Forum*, 35(1), 1–22. https://doi.org/10.1007/s12132-023-09514-1 — directly relevant to your Recommendation #2 (integrating informal collectors).