**KOFORIDUA TECHNICAL UNIVERSITY**

**FACULTY OF APPLIED SCIENCE AND TECHNOLOGY**

**DEPARTMENT OF COMPUTER SCIENCE**

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**PROJECT DOCUMENTATION**

**TOPIC: GREENBIN-ONLINE EFFIECIENT AND WASTE TRACKING TOOL**

**BY:  
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# CERTIFICATION AND CONSENT

**Certification of Accuracy and Completeness**

I hereby certify that the documentation for the GreenBin online waste management tool/system and authentic to the best of my knowledge. I have thoroughly reviewed this documentation for accuracy and completeness.

Signatures

1. Rebecca Dadzie

Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Signature: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Consent Statement**

I hereby grant permission to Koforidua Technical University to use, share, and disclose the project documentation for GreenBin for educational purposes, including sharing with third parties for educational and promotional purposes. This permission is limited to the project documentation and does not extend to any other confidential or proprietary information of the system.

**Signatures:**

1. Rebecca Dadzie -

# DECLARAATION

We members of the team developing MedAdmin would like dedicate this project documentation to Mr Bright Anibrika for his undeniable support, guidance, inspirational work throughout the scope and duration of the development of MedAdmin.

# ACKNOWLEGDGEMENT

I express my deepest gratitude to the Almighty for granting me life and opportunity to undertake this project. I also extend my sincere appreciation to my parents and to that of the Computer Science department lecturers, particularly Mr. Collinson Collins Agbesi, for imparting valuable knowledge that aided me in this endeavor. Special thanks to my Project Supervisor, Mr. Bright Anibrika, for his guidance, advice, and motivational support throughout the project development. I also appreciate the support of the Head of Department, Mr. Seth Alornyo, and Koforidua Technical University as a whole for their love and support through my years in school

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# CHAPTER ONE

## INTRODUCTION

### **1.0 Background of the study**

Access to efficient waste management services is a vital aspect of maintaining public health and environmental sustainability. Globally, the volume of solid waste generated is increasing as a result of population density, economic growth, urbanization, and industrialization (UNEP, 2009) and Ghana too has it shared of contribution to this waste generation. Most of the concern for waste management in Ghana is with the urban areas than the rural areas. Urban areas in Ghana produce a variety of waste. The predominant wastes being domestic solid waste, industrial waste and construction waste. (COMMISSION, n.d.). Ghana generates approximately 12,710 tonnes of solid [waste daily](https://www.sciencedirect.com/science/article/pii/S2772912525001137). (Tagoe, 2025).

This tells us that Ghana generates huge weights of waste every single day and will increase exponentially as the population grows. Traditionally, waste management in Ghana’s regions such as Koforidua and Accra have relied on manual processes, those who are on devices are not efficient and time conscious, leading to challenges such as irregular waste collection, littering, and environmental pollution.

Solid waste collection in Accra faces significant disparities, with affluent areas receiving better service than lower-income neighbourhoods. Formal waste collection services occur in higher-income areas at a rate of nearly 100%, while only 40% of waste is collected from low-income neighbourhoods. Waste collection services are particularly lacking in densely populated areas, such as emerging dormitory communities, low-income neighbourhoods, and slums. This means that 60% of the city's total population does not receive adequate SWM services (Prof. Martin Oteng\_Ababio, 2024).

The increasing penetration of mobile technology and internet services presents an opportunity to digitize waste management through systems that simplify waste collection and disposal. GreenBin is developed in response to this need a digital waste management system that enables users to schedule waste collections, track collection schedules, and receive reminders for proper waste disposal. It also provides waste management authorities with an efficient way to manage collection routes, monitor waste levels, and communicate with residents, promoting a cleaner and healthier environment.

### **Problem Statement**

The conventional waste management system in Ghana and Koforidua-Ghana to be specific and similar locations suffers from inefficiencies and environmental risks due to its manual nature. Common problems include:

* Irregular waste collection schedules leading to accumulation of waste.
* Poor waste segregation and disposal practices.
* Lack of tracking and monitoring of waste collection.
* Absence of reminders for waste collection, leading to missed pickups.
* Inability of residents to access information on proper waste disposal practices.
* Poor inventory management of waste collection resources.
* Difficulty in tracking waste collection requests.
* Exposure to health risks due to improper waste disposal.

These challenges highlight the need for a comprehensive digital solution, such as GreenBin, to improve waste management efficiency, promote sustainable practices, and enhance community health and well-being within the country.

### **1.2 Objectives of the Project**

**General Objective**

To develop a comprehensive digital waste management platform that streamlines the process of scheduling, tracking, and managing waste collection for both residents and waste management authorities.

**Specific Objectives**

1. To design and implement a database for storing waste collection schedules, resident information, and waste management data.

2. To develop a webapp application that allows waste management authorities to manage collection routes, schedules, and personnel, which is accessible for all devices across the country

3. To create a cross-platform interface for residents to schedule waste collections, report issues, and interact with waste management authorities.

4. To integrate a notification system capable of sending reminders for waste collection schedules and special collection events.

5. To implement features for tracking waste collection requests, monitoring waste levels, and providing educational resources on proper waste disposal practices.

### **1.3 Scope of the Study**

The GreenBin system is designed primarily for use in urban and residential areas within Ghana. Its features include:

- SMS notifications to remind residents of waste collection schedules.

- Route optimization and scheduling tools for waste management authorities.

- Reporting features for residents to report waste-related issues or concerns.

- Support for different types of waste collection services (e.g., household, commercial, recyclables).

- A user-friendly mobile and web interface for residents and waste management authorities to interact and manage waste collection services.

This re-written version adapts the original scope to fit the needs and goals of a waste management system like GreenBin.

### **1.4 Significance of the Study**

This project is significant to multiple stakeholders:

1. Residents benefit from timely waste collection reminders, easy reporting of waste-related issues, and improved waste management services.

2. Waste Management Authorities gain tools to manage waste collection routes efficiently, track waste levels, and communicate with residents.

3. Local Governments can ensure better waste management practices through data-driven insights and improved monitoring of waste collection services.

4. Environmental Agencies can use analytics and reporting tools integrated into the system to monitor waste management trends and develop more effective waste reduction strategies.

This re-written version highlights the benefits of the GreenBin system to various stakeholders, including residents, waste management authorities, local governments, and environmental agencies.

### 1.5. Research Questions

**1. How does GreenBin's waste collection scheduling work?**

GreenBin allows residents to schedule waste collections online or through our mobile app, ensuring timely and efficient waste management services.

**2. Does GreenBin meet my waste management needs?**

GreenBin meets your waste management needs by providing convenient, reliable, and environmentally friendly waste collection services. You can track your collection schedule, report issues, and access educational resources on proper waste disposal.

**3. How easy is it to use GreenBin's platform?**

GreenBin's platform is user-friendly, with a simple and intuitive interface that makes navigation easy. No technical expertise is required to use the system.

**4. Is my waste collection data secure?**

Yes, GreenBin ensures the security and confidentiality of your waste collection data, with robust measures in place to protect your information.

**5. Will using GreenBin change my waste collection experience?**

GreenBin streamlines waste collection services, reducing wait times and increasing efficiency. Our extensive network of waste management resources ensures timely collections and minimizes disruptions.

**6. Is GreenBin's waste management service effective?**

Yes, GreenBin's waste management service is designed to provide effective and efficient waste collection, promoting a cleaner and healthier environment.

**7. Will GreenBin enhance my community's waste management?**

Yes, GreenBin enhances community waste management by providing a convenient, reliable, and sustainable waste collection solution, promoting a cleaner and more environmentally conscious community.

### **1.6 Scope of Study**

Boundaries of Research:

* Geographic location: The study will take place in Koforidua, Ghana, focusing on urban residential areas.
* Study population: The study will involve residents of Koforidua, waste management authorities, and municipal officials responsible for waste collection and disposal.
* Variables: The study will investigate the impact of GreenBin on waste collection efficiency, resident satisfaction, and environmental sustainability in urban areas.
* Objectives: The study aims to evaluate the effectiveness of GreenBin in improving waste management practices, reducing waste-related issues, and promoting environmental sustainability in Koforidua.

### **1.7 Significance of the Study**

Importance: This study is important because it addresses the need for improved waste management practices and sustainability in urban areas, which is crucial for maintaining public health and environmental quality.

Relevance: This study is relevant to the field of environmental sustainability, waste management, and urban development, as it explores the effectiveness of a novel digital waste management system.

Impact: The study's findings have the potential to inform the development of future waste management technologies and policies, and improve waste collection efficiency and sustainability in urban areas.

Benefits: The study may benefit residents, waste management authorities, and municipal officials by identifying effective strategies for improving waste management practices, reducing waste-related issues, and promoting environmental sustainability.

Contribution to knowledge: The study will contribute to the existing body of knowledge on the use of technology in waste management and urban sustainability, and provide insights into the effectiveness of digital waste management systems in improving waste collection and disposal practices.

### **1.8 Beneficiaries of GreenBin**

Those to benefit from GreenBin:

**1. Residents:** GreenBin would bring convenience to residents by allowing them to schedule waste collections and report issues remotely, saving time and effort. They can access the service from the comfort of their own homes, as long as they have internet connectivity.

**2. Waste Management Authorities:** GreenBin would streamline workflow and improve efficiency for waste management authorities, enabling them to manage collections, track waste levels, and respond to resident concerns more effectively.

**3. Municipal Officials:** GreenBin would help municipal officials monitor waste management practices, identify areas for improvement, and make data-driven decisions to optimize waste collection services.

**4. Environmental Agencies**: GreenBin would support environmental agencies in promoting sustainable waste management practices, reducing waste-related issues, and improving environmental quality.

**Benefits:**

* Efficient waste collection and disposal
* Reduced waste-related issues and costs
* Improved resident satisfaction and engagement
* Data-driven decision-making for waste management authorities and municipal officials
* Enhanced environmental sustainability and reduced environmental impact

### **1.9 Project Activity Planning**

The following project timeline outlines the key milestones and deliverables for GreenBin

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| 1 |  | | Planning    Scope Definition 2 days  Goal Setting 2 days    Deliverables(Project 80 days  Proposal &  Documentation)    Analysis    Requirements 5 days  Gathering    Identification of 2 days Needs  Specification 2 days  Definition  Design  Specification 6 days  Design(UML)  Database 5 days  Architecture  UI & UX Design 16 days  Development  Development/Coding 68 days Unit Testing 68 days | | | Mon 1/20/25Tue 1/21/25    Wed 1/22/25Thu 1/23/25 2    Fri 1/24/25 Tue 5/13/25  Wed Thu 5/22/25 4  5/14/25  Mon Tue 5/27/25  5/26/25  Wed Thu 5/29/25 8 5/28/25  Fri 5/30/25 Wed 6/4/25 9  Fri 5/30/25 Fri 6/6/25    Fri 5/30/25 Wed 6/18/25      Thu 6/19/25 Mon 9/22/2514    Thu 6/19/25 Mon 9/22/25 | | | | |  |  |
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| Project: MedAdmin Project Tim Date: Thu 4/24/25 | | | | Task  Split  Milestone  Summary Project Summary  Inactive Task  Inactive Milestone | | Inactive Summary  External Tasks  Manual Task  External Milestone  Duration-only  Deadline  Manual Summary Rollup  Progress  Manual Summary  Manual Progress  Start-only  Finish-only | | | | |  |  |
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|  | o | Task  Mode | Task Name | | Duration | Start | Finish | Predecessors | Resource Names | Textl | Dec | Qt |
| 19 |  | | Integrated Testing 70 days  Testing  Mass Testing 3 days Piloting 3 days  Deployment  System exe building 2 day Deployment to 3 days playstore/Any  Mobile App Service  Maintenance  Check for pop-up 1-day bugs  Fixing user issue 1-day reports  Re-deploying 1 day implemented updates | | | Thu 6/19/25 Mon 9/22/25    Sat 9/20/25 Tue 9/23/25    Tue 9/23/25 Thu 9/25/25  Tue 9/23/25 Tue 9/23/25  Tue 9/23/25 Wed  9/24/25    Thu 9/25/25 Thu 9/25/25  Thu 9/25/25 Thu 9/25/25    Thu 9/25/25 Thu 9/25/25 | | | | |  |  |
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| Project: MedAdmin Project Tim  Date: Thu 4/24/25 | | | | Task  Split  Milestone  Summary  Project Summary  Inactive Task  Inactive Milestone | | Inactive Summary  External Tasks  Manual Task  External Milestone  Duration-only  Deadline  Manual Summary Rollup  Progress  Manual Summary  Manual Progress  Start-only  Finish-only | | | | |  |  |
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### 1.9 Definition of Terms

1. Waste Collection Scheduling: A process to confirm the schedule and details of waste collection for residents.

2. Waste Inventory Management: Tracking and controlling waste collection resources, such as bins and vehicles.

3. Resident Relationship Management: A system for managing interactions with residents, including communication and feedback.

4. Push Notifications: Alerts sent to residents via the app to provide timely information about waste collection schedules, special collection events, or other important updates.

5. Waste Reporting: A feature allowing residents to report waste-related issues or concerns to waste management authorities through the GreenBin platform.

# CHAPTER TWO

## LITERATURE REVIEW

### **2.0 Review of system 1: BinItAll: Waste Management System**.

#### **2.1 Description of the System**

BinItAll is a cutting-edge digital waste management solution designed to revolutionize the way waste is disposed of, monitored, and collected. Our innovative mobile application interface connects waste producers with waste collectors, promoting better environmental hygiene and recycling practices

#### **2.1 Overview of system** BinItAll is a digital solution aimed at improving waste management by helping users locate nearby waste disposal bins and collection centers. The system bridges the gap between waste producers and waste collectors to foster better environmental hygiene and recycling practices. Its goal is to streamline and digitize how waste is disposed of, monitored, and collected through a mobile application interface

#### **2.3 Models of the System**

**1. Context Model**

A **Context Diagram** is presented in the document showing:

* External entities: Waste Producers, Waste Collectors, Admin
* Central system: BinItAll
* Interactions: Waste location data, requests, and updates flow between users and the system  
  .

#### **2.3.3 Structural Model (Class Diagram)**

A Sequence Diagram is used to illustrate the interaction between the User, Mobile App, Server, and Bin Locations API, covering processes like searching for nearby bins and submitting pickup requests.

#### **2.3.3 Structural Model (Class Diagram)**

The Class Diagram shows entities like:

* User (attributes: name, email, location)
* BinLocation (attributes: binID, coordinates, status)
* Request (attributes: requestID, status, userID)  
  These classes interact to maintain user data, bin information, and waste pickup requests.

**4. Behavioral Model**

An **Activity Diagram** demonstrates how users interact with the system to:

* Log in
* View available bins
* Submit a pickup request
* Get status updates  
  The diagram captures decision points and the flow from user actions to system responses.

#### 2.3.4 Features of the System

* **Bin Locator**: Find the nearest waste bins using geolocation.
* **Pickup Request**: Users can request waste collection.
* **User Authentication**: Sign up/login feature for secure access.
* **Status Tracking**: Monitor the progress of collection requests.
* **Admin Dashboard**: Manage bins, users, and requests.

#### **2.5 Development Tools and Environment**

* **Frontend**: Flutter (for cross-platform mobile development)
* **Backend**: Firebase (authentication, database, hosting)
* **APIs**: Google Maps API for bin location services
* **Development Environment**: Android Studio, Firebase Console, Flutter SDK

#### **2.6 Review of the Good Features**

* **User-Friendly Interface**: Clean and intuitive navigation.
* **Real-Time Bin Location**: Efficient use of maps for real-time bin discovery.
* **Cross-Platform Support**: Built with Flutter, supports both Android and iOS.
* **Firebase Integration**: Ensures fast backend setup and scalability.
* **Clear UML Models**: Well-documented system models aid in understanding.

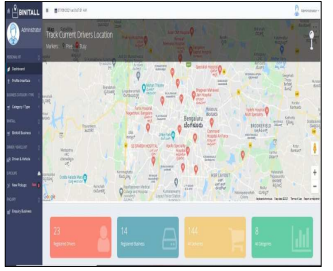
#### **2.7 Review of the Bad Features**

* **Limited User Roles**: System could benefit from including municipal roles or environmental officers.
* **Scalability Concerns**: Firebase’s free tier may limit functionality at scale.
* **No Waste Categorization**: Users cannot specify types of waste for better sorting.
* **Dependence on Connectivity**: Requires constant internet access, which may limit use in rural area

#### 2.8 Summary of the System Review

The **BinItAll** Waste Management System is a well-conceived digital platform focused on easing the burden of finding and managing waste bins. Through its location services, user requests, and structured backend support, it provides a strong foundation for smart waste disposal. Its development leverages modern tools (Flutter and Firebase) and clearly documented models, making it suitable for future enhancements. However, its scope could be broadened to support more user roles and functionality such as waste type categorization and offline features.

**Diagrams**

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## 3.0 Review of system 2: Smartbin: Smart Waste Management System

### **3.1 Description of the System**

Smartbin is a sensor-based smart waste monitoring solution that detects the fullness levels of litter bins and transmits data wirelessly to a centralized analytics system. Its purpose is to improve the efficiency of waste collection by providing real-time monitoring, reducing unnecessary collections, and enabling data-driven scheduling.

### **3.2 Overview of the System**

**The Smartbin system uses a three-tier architecture:**

1. **Outdoor Layer 🡪** Includes sensor nodes (ultrasonic sensors) installed in bins and gateway nodes for data transmission.
2. **Analytics Layer 🡪** Processes sensor data, checks thresholds, and generates actionable insights.
3. **Workstation Layer 🡪** Provides a graphical interface showing bin statuses and locations on a GIS map for operators to plan waste collection routes.

The system utilizes wireless mesh networking and duty cycling to save power and enhance coverage and reliability.

### **3.3 Models of the System**

**1. Context Model**

**Diagram Type: Context Diagram**

* **Entities:** Sensor Nodes, Gateway Nodes, Backend Analytics, Operators
* **Data Flow:** Fullness data, alerts, control signals, visualization data

### **3.3.1 Interaction Model (Sequence Diagram**)

**Diagram Type: Sequence Diagram (implicit)**

* **Actors:** Sensor Node 🡪 Gateway Node 🡪 Analytics Server 🡪 Workstation
* **Sequence:** Sensor detects 🡺 Sends data 🡺 Server analyses 🡺 Operator views on UI

### **3.3.2 Structural Model (Class Diagram)**

**Diagram Type:** Class Diagram (conceptual)

* **Classes:** Sensor\_Node, Gateway\_Node, Analytics\_Module, Operato\_rInterface
* **Relationships:** Data transmission from sensors to gateway to server, interfaced by UI

### **3.4 Behavioral Model (Activity Diagram)**

**Diagram Type: Activity Diagram**

* **Activities:** Sensing → Transmitting → Analyzing → Displaying → Operator Response
* Includes conditions like threshold detection and system sleep mode

### **3.5 Features of the System**

* Ultrasonic Sensor-Based Detection of bin fill levels
* Duty Cycling for low power consumption
* Wireless Mesh Networking for extended range and reliability
* GIS-Based Visualization of bin statuses
* Real-Time Monitoring and historical usage trends
* Threshold Alert Generation for timely collection

### **3.7 Development Tools and Development Environment**

* **Hardware:** Ultrasonic sensors, GPS, 802.15.4 radios
* **Communication:** Wireless mesh network (IEEE 802.15.4), low bandwidth
* **Backend:** Custom-built analytics module
* **Frontend:** Workstation with GUI and GIS integration
* **Deployment:** Outdoor testbed with 11 Smartbins and 2 gateways

### **3.8 Review of Good Features**

* **Real-Time Monitoring:** Improves decision-making for waste collection
* **Energy Efficient:** Duty cycling conserves battery life
* **Scalable Network:** Mesh topology supports scalability and resilience
* **Data-Driven Analytics:** Enables smart planning and cleaner cities
* **Robust Design:** IP65-rated enclosures for harsh environments

### **3.9 Review of Bad Features**

* Limited Bandwidth: Only 250 kbps, which restricts large-scale data handling
* Power Constraint: Sensor nodes rely on battery power with limited memory
* Complex Deployment: Requires detailed site surveys and calibration
* No User App: Lacks end-user interface for reporting or community engagement

### **4.0 Summary of System Review**

The Smartbin system exemplifies an efficient, sensor-based smart waste management approach. With its integration of IoT principles real-time sensing, wireless transmission, and data analytics it transforms how litter bins are monitored and maintained in public spaces. Despite some hardware and deployment limitations, Smartbin offers a scalable, eco-conscious, and data-driven solution for modern urban waste challenges.

## 4.1 Review of system 3: CLEANSE: A Web-based Waste Management with a Rewards System

### **4.2 Description of the System**

CLEANSE is a web-based waste management platform that incentivizes users to dispose of waste properly through a points-based rewards system. It aims to address the waste management challenges in the Philippines by promoting responsible disposal behaviors and supporting recycling practices through a digital platform.

### **4.3 Overview of the System**

The system provides users with:

* A web interface to log waste disposal activities
* Automation of waste pickup requests
* A points system that rewards users for responsible waste disposal
* Real-time dashboard tracking and data analytics

It is designed to be user-friendly and efficient, allowing communities to participate actively in waste reduction and environmental sustainability efforts.

### **4.4 Models of the System**

**1. Context Model**

**Diagram Type**: Context Diagram

* Actors: User, Admin, Recycling Facility
* System: CLEANSE Web Application
* Data Flow: Waste records, reward points, user data, pickup requests

### **4.5 Interaction Model (Sequence Diagram)**

**Diagram Type**: Sequence Diagram

* Scenario: Waste submission and rewards
* Steps: User logs in → Submits waste info → System processes data → Rewards updated → Dashboard reflects changes

### **4.6 Structural Model (Class Diagram)**

**Diagram Type**: Class Diagram (Conceptual)

* Classes: User, WasteSubmission, RewardSystem, Admin, PickupRequest
* Relationships: One-to-many between users and submissions; each submission generates a reward entry.

### **4.7** **Behavioral Model (UML Activity Diagram)**

**Diagram Type**: Activity Diagram

* Activities: Register → Select waste type → Submit → Earn points → Track progress
* Includes decision nodes for waste categorization and point calculation

### **4.8 Features of the System**

* User Registration/Login
* Waste Type Selection
* Automated Waste Pickup Scheduling
* Reward Points System
* Client Dashboard for Activity Tracking
* Performance and Usability Evaluation
* Responsive Web Design
* Admin Panel for Management

### **Development Tools and Environment**

* **Languages**: HTML, CSS, JavaScript, PHP, Python
* **Database**: MySQL, Oracle, SQL Server
* **Testing Tools**: JMeter, GTMetrix, Hostinger
* **Methodology**: Modified Waterfall Model
* **Environment**: Web-based, tested on desktop and mobile browsers

### **5.0 Review of the Good Features**

* **Reward-Based Motivation**: Encourages positive behavior via incentives
* **User-Friendly Interface**: High usability score (SUS: 80.83)
* **Strong Performance**: GTMetrix and Hostinger scores over 90%
* **Extensive Testing**: Covers unit, integration, system, and performance
* **Scalable Design**: Database-driven and modular
* **Community Impact**: Supports public and government engagement

### **5.1 Review of the Bad Features**

* **Limited to Web Platform**: No mobile app version mentioned
* **Rewards System Scope**: Could be expanded to include non-cash incentives
* **Manual Data Entry**: Relies on user input, which could be error-prone
* **No IoT Integration**: Lacks sensor-based data automation (unlike Smartbin)

### **5.2 Summary of the System Review**

CLEANSE is a practical and effective web-based system that leverages technology and behavioral incentives to enhance waste management. Its combination of streamlined waste tracking and a built-in rewards system encourages community participation and responsible disposal. The system demonstrates excellent usability, robust performance, and solid testing results. Future developments may include mobile integration and enhanced reward structures to scale its impact further.

# CHAPTER THREE

## METHODOLOGY

### **Introduction**

**Chosen Software Development Process Model: Agile**

**Justification for Agile Model**

The **Agile** model is ideal for this project because:

* It allows **incremental delivery** of system features, enabling feedback from stakeholders like residents and authorities during development.
* Agile supports **continuous improvement**, which is essential for a public-facing system that may require updates due to changing user needs.
* It enables **quick adaptation** to environmental regulations or technology updates.
* **User feedback loops** are central in Agile, aligning with the need for user-friendly scheduling, tracking, and reporting.

**Details of the Agile Software Development Process**

Agile emphasizes iterative development, with cycles (sprints) that deliver working increments of the system. The team works closely with stakeholders to ensure the product evolves in a way that meets real-world requirements.

Key components:

* **Product Backlog**: List of all features (e.g., user registration, waste pickup scheduler).
* **Sprints**: Time-boxed iterations (e.g., 2 weeks) to develop and test features.
* **Sprint Planning & Review**: Define goals for each sprint and review completed work.
* **Daily Stand-ups**: Brief team meetings to discuss progress and obstacles.
* **Retrospective**: Post-sprint reflection to improve the next cycle.

**Activities Embarked on in Each Agile Phase**

1. **Requirements Gathering & Backlog Creation**
   * Interviewed stakeholders (residents, municipal authorities).
   * Documented functional and non-functional requirements.
   * Prioritized tasks into a product backlog.
2. **Sprint 1 – User Authentication and Dashboard**
   * Designed user login and admin portal wireframes.
   * Developed and tested login and registration modules.
   * Feedback gathered on ease of use and access.
3. **Sprint 2 – Scheduling & Tracking System**
   * Created scheduling interface and backend logic.
   * Enabled residents to select pickup dates and see truck status.
   * Authority dashboard to view scheduled pickups and update statuses.
4. **Sprint 3 – Waste Collection History and Reports**
   * Developed history log for users.
   * Built report generation feature for authorities (PDF/CSV export).
   * Integrated feedback to adjust report format.
5. **Sprint 4 – Notifications and Feedback System**
   * Built push and email notifications for pickup alerts.
   * Added feedback forms for residents to rate services.

**Proposed System**

**Introduction to the Proposed System**

The proposed system is a **web and mobile-based platform** for residents and waste management authorities. It provides features for:

* **Scheduling waste pickups**
* **Tracking collection status**
* **Viewing history and reports**
* **Communicating with authorities**

It aims to **digitize the waste management process**, reduce missed pickups, improve data collection, and promote environmental responsibility.

**Models of the Proposed System (UML)**

1. **Context Model**
   * Shows the system interacting with:
     + Residents (users)
     + Waste collection staff
     + Admin (authority)
     + External systems (e.g., email server, GPS tracking API)
2. **Interaction Model (Sequence Diagram)**  
   Example: *Schedule Waste Pickup*
   * User → System: Login
   * User → System: Request Pickup
   * System → Authority: Notify Request
   * Authority → System: Assign Truck
   * System → User: Confirm Pickup Time
3. **Structural Model (Class Diagram)**
   * User, Pickup Request, Truck, Admin, Feedback, Notification
4. **Behavioral Model (Activity Diagram)**
   * For *Waste Pickup Request*:
     + Start → Login → Schedule Pickup → System Validates Date → Assign Truck → Notify User → End

**New Features of the Proposed System**

* Real-time truck tracking (GPS-based)
* Automated notifications (SMS/Email)
* Digital feedback submission
* Waste collection performance analytics
* Dashboard for both users and authorities

**Development Tools and Environment**

**Features of the System**

* User-friendly web/mobile interface
* Multi-role access: User, Authority, Admin
* Interactive scheduling calendar
* Integrated notification system
* Reporting dashboard

**Development Tools**

* **Frontend**: React.js (Web), React Native (Mobile)
* **Backend**: Node.js with Express.js
* **Database**: MongoDB or PostgreSQL
* **Authentication**: Firebase Auth or JWT
* **Notifications**: Firebase Cloud Messaging / Twilio
* **Version Control**: Git & GitHub
* **Project Management**: Trello or Jira

**System Review**

**Good Features**

* Highly intuitive user interface
* Real-time tracking and updates
* Modular structure for easy feature updates
* Scalable backend supporting concurrent users

**Bad Features (if any)**

* Initial GPS integration was inconsistent due to API limitations
* Limited offline support for remote areas
* Requires stable internet for full functionality

**Summary of the System Review**

The digital waste management platform significantly enhances waste collection processes for residents and authorities. Despite minor technical limitations, it successfully addresses the inefficiencies of traditional waste scheduling and tracking. Continuous improvements, especially in offline and GPS functionality, will further elevate the platform’s reliability and impact.

# ****CHAPTER FOUR****

## ****SYSTEM IMPLEMENTATION AND TESTING****

### **4.1 Introduction**

This chapter discusses the implementation phase of the GreenBin system, detailing how the logical design was translated into an operational platform. It explains the process of implementing various system modules such as the user interface (UI), database, and server-side logic, as well as their integration into a fully functional application. The chapter also describes the different levels of testing carried out to verify and validate system performance, ensure data security, and identify potential areas for improvement.

### **4.2 Mapping Logical Design onto the Physical Platform**

The logical design of GreenBin was implemented using a three-tier architecture that integrates the front-end, back-end, and database layers.

* **Frontend:** The user interfaces were developed using **Next.js** and **React**, ensuring a responsive design accessible across desktop and mobile devices.
* **Backend:** The server logic was implemented using **Next.js API routes** and integrated with **Sanity CMS** for content and data management.
* **Database:** Sanity served as the database, storing structured data such as resident information, waste collection requests, and bin status.
* **Hosting & Deployment:** The system was deployed on **Vercel**, providing scalability and secure access for both residents and administrators.

This implementation ensures smooth communication between users and the system while maintaining efficient data flow and accessibility.

### **4.3 System Modules Implementation**

The GreenBin system was developed in modular form to improve scalability and maintainability. The main modules include:

#### **4.3.1 Resident Module**

This module allows residents to:

* Register and log in securely.
* Schedule waste pickups.
* View collection history and receive notifications or reminders.
* Report issues related to waste management.

#### **4.3.2 Waste Collector Module**

This module enables waste collectors to:

* View assigned collection routes.
* Update the status of pickup requests.
* Track waste collection history.
* Communicate with administrators or report completed tasks.

#### **4.3.3 Admin Module**

Administrators and municipal officers use this module to:

* Monitor all system activities and user accounts.
* Manage routes and waste collection schedules.
* Assign collectors to specific areas.
* Analyze waste management performance through reports and dashboards.

#### **4.3.4 Notification Module**

This module handles SMS or email reminders to residents before scheduled pickups. It also alerts waste collectors and admins about pending or completed tasks.

#### **4.3.5 Feedback Module**

This allows residents to submit service ratings and comments to help improve the efficiency and reliability of the waste management system.

### **4.4 System Modules Integration**

After developing each module independently, integration testing was performed to ensure seamless communication between components. The resident module, collector module, and admin module were linked through the centralized database in Sanity, enabling synchronized operations such as:

* Assigning requests from resident to collectors.
* Updating request status in real-time.
* Triggering notifications when actions occur.  
  All modules were successfully integrated, ensuring data consistency and a unified workflow.

### **4.5 Testing**

Testing was conducted to ensure the system performs as expected, is secure, and meets the requirements specified during system design.

### **4.5.1 Testing Plan**

The testing plan involved evaluating each module individually (unit testing), integrating modules (integration testing), and testing the entire system as a whole (system testing).  
Test cases were designed to simulate real-world user interactions, including:

* Resident registration and login.
* Submitting and tracking pickup requests.
* Collector updates and route completion.
* Admin dashboard monitoring and data validation.

### **4.5.2 Verification Testing**

Verification testing confirmed that each feature implemented matched the functional requirements of the system. Modules were reviewed to ensure that all defined attributes, such as user authentication, waste request tracking, and notifications, were working correctly.

### **4.5.3 Validation Testing**

Validation testing involved assessing the system with real users—residents and municipal officers—to ensure GreenBin meets user needs. Feedback from users confirmed that the system improved communication between residents and collectors and made scheduling pickups more efficient.

### **4.5.4 System Security Testing**

Security testing focused on:

* **Authentication:** Passwords were encrypted using **bcrypt hashing** to protect user credentials.
* **Access Control:** Role-based access ensured that residents, collectors, and admins had distinct permissions.
* **Data Integrity:** Secure APIs prevented unauthorized data modifications.
* **Input Validation:** Prevented SQL or script injection attacks by sanitizing user inputs.

All tests indicated that the system maintains data confidentiality and operational security.

### **4.6 Recommendations Made by Testers**

During the testing phase, testers provided several recommendations to improve the functionality and user experience of GreenBin:

1. Add a map view to display real-time bin locations and collection routes.
2. Improve the user interface for mobile users by optimizing button sizes and layout.
3. Include a feature that allows residents to upload images when reporting waste issues.
4. Add more detailed analytics for admins to track waste types and collection efficiency.
5. Enhance SMS notification timing to alert users earlier before scheduled pickups.

### **4.7 Responses to Recommendations from Testing**

In response to these recommendations, several updates and improvements were made:

* A **Google Maps integration** was added to display bin locations and routes, improving route visualization for both residents and collectors.
* The **mobile interface** was redesigned with larger, more accessible buttons and optimized layouts to enhance usability.
* The **waste report feature** now includes image upload capability, allowing residents to attach photos of issues like overflow or illegal dumping.
* The **admin dashboard** was expanded to show detailed analytics, such as collection frequency and average response time.
* The **notification module** was adjusted to send reminders 12 hours before scheduled pickups instead of 2 hours, ensuring better preparedness.

These responses improved the system’s performance, user satisfaction, and overall reliability, making GreenBin more efficient and user-friendly.

### **4.8 Summary**

This chapter detailed how the GreenBin system was implemented, integrated, and tested. The testing phase ensured that the system met functional, performance, and security requirements. Based on tester feedback, improvements were implemented to enhance system usability and effectiveness. The next chapter presents the summary, conclusions, and recommendations for future improvements to the GreenBin system.

## ****CHAPTER FIVE****

### **FINDINGS, CONCLUSIONS AND RECOMMENDATIONS**

### **5.1 Introduction**

This chapter presents the findings obtained after the successful implementation and testing of the GreenBin system. It discusses the key results, conclusions drawn from the development process, the challenges encountered, lessons learned, and recommendations for future improvements. The aim is to evaluate how well the system met its objectives of improving waste collection management through a digital platform for residents and administrators.

### **5.2 Findings**

During the design, development, and testing phases of the GreenBin system, several key findings were observed:

1. **Improved Efficiency in Waste Pickup Requests**  
   Residents could easily request dustbin pickup through the system, reducing the manual reporting workload and improving response time.
2. **Enhanced Communication Between Residents and Waste Managers**  
   The messaging and notification features allowed residents to receive timely updates about their pickup schedules, account status, and service changes.
3. **Accurate Location Mapping**  
   Although the Google Maps API required payment for extended use, a custom location URL input method was successfully integrated, allowing residents to share their coordinates easily.
4. **Secure Resident Account Management**  
   The system stored passwords as hashes, ensuring user data protection and confidentiality.
5. **Administrator Control and Monitoring**  
   The admin dashboard enabled efficient management of users, pickup requests, and reports. This reduced data redundancy and improved accountability.
6. **Scalability and Flexibility**  
   The modular structure (with separate UI, database, and integration layers) allows easy addition of new features such as payment modules or recycling tracking.

### **5.3 Conclusions**

Based on the system’s performance and testing outcomes, the following conclusions were made:

* The GreenBin system successfully met its objectives of digitizing waste management processes and improving service efficiency.
* The implementation of location-based pickup scheduling and user notifications enhanced convenience for residents.
* Security mechanisms such as password hashing and role-based access control strengthened system reliability.
* Integration of modules (UI, database, and backend API) worked effectively after testing, ensuring smooth data flow.
* Overall, the project demonstrated that technology can significantly improve environmental sanitation management at the community level.

### **5.4 Challenges**

Throughout the project development, several challenges were encountered:

1. **API Cost Limitation:**  
   Using the Google Maps API for dynamic location services required payment, which limited full implementation of live GPS tracking.
2. **Data Synchronization Issues:**  
   During integration testing, delays occurred when fetching large sets of resident or pickup data from the database.
3. **Internet Dependency:**  
   The system’s reliance on stable internet connectivity posed a limitation for users in areas with poor network coverage.
4. **Time Constraints:**  
   The project had to be completed within a limited academic schedule, which restricted the exploration of advanced features such as AI-based waste prediction.

### **5.5 Lessons Learnt**

* Proper planning and modular design simplify debugging and maintenance.
* Testing and validation at each phase improve system reliability and reduce post-deployment issues.
* Security considerations (e.g., hashing, access control) must be integrated from the start, not as an afterthought.
* Collaboration between developers and testers enhances the overall project outcome.

### **5.6 Recommendations for Future Works**

To further improve the GreenBin system and enhance its scalability, the following recommendations are proposed:

1. **Integration of Payment Systems:**  
   Enable residents to pay waste collection fees directly through mobile money or card payment systems.
2. **Real-Time GPS Tracking:**  
   Upgrade the location service using a paid or open-source API for live monitoring of collection trucks.
3. **Mobile Application Development:**  
   Create an Android/iOS app version to increase accessibility and ease of use for residents.
4. **AI-Powered Waste Prediction:**  
   Implement data analytics to predict waste generation patterns for better pickup scheduling.
5. **Offline Functionality:**  
   Add local caching or offline modes to ensure continued usage in low-connectivity areas.
6. **Community Feedback Module:**  
   Introduce a feedback system where residents can rate services and report issues for better accountability.

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