Web-Based E-Waste Management System

G.G.D.Wimalasena

2024

Web-Based E-Waste Management System

A dissertation submitted for the Degree of Master of Information Technology

G.G.D.Wimalasena
University of Colombo School of Computing
2024

Declaration

Name of the student: G.G.D Wimalasena
Registration number: 2018/MIT/088
Name of the Degree Programme: Master of Information Technology (MIT)
Project/Thesis title: Web-Based E-Waste Management System

1. The project/thesis is my original work and has not been submitted previously for a degree at this or any other University/Institute. To the best of my knowledge, it does not contain any material published or written by another person, except as acknowledged in the text.

2. I understand what plagiarism is, the various types of plagiarism, how to avoid it, what my resources are, who can help me if I am unsure about a research or plagiarism issue, as well as what the consequences are at University of Colombo School of Computing (UCSC) for plagiarism.

3. I understand that ignorance is not an excuse for plagiarism and that I am responsible for clarifying, asking questions and utilizing all available resources in order to educate myself and prevent myself from plagiarizing.

4. I am also aware of the dangers of using online plagiarism checkers and sites that offer essays for sale. I understand that if I use these resources, I am solely responsible for the consequences of my actions.

5. I assure that any work I submit with my name on it will reflect my own ideas and effort. I will properly cite all material that is not my own.

6. I understand that there is no acceptable excuse for committing plagiarism and that doing so is a violation of the Student Code of Conduct.

Signature of the Student	**Date**
	22/09/2024

Certified by Supervisor(s)

This is to certify that this project/thesis is based on the work of the above-mentioned student under my/our supervision. The thesis has been prepared according to the format stipulated and is of an acceptable standard.

	Supervisor 1	**Supervisor 2**	**Supervisor 3**
Name	Prof. G.K.A. Dias		
Signature			
Date	22/09/2024		

Abstract

Sri Lanka is a developing country which is facing the growing challenge of electronic waste disposal and management as many other countries worldwide. This project presents an innovative online system for managing electronic waste in Sri Lanka. The system's fundamental goal is to improve the sustainable handling of e-waste, from its initial generation to the recycling stage, with minimal environmental impact. It is tailored to meet the diverse requirements of stakeholders in e-waste management by offering specialized user interfaces.

The innovative system addresses the shortcomings of traditional e-waste management approaches, which often suffer from the absence of tracking systems, delayed reporting, and poor communication among stakeholders. Such inefficiencies hinder adherence to environmental regulations and pose challenges in keeping pace with the growing volume and complexity of e-waste, impacting both formal and informal sectors of e-waste management.

The system's notable functionality includes streamlined tracking and management of e-waste inventory in real-time. This enhances the efficiency of the entire e-waste supply chain. A critical component is the dynamic notification framework, which fosters effective communication among all parties. Additionally, the system is equipped with key reporting tools, delivering critical insights into e-waste-related activities. These tools are pivotal for regulatory adherence and for gaining a deeper understanding of e-waste generation trends. The platform also plays an essential role in raising public awareness about responsible e-waste management.

From a technological standpoint, the system integrates HTML, CSS, and JavaScript for the development of its front-end, ensuring structured interfaces, visually appealing layouts, and interactive elements. For back-end processes, PHP is utilized, providing robust integration with HTML, effective session management, and broad database compatibility. MySQL is employed as the database management system, proficiently handling all data pertinent to e-waste.

This project's data was gathered through various methodologies, including online surveys, interviews, and observational studies, merging user insights with quantitative performance data. This approach guarantees that the system complies with established standards and ensures its security, scalability, and efficiency.

Acknowledgements

Gratitude is first extended to Prof. G.K.A. Dias, the supervisor of this project. His dedication, guidance, and support were pivotal in its successful completion. His readiness to impart extensive knowledge in both theoretical and practical aspects significantly enhanced the work.

The lecturers and staff at the University of Colombo School of Computing (UCSC) are also appreciated. Their assistance and the supportive environment they have provided contributed to the successful completion of the individual project.

I have since expressed my sincere appreciation to my friends and family for their continued support and assistance throughout the project. They serve as great motivation and are an integral part of this journey.

Finally, acknowledgment is due to all who supported the completion of this final year project in various ways. The value of these contributions cannot be overstated and is deeply appreciated.

Table of Contents

Table of Figures

List of Tables

List of Acronyms

AI - Artificial Intelligence
CSS - Cascading Style Sheets
EWMS - Electronic Waste Management System
HTML - Hypertext Markup Language
IoT - Internet of Things
ML - Machine Learning
MVC - Model Viewer Controller
NGO - Non-Governmental Organizations
OOP - Object Oriented Programming
PHP - Hypertext Preprocessor
SDLC - Software Development Life Cycle
TDD - Test Driven Development
UI - User Interface
UML - Unified Modeling Language
UPM - Unified Process Model
WEEE - Waste Electrical and Electronic Equipment

Chapter 1 – Introduction

1.1. Project Overview

This project is centered on web-based electronic waste management, which is an evolving environmental issue that is currently gaining recognition worldwide. Electrical and electronic equipment are electronic or electrical equipment that have become unwanted, nonfunctional, or obsolete due to technological advancements or that have reached the end of their useful life called as E-waste or WEEE which stands for waste electrical and electronic equipment (Ranasinghe and Athapattu, 2020).

E-waste consists of discarded electronic devices and components, which present unique challenges due to their complex composition and potentially harmful components. Currently, there is a lack of sufficient e-waste management systems in Sri Lanka, which leads to environmental and health risks and the loss of valuable recoverable materials. The growth of economics and expanding of the country and manufacturing industry in recent years including the significant competition in the market which leads to the rapid develop of technologies to need of new electronic products of consumers in the market, worse in quality and shorter life for many electric appliances would be happened as electronic waste or e-waste (Shibly and Thelijjagoda, 2015).

Thus, this project proposes a web-based e-waste management platform to address this issue. The suggested system unites individual and organizational e-waste generators, collectors, recyclers, government regulatory agencies, and system administrators. Within this platform, functionalities such as user registration for all participants, listing of e-waste, bidding processes, scheduling of pickups, management of purchases, updates to inventory, communication channels, and the generation of reports will be simplified and automated.

There are some e-waste collecting and recycling platforms in the country, but no comprehensive web-based management system can serve all stakeholders. Therefore, this project's approach to Sri Lanka's e-waste management problem is innovative. This platform offers a unique option that could transform Sri Lankan e-waste management.

This project has used a solid methodology based on current software development to achieve its goals. It is built on reliable web technologies and incorporates user feedback throughout its development to ensure usability and effectiveness.

The potential value of this project is varied. This web-based platform streamlines e-waste collection, recycling, and compliance, including real-time tracking and managing e-waste inventory. This helps environmental sustainability, safeguards public health, recovers resources, and promotes regulatory enforcement.

An innovative web-based approach for sustainable development with zero or minimal environmental impact by electronic devices is the goal of this project.

1.2. Motivation

Rapid technical advancements, shorter device life cycles, and rising consumer demand for electronics have made e-waste one of the world's fastest-growing waste streams. This pattern shows the growth of digital technology but also an environmental issue. Therefore, the expanding worldwide and local e-waste management difficulties motivated the study.

With the rapid development of electronic industry, the continuous upgrading of electronic products lead to the elimination of more and more waste electronic products and electrical equipment around the world which would result in the formation of a large amount of electronic waste (Shibly and Thelijjagoda, 2015). However, the current situation is characterized by more e-waste accumulating in various locations, including households, due to incorrect e-waste disposal and informal recycling practices. These practices pose serious environmental risks and economic losses from the waste of valuable materials, as well as significant public health risks.

Therefore, this project's topic choice is driven by its substantial relevance and urgency in Sri Lanka's present scenario. This study has uncovered that organizations employ diverse strategies to reduce e-waste generation. Many organizations import high-quality products and materials to minimize e-waste. Most organizations opt for new product designs, green procurement policies and Reduce, Reuse, Recycle (3Rs) approach to reduce electronic waste generation (Mallawarachchi and Karunasena, 2012).

This project may affect countries beyond Sri Lanka, serving as a blueprint for other developing nations with e-waste management concerns. It aims to improve e-waste management methods and have a significant impact, potentially influencing global e-waste management strategies. Efforts are directed toward making e-waste management effortless, encouraging effective listing, collection, responsible recycling, and compliance with environmental regulations.

The study is motivated by the belief that technology may significantly contribute to tackling environmental concerns. Utilizing digital tools and platforms has the potential to convert

outdated and ineffective techniques into logical and enduring methods. The initiative demonstrates the capacity of digital technology to advance environmental sustainability.

The interest in this project arises from its comprehensive integration of environmental science, technology, and public policy to address a complex problem. By integrating these varied dimensions, the project emphasizes a thorough and diverse approach to e-waste management, making the endeavor both challenging and engaging.

1.3. Project Objectives

This project aims to develop an effective web-based e-waste management system to improve e-waste management practices. The system aims to streamline the process of e-waste listing, collection, recycling, activity monitoring, license tracking, and promoting sustainability and environmental protection.

To accomplish this primary aim, the study has established the following specific objectives:

1. **Real-Time E-Waste Tracking and Inventory Management:** The project aims to develop an advanced tracking system that maintains accurate inventory records, enabling effective resource management throughout the e-waste management lifecycle.
2. **Compliance with Environmental Regulations:** This aims to assist governmental bodies in effectively monitoring compliance with environmental regulations. The system will verify collector and recycler licenses and oversee initial activities to ensure adherence to standards.
3. **Comprehensive Reporting System:** The introduction of a reporting mechanism is planned, which will generate crucial insights into e-waste management activities. This is intended to support regulatory bodies in their environmental governance roles.
4. **Enhanced Stakeholder Communication:** The project plans to enhance communication among all e-waste management stakeholders through integrated communication tools and real-time notifications, significantly improving information flow.
5. **Circular Economy Promotion:** By supporting the reuse and recycling of e-waste, the system aims to foster sustainable disposal practices and the recovery of valuable materials, contributing to both environmental sustainability and economic benefits.

6. **Public Awareness on Sustainable E-Waste Management:** A key objective is to increase public awareness regarding proper e-waste handling and sustainability practices through the platform, furthering the project's commitment to environmental education.
7. **Development of an Accessible Interface:** The creation of a user-friendly interface is targeted to accommodate a diverse range of users, ensuring the system is accessible, inclusive, and efficient for all parties involved in e-waste management.

These objectives are addressed throughout the project's phases, from conceptual design to the system's final implementation, aiming to present a robust solution for e-waste management in Sri Lanka.

1.4. Background of the Study

The emergence of electronic devices and the exponential increase in their use have resulted in an unprecedented amount of e-waste. This exponential increase in e-waste has made the management of e-waste a critical global concern. E-waste contains valuable compositions that have economic value when it recycled correctly. Unfortunately, Sri Lanka has not improved in e-waste recycle and e- waste management. (Panduwawala and Samarakoon, 2020).

In Sri Lanka, the management of e-waste is a significant challenge. Despite having several companies and initiatives in place for e-waste management, such as Green Links Lanka (2016), Ceylon Waste Management (2010), and Cleantech (2003), the overall practices of e-waste management remain fragmented and inefficient. Alahakoon and Gunarathne (2022) discussed the current status and challenges of e-waste management in Sri Lanka, indicating a need for a more coordinated approach.

Several studies, such as those by Mallawarachchi and Karunasena (2012), Panduwawala and Samarakoon (2020), and Ranasinghe and Athapattu (2020), have assessed the situation of e-waste management in Sri Lanka and highlighted the issues associated with it. They all emphasize the need for efficient e-waste management practices incorporating technological solutions.

Recently, there has been a trend toward utilizing online platforms for e-waste management. A study by Gomathy (2022) suggested the potential of online platforms in e-waste management. However, there is limited work on developing a comprehensive online e-waste management system specifically tailored to Sri Lanka's context.

This project applies in the area of e-waste management, specifically within the framework of using online platforms to facilitate this process. Based on previous studies and current methods, this project suggests a more integrated and effective approach. This project fills the gap for a user-friendly, efficient, and comprehensive web-based system to handle e-waste in Sri Lanka. The project becomes interesting and relevant due to the increasing importance of proper e-waste management and the potential of technological solutions to address this issue.

1.5. Scope of the Study

The study's primary objective is to design, develop, and evaluate a robust web-based e-waste management system for Sri Lanka. This system aims to implement digital solutions that will improve the efficiency of the country's e-waste management operations, support environmental sustainability, and assure compliance with regulations.

Stakeholders and their responsibilities: This system considers many parties involved in the life cycle of e-waste management, including e-waste generators (including individuals and organizations), e-waste collectors, e-waste recyclers, and government regulatory agencies. Every stakeholder possesses a distinct function and responsibility in the efficient and effective management of e-waste.

Project modules and functions: The e-waste management system is designed to provide multiple modules, each supporting certain functions linked to e-waste management. The modules include user management, e-waste listing management, e-waste collection management, e-waste purchasing management, inventory management, e-waste recycling management, reporting and regulatory compliance, communications, and system administration. Every module has a specific purpose and allows for implementing operations related to e-waste management.

System design and implementation: The web-based platform design is intended to facilitate accessibility via any internet-enabled device. It is expected that a client-server architecture will be implemented, along with the use of a Model-View-Controller (MVC) design pattern. The development process is expected to be conducted iteratively, enabling ongoing improvement and adjustment.

System user interface: the user interface of the system has been designed to prioritize accessibility and usability for all users with different technical levels. It optimizes functionality and speeds up access to all features.

Evaluation approach: The system's effectiveness will be assessed using user testing and data analytics. Stakeholder feedback will be analyzed to see how the system contributes to e-waste management.

In-Scope elements

Geographic Focus: The initiative targets the e-waste management difficulties in Sri Lanka precisely by providing solutions customized to the country's unique circumstances.

Processes: Integration of diverse e-waste management procedures, including e-waste listing, collection, inventory control, recycling, report production, and compliance monitoring, while adhering to regulatory compliance standards in Sri Lanka.

Out-of-Scope elements

Physical Handling: The platform does not cover physical e-waste handling activities, including collection, transportation, and recycling.

Beyond Local Scope: While the system is designed for stakeholders within Sri Lanka, it does not cater to users outside this geographic area.

Assumptions and Constraints:

The project assumes reliable internet access for users and anticipates stakeholders' willingness to adopt the online management system. It acknowledges Sri Lanka's unique context, suggesting any adaptation for other regions would require modifications beyond this study's scope.

Future Development Potential

While focused on Sri Lanka, the project recognizes the potential for adapting its approach to other geographical and regulatory environments. This opens paths for future refinement and system modifications to suit different contexts.

1.6. Structure of the Dissertation

This dissertation unfolds six chapters, each outlining specific parts of a web-based e-waste management system project. These chapters help in understanding the primary goal of the project.

Chapter 1: Introduction

The introductory chapter provides an overview of the project, including the problem statement, objectives, and significance of the study. It also outlines the scope and limitations of the project.

Chapter 2: Background

The second chapter involves a thorough examination of existing literature related to e-waste management systems. This analysis includes studies on various methodologies, systems in place, potential improvements, and gaps in the field. It provides the theoretical and conceptual background necessary for this project.

Chapter 3: Design

System design proposes and evaluates a system's architectural design, technologies used, and development methodologies. The architectural design is visually explained using Unified Modeling Language (UML) diagrams. Static and dynamic views of the design and the layout of the user interface are incorporated. It is critical to reference all figures and tables appropriately.

Chapter 4: Implementation

The Implementation section discusses in detail about implementation methodologies and technologies used. It discusses the organization of the code and modules, the environment for implementation, the reusability of code, and the tools used for development.

Chapter 5: Testing and evaluation

The fifth chapter deals with the evaluation of the system. It discusses strategies for testing and provides examples of test plans and their results. Descriptions of the execution of testing and validation tasks are included, alongside evidence of a diverse range of test data.

Chapter 6: Conclusion and future work

The last chapter concludes the project. The conclusion offers a summary of the problem, the accomplishments, and prospects for future work. It refers to the challenges faced and the solutions created, elaborates on how the project's original objectives were fulfilled, and proposes potential work for the future.

Chapter 2 – Background

2.1. Introduction

Sri Lanka has few web-based e-waste management systems. This chapter examines existing e-waste management systems' structure, processes, and stakeholders. Comprehensive literature evaluation and analysis have set the groundwork for this web-based e-waste management system to improve sustainable management.

Figure 2.1 shows the top-level use case diagram of the proposed system, illustrating stakeholder roles and e-waste management platform flow. The complex interactions from e-waste generation to recycling are simplified in this figure, helping identify system strengths and flaws. The Appendix has more detailed pictures to keep the chapter simple and readable.

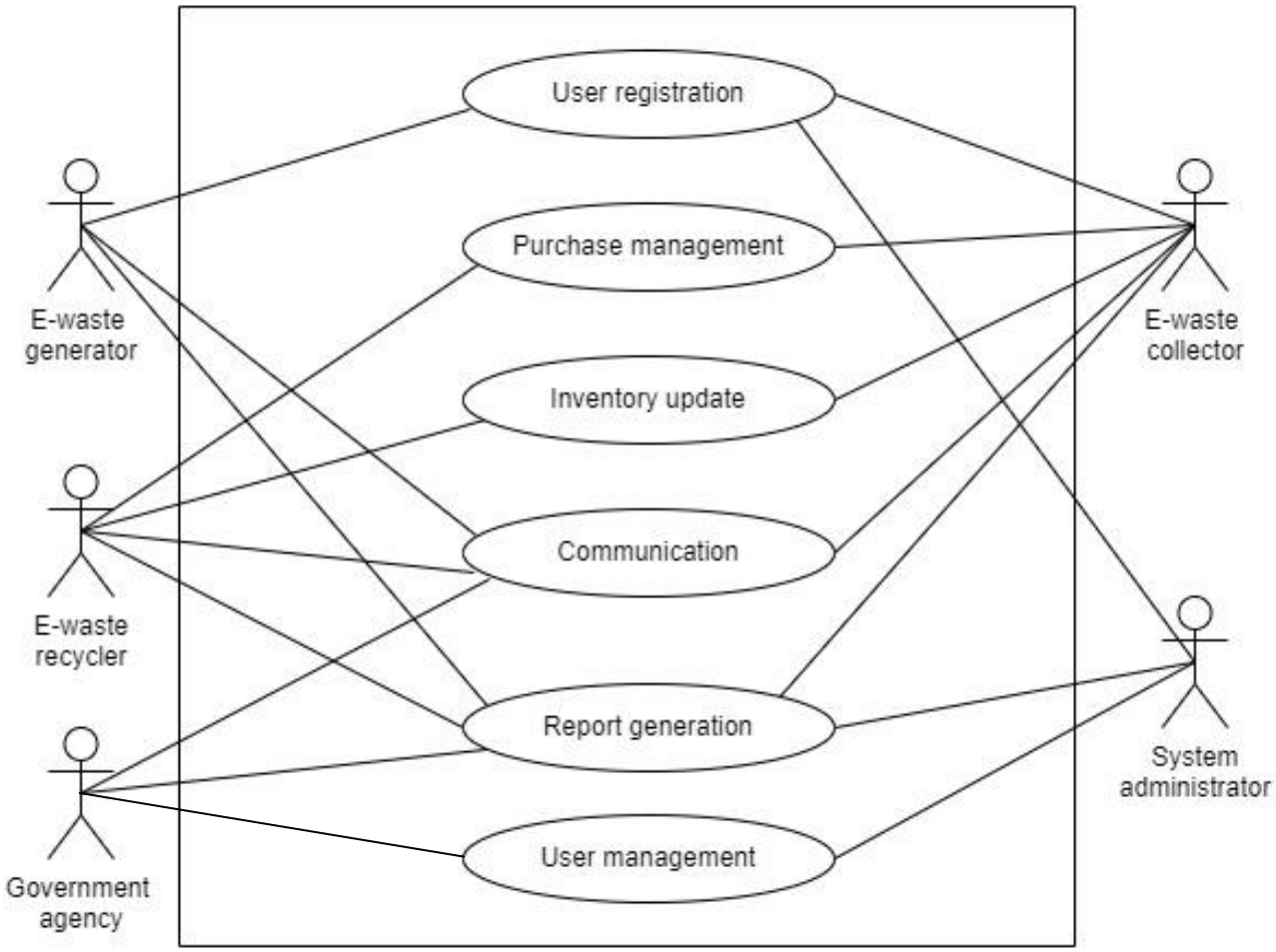


Figure 2.1: Top level use case diagram of the existing system

2.2. Requirement Analysis

A requirements analysis was conducted for this project, focusing on the system requirements and ensuring that the developed solution is robust, efficient and user-friendly. Interviews, surveys, document analysis and observation were used to collect data from various stakeholders in the e-waste management process.

Stakeholder Identification: Key stakeholders in this system are e-waste generators, collectors, recyclers, and government regulatory agencies.

Data Gathering: In-person and online interactions were used to gather data. This method showed current e-waste management approaches and their drawbacks.

The requirement analysis ensured that both the development and the design of the e-waste management system would align with the needs and expectations of stakeholders, establishing a solid basis for the project's success.

2.2.1. Functional Requirements

To transform the project's objectives into actionable functionalities, the development of the e-waste management system adheres to specific functional requirements:

User Registration and Authentication:

The platform provides secure registration and authentication for users, including e-waste generators, collectors, recyclers, and government regulatory agencies, with tailored access and dashboards.

E-Waste Listing, Collection, and Recycling:

Users can efficiently list e-waste for pickup, engage in a bidding and request process, and schedule pickups, fostering a transparent and competitive e-waste management marketplace.

Inventory Management and Updates:

Collectors and recyclers have access to tools for managing and updating e-waste inventories, enhancing operational accuracy and efficiency.

Activity Monitoring:

Innovative tools provide governmental regulatory agencies the ability to conduct thorough oversight of e-waste management practices.

User Interaction and Feedback:

The system integrates interaction and feedback mechanisms to promote continuous improvement and user satisfaction.

Notifications and Communication:

The system's comprehensive notifications and communication feature ensures all stakeholders are kept up-to-date with real-time alerts and essential information, promoting effective collaboration and streamlined e-waste management.

2.2.2. Non - Functional Requirements

The primary non-functional requirements for the web-based e-waste management system have been identified as follows:

Usability: Ensuring an intuitive and user-friendly interface.

Performance: High responsiveness and consistent performance.

Security: Protecting data confidentiality and integrity.

Scalability: Ability to handle increasing workloads.

Availability: Consistent accessibility, barring maintenance periods.

This comprehensive approach aims to make the e-waste management system reliable, secure, and efficient, promoting enhanced e-waste management practices in Sri Lanka.

2.3. Review of Similar Systems

Everyday new electronic devices and gadgets are introduced to the market due to rapid technological developments. Consequently, consumers tend to discard their old equipment that contains valuable materials, even though they are in good working condition. (Gunarathne, 2015) In Sri Lanka, there is a lack of a functioning management system for e-waste. Therefore, a detailed analysis was conducted on similar existing systems to develop the proposed web-based e-waste management solution.

The proposed web-based e-waste management system was compared against Green Links Lanka, Ceylon Waste Management, Cleantech, and eWaste Recycle. Key elements of these systems were analyzed to determine how to improve or differentiate the proposed system. Table 2.1 compares these similar systems.

Table 2.1: Comparative analysis of similar systems

Feature	**Proposed System**	**Ceylon Waste Management**	**eWaste Recycle**	**Cleantech**	**Green Links Lanka**
Web-based	Yes	Yes	Yes	No	Yes
User friendly Interface	Yes	Yes	Yes	No	Yes
Tracking e-waste	Yes	Yes	Yes	No	No
Customizable reporting	Yes	Yes	Yes	No	No
Secure data management	Yes	Yes	Yes	No	Yes
Integration with existing systems	Yes	No	No	No	No
Web address		https://www.ewaste.lk/	https://ewasterecycle.co.uk/	https://cleantech.lk/ewastemanagement-sri-lanka/	https://www.greenlink.lk/

The web-based system, Green Links Lanka (Green Links Lanka, 2016), is primarily designed for the gathering of e-waste. On the other hand, the web-based system, Ceylon Waste Management (Ceylon Waste Management, 2010), is developed for the tracking of e-waste and ensuring the secure management of data. Though it has a user-friendly design and offers features such as e-waste tracking, safe data management, and configurable reporting, it cannot interact with existing systems.

The eWaste Recycle (e-waste recycle, 2015) was established in the UK, and this website is also designed for the gathering of e-waste. This is recognized for its user-friendly interface, collection and processing of unwanted and decommissioned IT equipment and secure handling of all data-bearing equipment. Nevertheless, it lacks the capability to integrate with existing systems.

Cleantech (Cleantech, 2003), serves as an e-waste collection entity in Sri Lanka, yet it operates without an online management system. Its operations limit to gathering e-waste at designated locations, lacking mechanisms for monitoring or generating customized reports.

The introduced e-waste management system aims to surpass these limitations by offering a web-based solution that ensures user-friendliness. Features include tracking of e-waste, production of tailored reports, secure data handling, and compatibility with existing systems, catering to the diverse needs of stakeholders in e-waste management. While existing systems demonstrate robustness, they present room for enhancement and innovation. The suggested system promises to elevate e-waste management practices by addressing current strengths and weaknesses, aiming to boost efficiency and sustainability in Sri Lanka's e-waste management.

2.4. Related Technologies

Various technologies were utilized when developing this system; each technology has contributed to different parts of the project.

HTML, CSS, and JavaScript: The system employed HTML, CSS and JavaScript for front-end development. HTML was utilized as a foundation to structure web pages, CSS was applied to enhance the display and layout of the web page, and JavaScript was integrated to provide form validation and dynamic content.

PHP: PHP handles sessions, connects with HTML, and works with multiple databases. This server-side component handles form processing, user authentication, and database interactions.

MySQL: MYSQL has handled all the data related to this e-waste management system. This includes user information, e-waste listing and purchasing details, and scheduling. The efficiency of data handling is ensured by the compatibility with PHP, dependability, and robustness.

The technology stack can be expanded to include specific libraries or frameworks to address increasing requirements and difficulties. This approach guarantees the flexibility to adjust and

expand, which is crucial for managing dynamic e-waste management requirements in Sri Lanka.

These technologies mentioned above were chosen for their unique characteristics and collaborative efficiency, producing a convenient, safe, and efficient online platform. This decision supports the project's goal of improving e-waste management by providing stakeholders with a user-friendly, responsive, and accessible digital solution.

2.5. Development Process Model Selection

For the development of the e-waste management system, a Software Development Life Cycle (SDLC) model, known as the Iterative Development methodology, is chosen. It is based on the models' fundamental benefits, which align with the specific requirements and limitations of the project.

Iterative Development Methodology

The Iterative Development process divides this e-waste system into smaller, manageable modules. Each module represents a complete and functional element of the software, progressing through every stage of the development life cycle, including planning, designing, implementation, testing, and deployment. This cycle is repetitive, and each iteration releases an improved iteration of the system, integrating the capabilities and features of the previous versions while introducing new capabilities and features.

Why choose the Iterative Development Methodology for EWMS?

The reasons for choosing the Iterative Development methodology for this project are shown below.

Step-by-Step Development: Iterative development helped to develop the system gradually, based on well-defined requirements and timely delivery of functional components.

Continuous Value Delivery: This technique ensures a continuous flow of value, allowing stakeholders to observe and derive benefits from the incremental growth of the system.

Feedback Loop: This feedback loop guarantees that feedback is included in every iteration to address emerging needs and requirements. Therefore, an effective collaboration between the developer and stakeholders is promoted by this.

Flexibility and Adaptability: This methodology helped to reduce risks in the early stages of development. This offers flexibility and adaptability to effectively address emerging requirements.

Faster Time-to-Market: This approach facilitates a quicker route to market, as operational functionalities can be introduced and assessed earlier.

Scalability and Extensibility: Future growth and customization facilitated by the incremental approach of the development process.

User-Centric Design: These factors merge to create a design strategy that genuinely focuses on the user, which is crucial for the system's effective functioning.

Iterative Development is the most appropriate solution due to the project's complexity, team dynamics, timeframe, and need for constant value delivery and feedback integration. It makes the system flexible and adaptable to Sri Lanka's evolving e-waste management requirements.

Chapter 3 – Design Architecture

3.1. Introduction

This chapter addresses the design strategies and system architecture of the e-waste management system and user interfaces. UML (Unified Modelling Language) diagrams have been used to visually represent the design of this system.

An iterative development methodology had been utilized in this project for progressive development, value addition, adaptability, risk reduction, rapid market time, scalability and extensibility. Through this, the project intends to develop a comprehensive, user-friendly web-based e-waste management system that streamlines e-waste management and promotes environmental protection.

3.1.1. Design Aspects:

Design Strategies, System Architecture, UML diagrams, and User Interface Design are briefly mentioned below:

1. **Design Strategies**

   User interfaces, e-waste scheduling and data were optimized through targeted approaches to improve and safeguard them. The requirements of stakeholders, including e-waste generators, collectors and recyclers, were addressed by these design strategies, ensuring a safe and effective user experience.

2. **System Architecture:**

   This system architecture design accommodated the complexity of this system and offered flexible adaptations for future modifications. Model-View-Controller (MVC) pattern and client-server model were merged in this system architecture.

3. **UML Diagrams:**

   The Unified Model Language (UML) diagrams, such as use case diagrams, class diagrams, sequence diagrams, and ER diagrams, have been utilized to illustrate and graphically represent the flow of the system and to specify software systems components.

4. **User Interface Design:**

   In this e-waste management system, User Interfaces (UI) were carefully designed to prioritize User friendliness. Therefore, users with different technological levels could access and navigate the system effortlessly. This will reduce the complexity of the system with its diverse functionalities, such as e-waste listing, e-waste bidding, etc.

3.2. Related Design Strategies

Customized layouts were employed to build the web-based e-waste management system. The following techniques focused on user experiences, seamless functionality, scalability and adaptability. These concepts were impacted by Sri Lankan e-waste management requirements.

1. **Modular Design Strategy:**

The system's modular architecture followed iterative development. This MVC pattern enables modularity, and it ensures autonomous functionality and seamless integration. Each module, from user registration to e-waste listing, bidding, and purchasing, may work independently and together using the Model-View-Controller (MVC) pattern.

2. **User-Centered Design Strategy:**

This user-centered design strategy supports the project goal of facilitating e-waste generators, collectors, and recyclers to manage e-waste in a sustainable manner. It prioritizes end users in this design. These user interfaces, navigation, and customer support systems exhibit in this strategy is specific to Sri Lanka.

3. **Scalability Strategy:**

The design adjusted with user and service expansion. Foresight guarantees system functioning as new features are implemented.

4. **Adaptability and Flexibility Strategy:**

Adaptability and flexibility of the system design enable continuous value delivery and adaptation to evolving requirements. The iterative approach utilized in the system allows progressive system enhancements and flexible library or framework implementation.

5. **Security and Compliance Strategy:**

The design strategy prioritized data security by emphasizing the confidentiality, integrity, and availability of user data. Moreover, ensuring that the system adheres to local e-waste management legislation and standards was a crucial element of the design.

Comparison with other strategies: Due to its flexibility and ease of maintenance, modular and user-centric architecture was chosen instead of monolithic architecture. Sri Lanka's dynamic e-waste management makes this technique suitable.

Alignment with industry standards: The selected system design strategies align with internationally recognized best practices while the security and compliance adhere to industry standards and local regulations for managing e-waste. The emphasis on scalability and adaptability guarantees the system's durability and applicability in the ever-changing technological environment.

3.3. System Architecture

In system design, its architecture is important and influences performance, scalability and maintenance (Bass et al., 2013). Client-server models and model view control (MVC) patterns have been adopted in accordance with recommendations for methods and technologies.

Figure 3.1 illustrates the system architecture. Although a monolithic architecture is praised for its capacity to scale, we have decided to opt for a client-server approach for our current project. This decision is based on our specific requirements and the desire for a simpler management of the e-waste system.

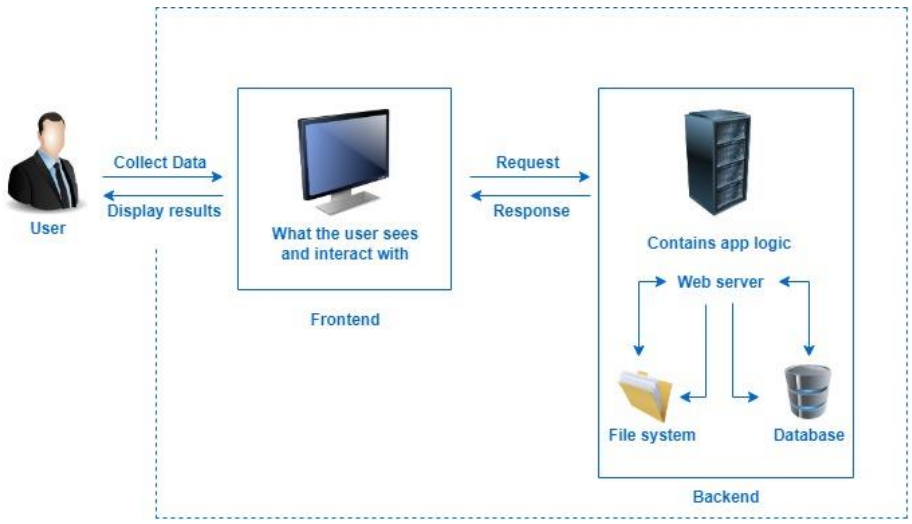


Figure 3.1: System architecture of proposed system

1. **Client-Server Model**

This system is a client-server. Back-end servers efficiently process requests, resources, and databases for user registration, e-waste listing, and financial transactions. On the front end, clients present data and accept inputs. This division simplifies updates without impacting the other end.

2. **Model-View-Controller (MVC) Pattern**

The system design uses MVC patterns and segmented it into three interconnected components: models (data), views (user interfaces) and controllers (system logic). This department simplifies complex application management and facilitates maintenance and adaptation to evolving requirements (Bass et al., 2013).

3. **Scalability and Flexibility**

The web-based deployment strategy was adopted for ease of use, accessibility, and minimal hardware requirements. Technology selection, including the capability of incorporating specific libraries and frameworks, ensures system adaptability and readiness for future demands.

4. **User-Centric Design**

The system architecture emphasizes user-centered design approaches. This strategy prioritizes the development of a user-friendly and interactive interface so that users can navigate the system easily regardless of their technical abilities (Norman, 2013).

3.4. UML Diagrams

Unified Modelling Language (UML) diagrams are functioning as blueprints of the system. They facilitate clear communication between the developer and stakeholders regarding the design of the system, in return it helps to improve systems' planning and execution. These UML diagrams explain the structure, behavior, and interaction of systems' objects. When providing a visual illustration of the system design, Unified Modelling Language (UML) diagrams are vital. For the web-based electronic waste management system, UML diagrams have been used to visually explain the design of the system, thus improving clarity and coherence throughout the development journey (Dennis et al., 2021).

1. Use Case Diagrams

Figure 3.2 displays a use case diagram detailing the interaction between users and the system. They showcase the various methods users can use to engage with the system by documenting primary and alternative processes. This guarantees that all potential user behaviours and system responses are considered throughout the design phase, resulting in a more comprehensive system.

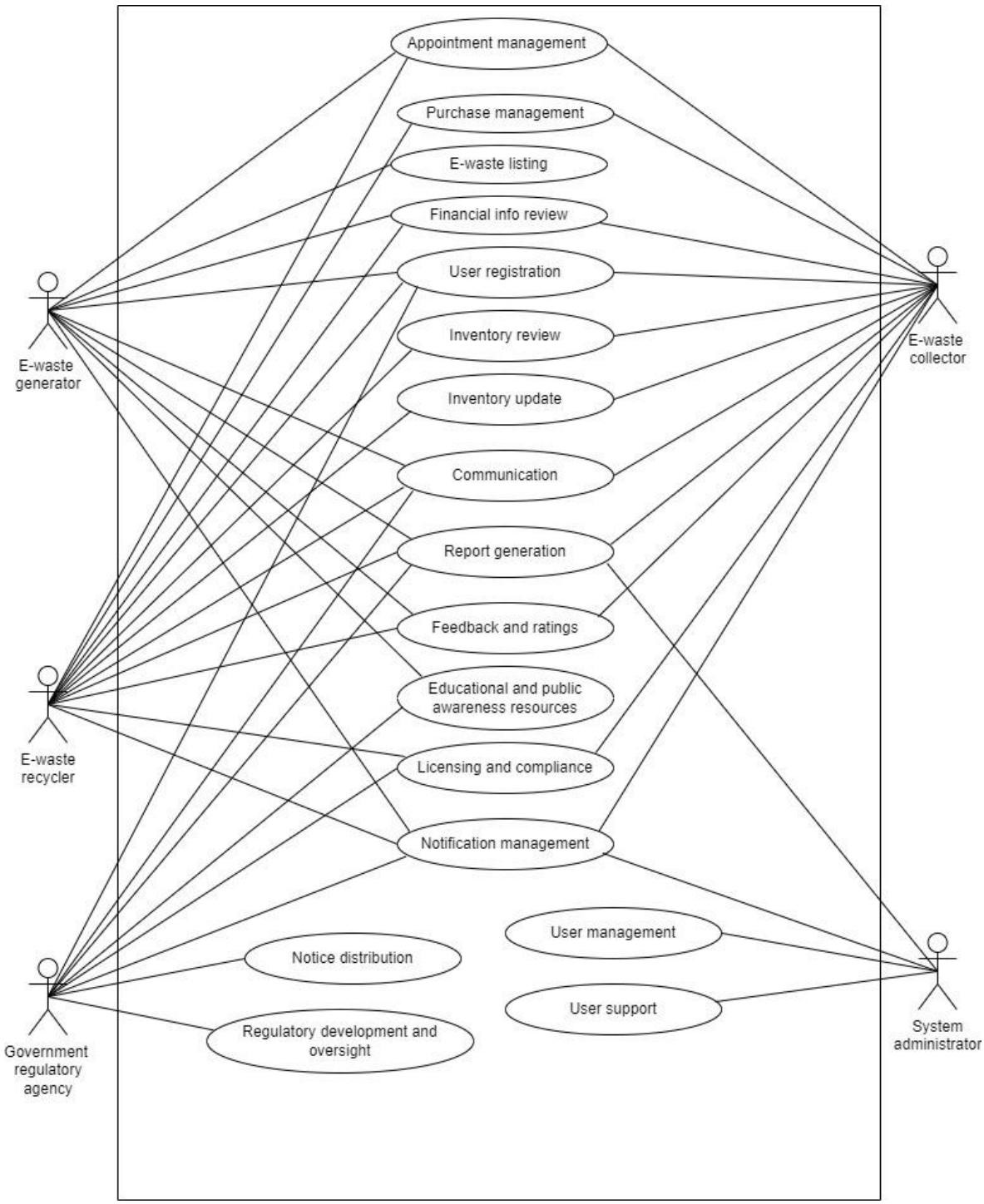


Figure 3.2: Use-case diagram for proposed system

Use-case Narratives:

The use case narratives deepen the scenarios described in the use case diagrams. The Narratives provide detailed descriptions of each interaction, including user steps, system reactions, and possible alternatives or exceptions. This detailed level helps developers understand the exact requirements and expectations of each function. The following Table 3.1 presents a comprehensive narrative for the user registration process, encompassing all relevant scenarios to ensure a complete understanding of the system's behavior.

Table 3.1 Use-case narrative for user registration

Use-Case Number	UC-01
Use-Case Name	User Registration
Priority	High
Actor/s	E-waste Generator, E-waste Collector, E-waste Recycler, Government Agency (Government Regulatory Agency)
Description	Allows different actors to enroll in the system by providing relevant details, ensuring unique and secure profiles.
Pre-condition	The actor has not yet registered in the system. Internet access is available.
Post-condition	The actor has a unique and secure profile within the system.
Basic Course of Action	**User Action**
	1. Selects "Register" on the platform. 2. Enters relevant personal or business details. 3. Provides required credentials. 4. Reviews and confirms details. 5. Clicks "Submit."
	System Response
	1. Presents registration form. 2. Validates entered details. 3. Checks for uniqueness of profile. 4. Confirms registration. 5. Sends confirmation email/notification.

Alternate Course of Action	If details are incorrect or incomplete: 1. The system highlights fields that need correction. 2. The user modifies the details and resubmits. If the profile is not unique: 1. The system informs the user that the profile already exists. 2. The user may choose to log in or reset the password.

Table 3.2 provides a detailed use-case narrative for the inventory update process managed by an e-waste recycler. It outlines the steps involved in adding or modifying e-waste items to ensure that the system's inventory is up-to-date, including pre-conditions, post-conditions, and both the primary and alternate courses of action. This narrative highlights the importance of accurate inventory management in the e-waste recycling process.

Table 3.2 Use-case narrative for inventory update of e-waste recycler

Use-Case Number	UC-20
Use-Case Name	Inventory update
Priority	High
Actor/s	E-waste recycler
Description	Enables the e-waste recycler to add or modify e-waste items post-recycling, ensuring that the system's inventory reflects the most current status of materials processed.
Pre-condition	E-waste recycler is logged into the system, has an active profile, and has access to the inventory module.
Post-condition	The inventory within the system is updated to align with the e-waste recycler's actual post-recycling inventory.

Basic course of Action	**User Action**
	1. E-waste recycler accesses the inventory module. 2. E-waste recycler selects an action (add or modify). 3. E-waste recycler inputs the details of the e-waste item(s). 4. E-waste recycler confirms the update. 5. E-waste recycler reviews the updated inventory.
	System Response
	1. System displays the inventory interface. 2. System provides options for add or modify. 3. System displays the necessary forms for the selected action. 4. System updates the inventory as per the e-waste recycler's request. 5. System shows the updated inventory to the e-waste recycler.
Alternate Course of Action	Input Error: 1. System alerts the e-waste recycler about incorrect input. 2. E-waste recycler corrects the input and resubmits. Item Not Found (for modify or remove): 1. System shows an error message. 2. E-waste recycler may choose another item or contact support.

2. Sequence Diagrams:

The sequence diagrams represent interactions between classes and objects in a time-order sequence. These diagrams are valuable for decrypting processes within the system, ensures that all interactions occur in the correct order and identifying potential bottlenecks or problems at the beginning of the design phase. Sequence diagram of the user registration for the system was illustrated in Figure 3.3, which will be the entry point for the system for all the users.

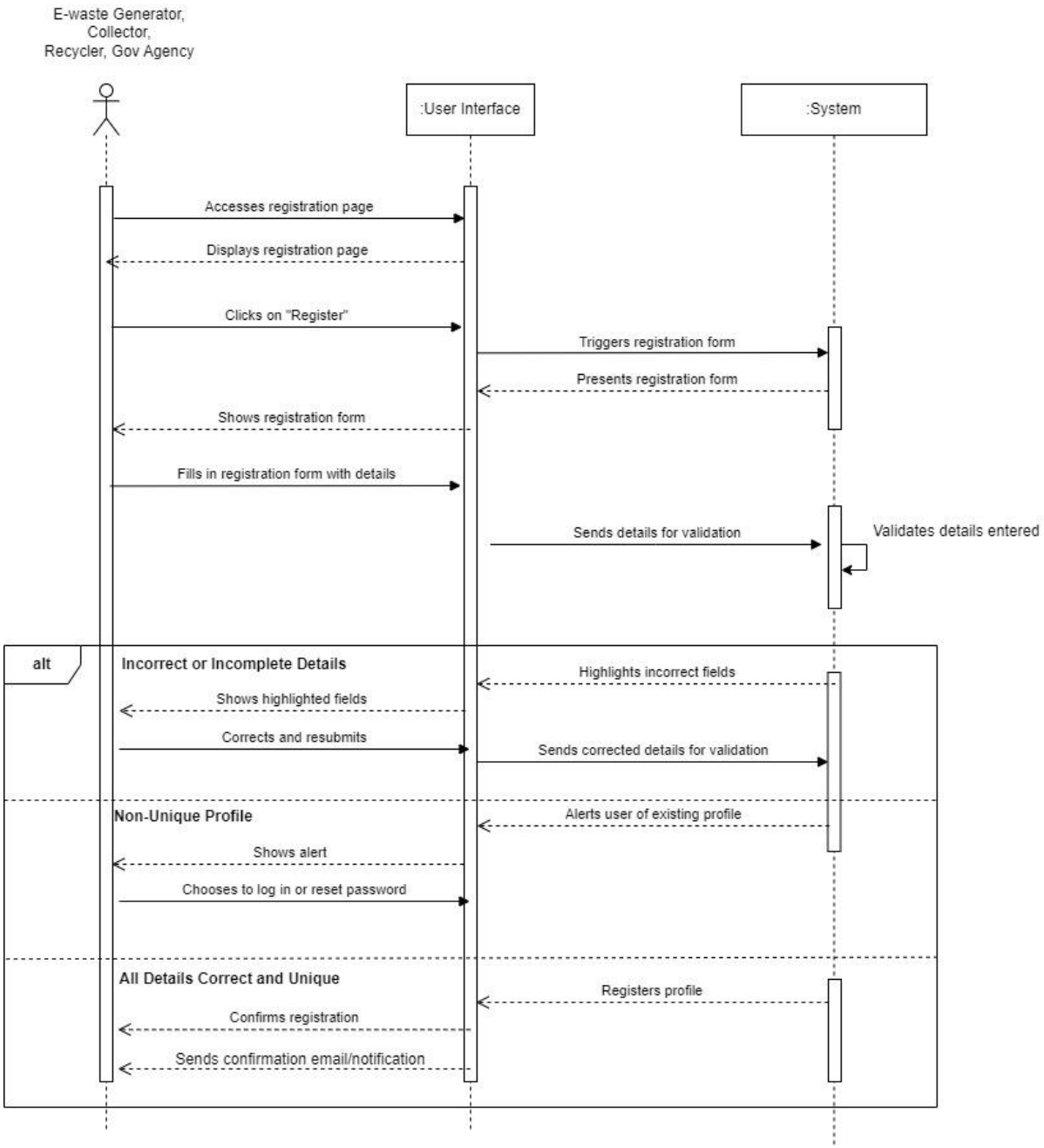


Figure 3.3: Sequence diagram for user registration

One of the main functions in the proposed system are shown in the Figure 3.4 shows the sequence diagram for the inventory update of the recycler. Sequence models are dynamic models that describe, for each mode of interaction, the sequence of object interactions that take place. When documenting a design, you should produce a sequence model for each significant interaction (Sommerville, 2011).

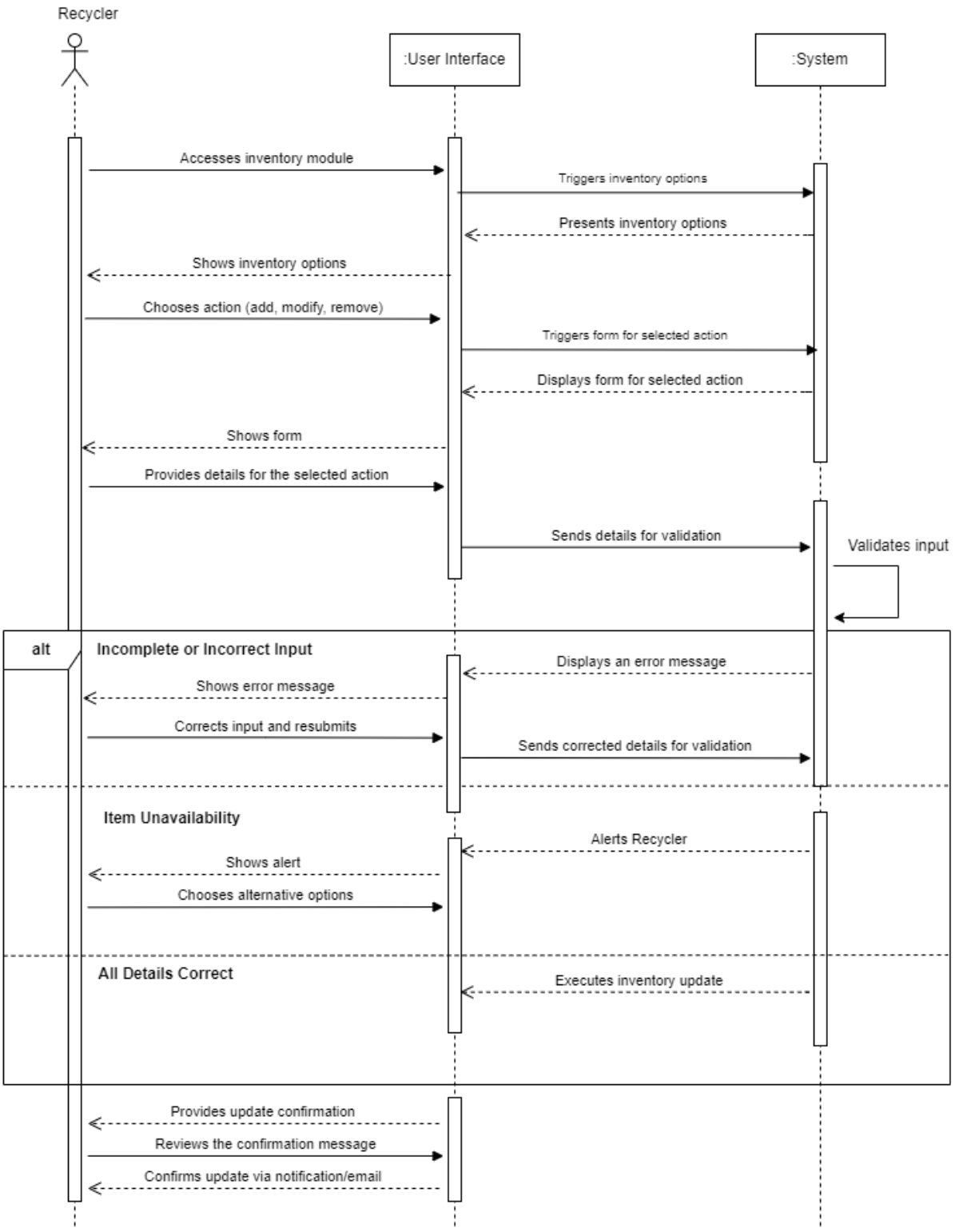


Figure 3.4: Sequence diagram for inventory update of e-waste recycler

3. Class Diagrams

Class diagrams were essential to the project's UML representation. These diagrams illustrate the system's static classes, attributes, operations, and complex object network. This diagram allows developers to understand how the systems' components interact with the data flows. This concept is graphically illustrated in the following class diagram. (Figure 3.5).

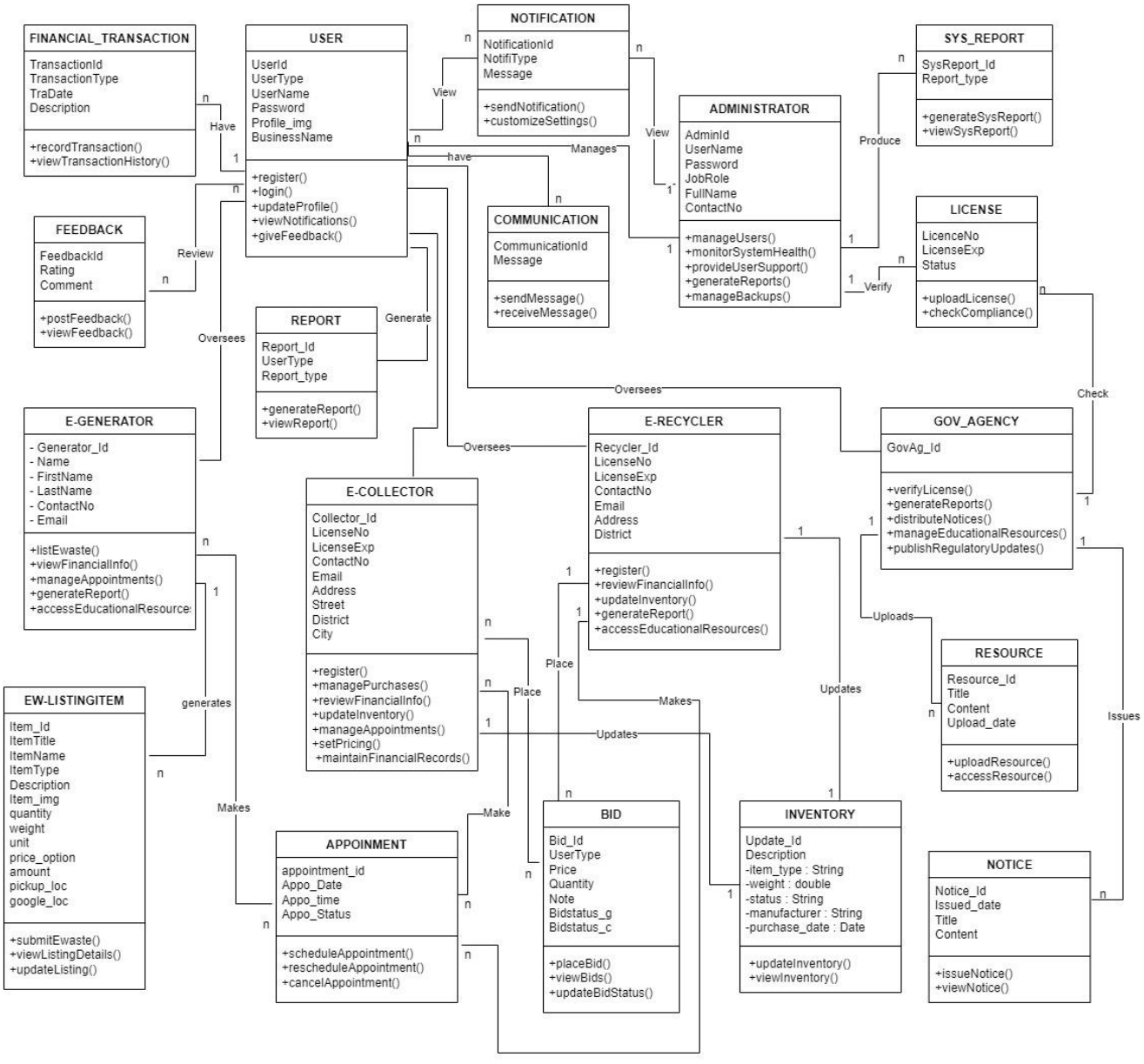


Figure 3.5: Class diagram for the proposed system

For e-waste management design, UML diagrams, such as use case, sequence, and class diagrams, are crucial. These diagrams illustrate system design, behaviour and interaction with them. This visual guide maintained the project aligned with aims and objectives, stakeholders and modules. As a result, a user-centric web-based platform was developed that effectively manages e-waste in an environmentally beneficial manner.

3.5. User Interface Design

The web-based e-waste management system's User Interface (UI) has been designed to emphasize simplicity and user-centeredness, essential for an effective and intuitive user experience. Exploring the main features of UI design:

1. **User-Friendly Navigation:** Navigation is designed to be simple and intuitive. (Cooper et al., 2014) The system allows users to navigate effortlessly, providing access to features starting from user registration, e-waste listings, e-waste bidding, scheduling of pickups, and user profile management. This simplicity serves individuals from various backgrounds, even those with limited knowledge of technology.
2. **Responsive Design:** The designed UI of this system is responsive to different devices such as desktops, tablets, and smartphones. It provides a consistent and uncluttered experience. This adaptability is crucial for user engagement and accessibility.
3. **User-Centric Approach:** This design is based on a user-centric approach. It is evident that accessing and maintaining e-waste listings, analyzing payment transactions and communicating among users on the platform is effortless.
4. **Consistent Visual Appearance:** All user interfaces share a visually appealing design with a consistent colour palette and layout. The consistency of the design not only adds to its visual appeal but also helps users easily navigate and orient themselves within the system.
5. **Future Development Considerations:** This flexible and adaptable design is based on an upcoming perspective. It lays a foundation for potential improvements, ensuring compatibility with evolving user preferences and technological advancements.

The UI design of the home page of the e-waste management system is shown in Figure 3.6, and Figure 3.7 displays a new user registration form for an e-waste collector. A prototype of the user interface was created for preliminary user testing. Furthermore, other user interfaces are included in the appendix to maintain the chapter's simplicity and readability.

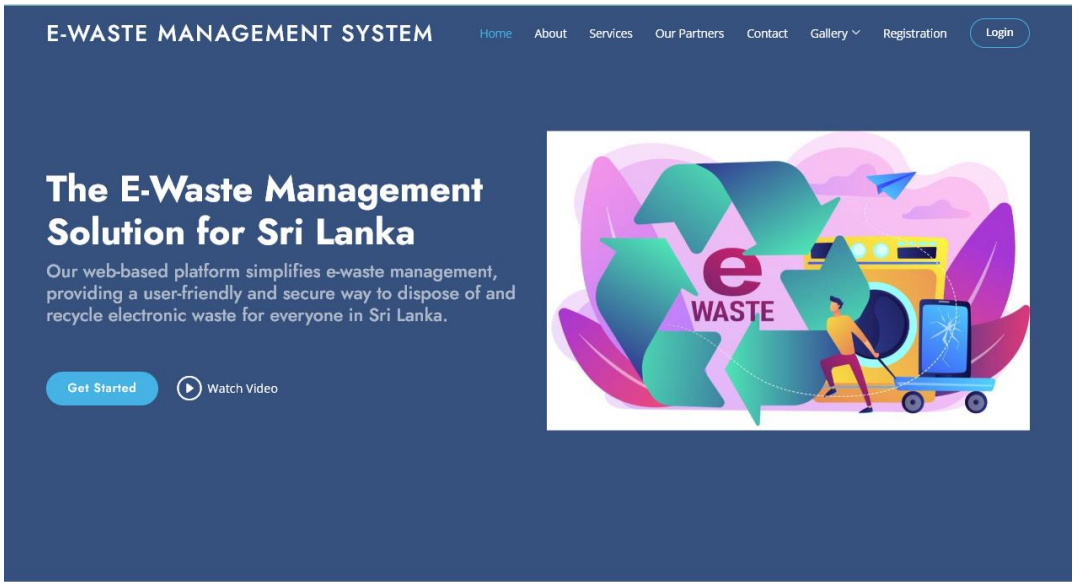


Figure 3.6: UI design of home page of the e-waste management system

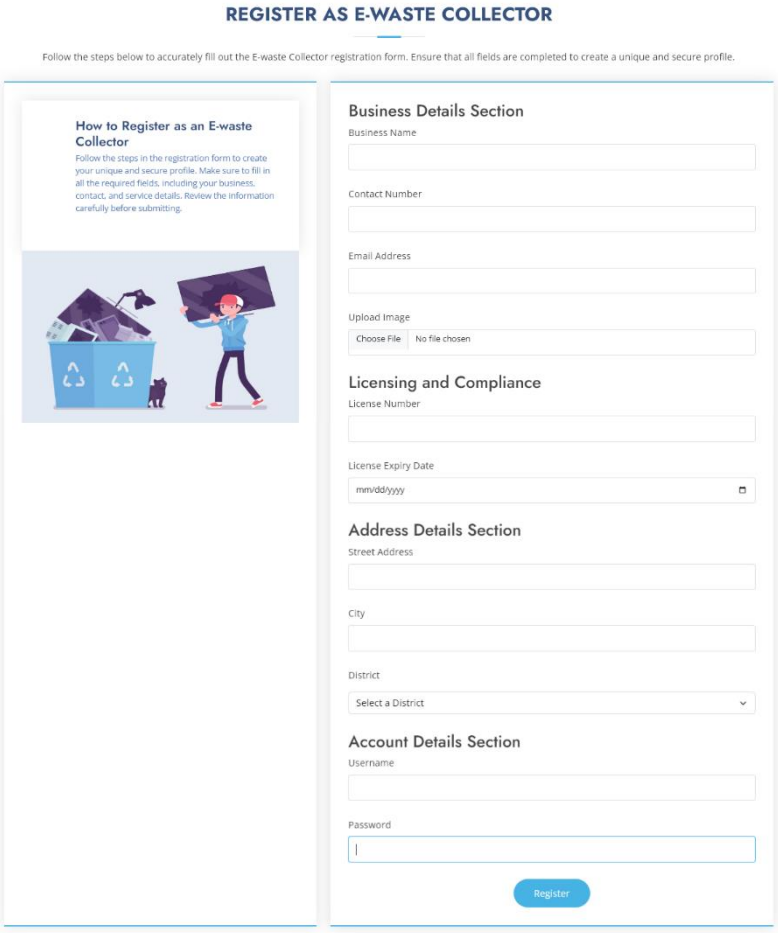


Figure 3.7: New user registration form of an e-waste collector

Chapter 4 - Implementation

4.1. Introduction

This chapter describes the implementation of the web-based e-waste management system, from fundamental requirements to detailed architecture. It includes hardware, software, code fragments, and configuration settings. The focus is on:

Comprehensive understanding: presenting a clear picture of the project's scale, capabilities, and social impact.

Challenges and strategies: highlighting development challenges and the adopted strategies to overcome them, providing insights for future projects.

4.2. Implementation Methodology

The project utilizes Object-Oriented Programming (OOP) and the Model-View-Controller (MVC) design pattern to manage complicated systems.

Object-Oriented Programming (OOP): Through this paradigm, modularity and maintainability are improved by principles like encapsulation, polymorphism, and inheritance. Security is enhanced by protecting sensitive data and reducing code repetition, especially in user management.

Model-View-Controller (MVC) Architecture

Using the CodeIgniter 4 framework, the system architecture follows the MVC pattern for effective separation of business logic, user interface, and data management. jQuery is integrated to enhance user interaction and responsiveness.

Model: Manages the data structure, including database interactions.

View: Handles presentation and user interface elements.

Controller: Serves as the central mediator for requests, linking the model and view. All requests the controller receives are transmitted to the model and view to process the information. It is the center of each request in the web application. Acts as a mediator in the management of the system's operations. Figure 4.1 provides a visual representation of the MVC pattern.

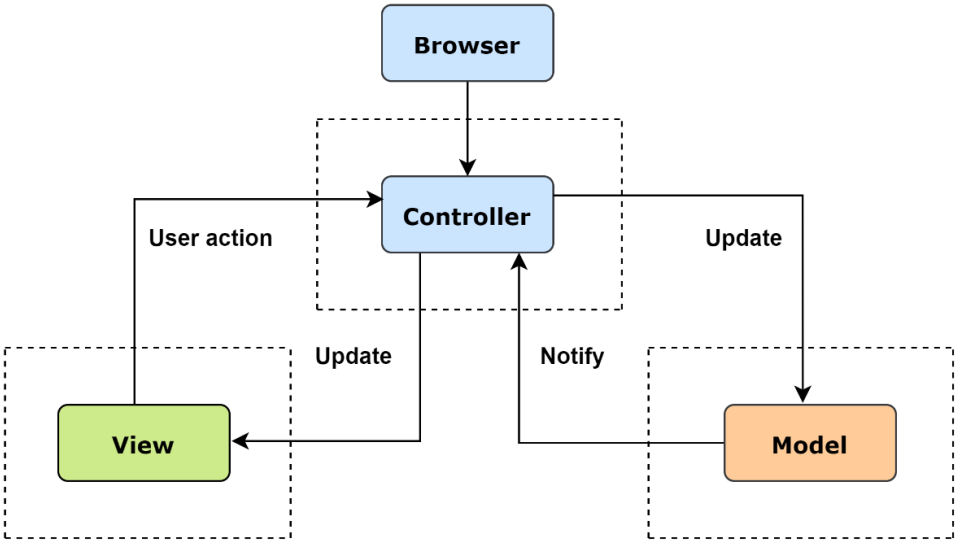


Figure 4.1: Model-View-Controller (MVC) Pattern

Tools and Technologies

Given the hardware and software environments described in section 4.3, the following development tools and technologies were employed:

1. **Development Environment:** XAMPP for local development, Apache Webserver for production.
2. **Programming Language:** PHP for server-side scripting and SQL for database management.
3. **Front-end Framework:** Bootstrap 5.0 - for responsive design.
4. **Back-end Framework:** CodeIgniter 4 with Bootstrap-based admin template.
5. **Database Management:** MySQL and PHP My-Admin.
6. **Scripting/Library:** jQuery for client-side operations.
7. **Version Control:** Git for source code management.

Code Review and Quality Assurance

In order to maintain the high quality of the code, static analysis is performed at regular intervals. Dynamic analyses were also performed. The project also incorporates Test-Driven Development (TDD) as a core component of the quality assurance strategy.

4.3. Implementation Environment

4.3.1. Hardware Requirements and Environment

The hardware setup for the e-waste management system is classified into three segments: System Development, Webserver, and Client Computer.

Table 4.1 displays the hardware specifications essential for each category.

Table 4.1: Required hardware components for the system development

Hardware component	**System development**	**Webserver**	**Client computer**
Processor	Core i7 3.0 GHz	Core i7 3.4 GHz	Core i5 2.3 GHz
Cache	8 MB	12 MB	6 MB
RAM	16 GB	32 GB	8 GB
Hard Disk	1 TB SSD	2 TB SSD	512 GB SSD

4.3.2. Software Requirements and Environment

Front-End:

Framework: Bootstrap 5 for responsive design.

Languages: HTML, CSS, JavaScript for building the user interface.

Libraries: jQuery Version 3.7.0 to enhance front-end functionalities.

Back-End:

Framework: CodeIgniter 4, chosen for its MVC architecture and ease of integration.

Languages: PHP for server-side scripting.

Database Management: MySQL for database operations and PHPMyAdmin for database administration.

Web Server and Development Tools:

XAMPP is employed for local development and testing, supporting Apache Webserver, MySQL, and PHP.

Apache Webserver, configured with HTTPS for security, manages web requests in the production environment.

Table 4.2 summarizes the software components for system development, webserver, and client computer environments.

Table 4.2: Required software components for the system development

	System Development	**Webserver**	**Client Computer**
Web Server	XAMPP	Apache Webserver	Web Browser
Database	MySQL	PHP My-Admin	PDF Reader
Programming	PHP language	MYSQL	Internet connection
Framework	CodeIgniter 4	jQuery	
Scripting/Library	jQuery		
UI Framework	Bootstrap 5.0		

4.3.3. Web Server Configuration and Connectivity

Table 4.3 summarizes the features, details and justifications for required web server configuration and connectivity.

Table 4.3: Required web server configuration and connectivity

Feature	**Details**	**Justification**
Domain Name	www.ewastemanagement.org	Aligns with project's focus & SEO
Internet Connectivity	Minimum 50 Mbps	Optimal performance
Web Server	Apache with HTTPS	Secure & Reliable

XAMPP Configuration

To ensure a smooth development process, XAMPP was used for local hosting. This provided a reliable environment for using Apache Webserver, MySQL, and PHP for development. Figure 4.2 shows the XAMPP control panel.

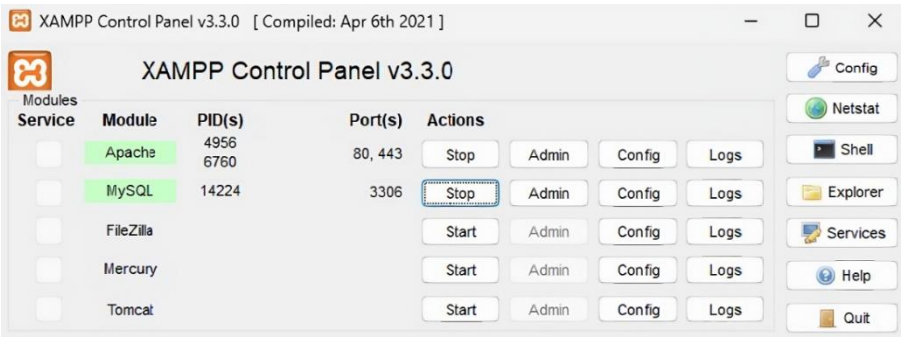


Figure 4.2: XAMPP control panel

Figure 4.2 displays the XAMPP control panel, illustrating the software interface used for local hosting and management of the project's Apache Webserver, MySQL, and PHP environments.

SQL Database Configuration

SQL database configuration: The project utilizes MySQL for database management. The setup of critical system tables involved using SQL queries. Figures 4.3 to 4.6 illustrate these SQL queries, with Figure 4.3 specifically depicting the query for initializing the main database. This foundational database setup is crucial for structuring other tables and relationships within the system.

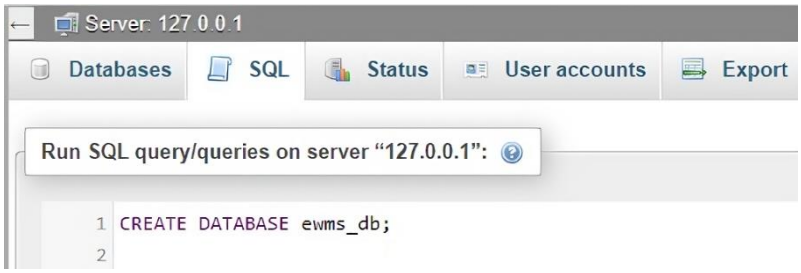


Figure 4.3: SQL query to set up the database

In Figure 4.4, the SQL query code responsible for creating the table that stores data related to e-waste generators, such as individual households or companies, is presented.

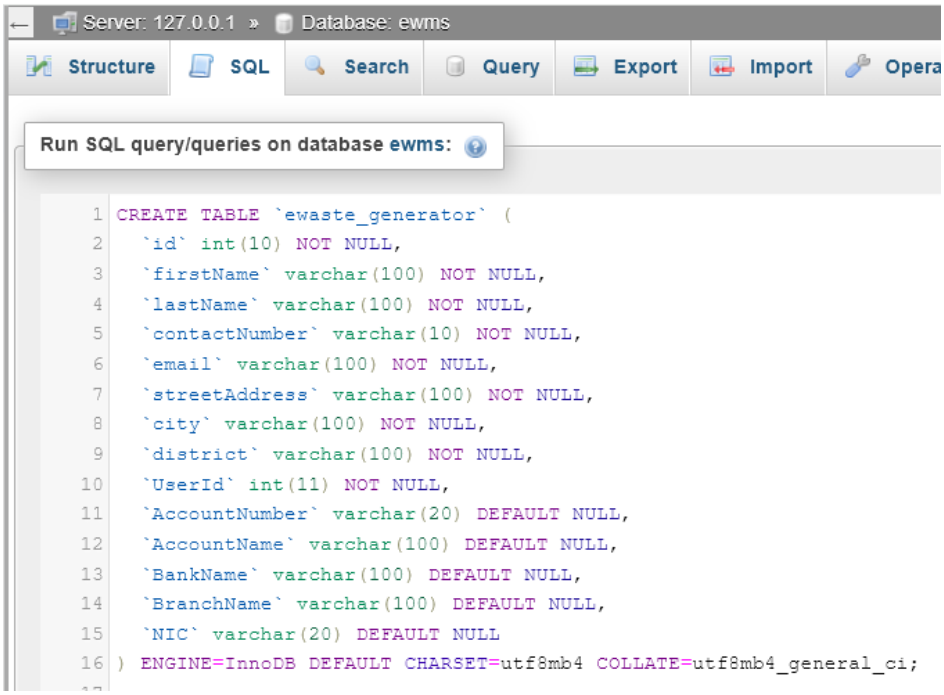


Figure 4.4: SQL query to set up the e-waste generator table

In Figure 4.5, the SQL query code for establishing the e-waste listings table, where all data regarding listed items are stored, is showcased.

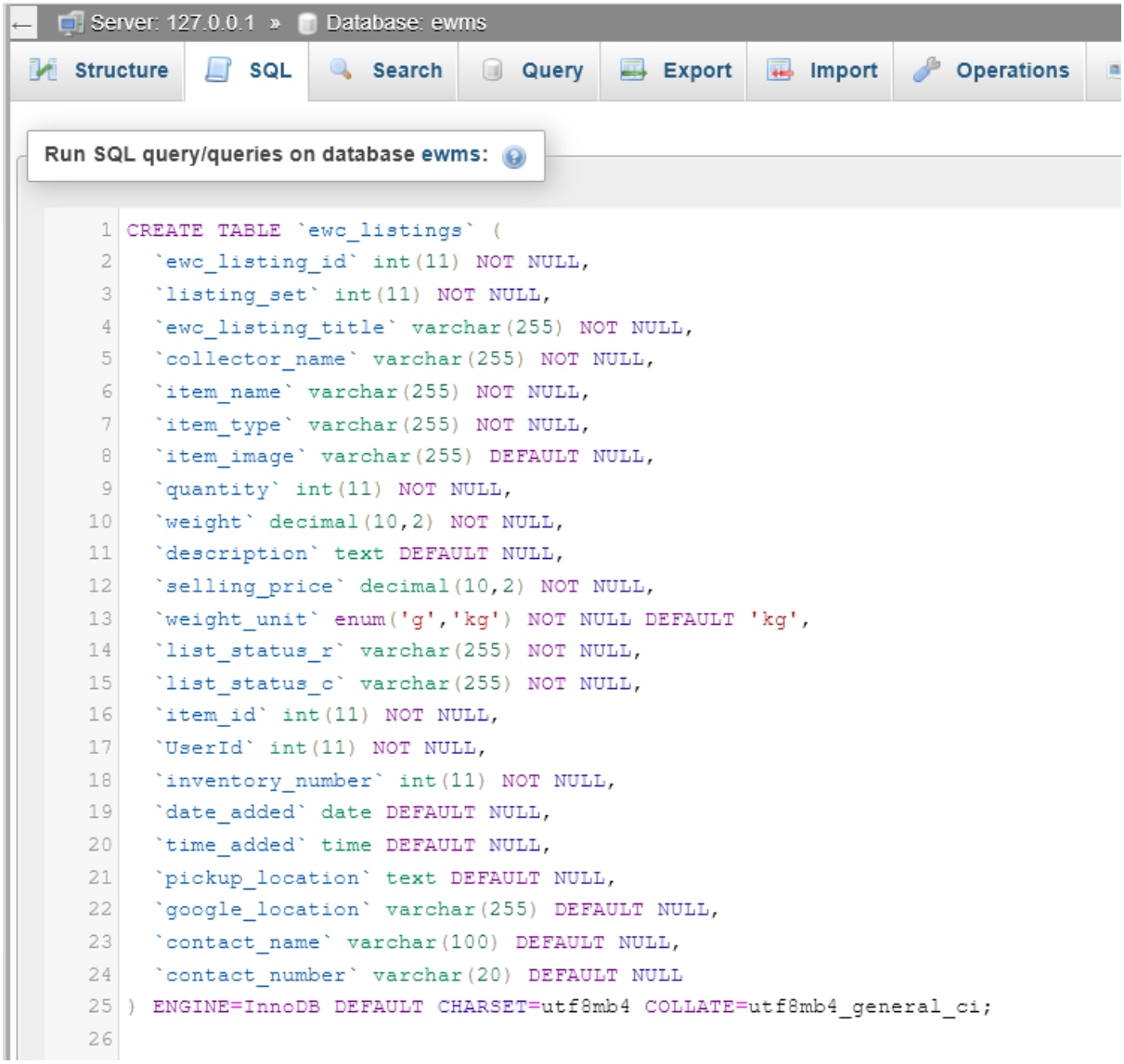


Figure 4.5: SQL query to set up the e-waste listings table

Featured in Figure 4.6 is the SQL query code that sets up the table designed to hold information about bids made by e-waste collectors.

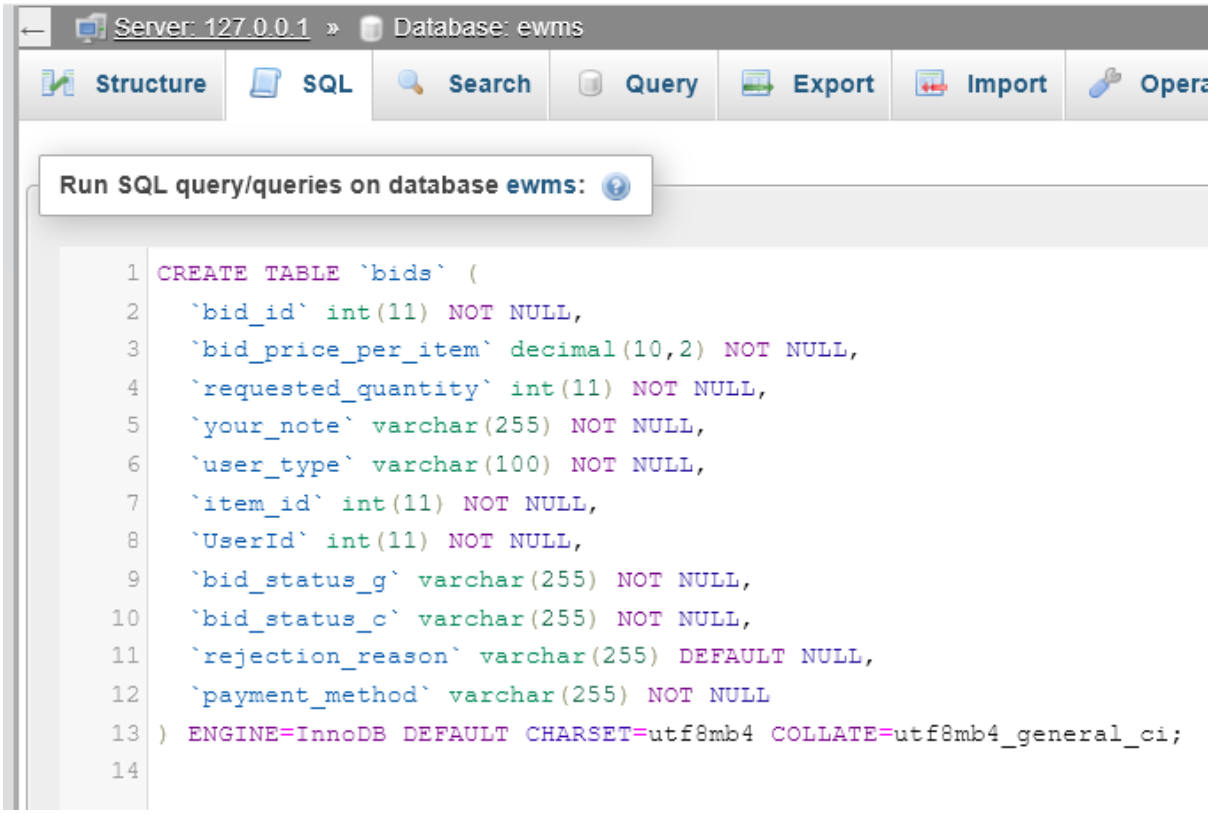


Figure 4.6: SQL query to set up bids table

Justification for Software Choices

1. **XAMPP:** The choice of XAMPP for local hosting was influenced by its ease of use, reliability, and seamless integration with Apache, MySQL, and PHP—key technologies in this project.
2. **Bootstrap templates:** These are chosen for their high compatibility with the CodeIgniter 4 framework and rich feature sets, which make the front-end and back-end visually appealing and functional.

4.4. Existing Code and Reuse

The web-based e-waste management system initially employed bootstrap-based templates to accelerate the early stages of front-end and back-end development.

While the templates provided a reliable foundation, substantial customizations were undertaken to meet the project's unique demands. These customizations ranged from front-end adjustments for better user interface to back-end alterations for specialized administrative functionalities.

Due acknowledgement has been extended to the creators and contributors of the original bootstrap-based templates, which significantly aided the project's rapid prototyping and early-stage development.

4.5. Major Code and Module Structures

Figure 4.7 provides an overview of the EWMS project's architecture organized within the Apache NetBeans IDE. It delineates the Model-View-Controller (MVC) structure, featuring Controllers like "User.php" for application logic, Models such as "EwasteRecyclerModel.php" for data management, and Views including "ewc_inventory.php" and "bidding_form.php" for the user interface.

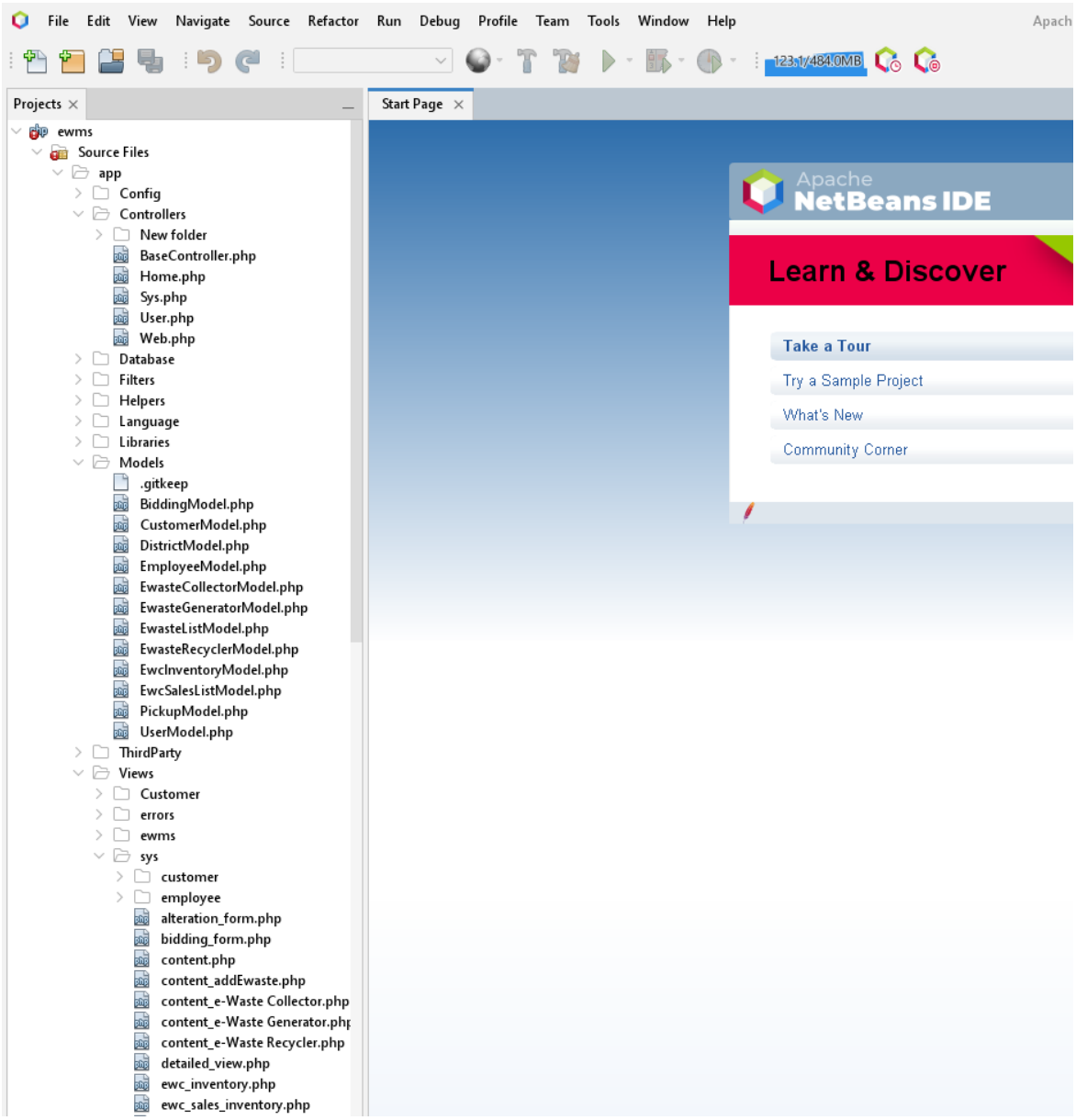


Figure 4.7: EWMS Project Architecture in Apache NetBeans IDE

4.6. Important Code Snippets

Code snippet 1

An essential section of the code focuses on the responsive design aspects of the front end. This code section guarantees a consistent and user-friendly experience on various devices using Bootstrap's grid system and custom CSS.

The utilization of Bootstrap's grid system and custom CSS in Figure 4.8 illustrates a responsive and visually appealing front-end design across various devices.

content_e-Waste Generator.php

Source | History

```
<div class="pagetitle">
    <h1>Dashboard</h1>
    <a href="<?php echo base_url('sys/addEwasteView'); ?>" class="btn btn-primary">Add New E-waste</a>


    <nav>
        <ol class="breadcrumb">
            <li class="breadcrumb-item"><a href="<?php echo base_url('sys/index'); ?>">Home</a></li>
            <li class="breadcrumb-item active">Dashboard</li>
        </ol>
    </nav>
</div>

<section class="section">
    <div class="row">
        <div class="col-lg-12">
            <div class="card">
                <div class="card-body">
                    <h5 class="card-title">e-Waste Listings</h5>
                    <p>View and manage your e-Waste listings and bids.</p>

                    <!-- Datatable for listings -->
                    <div class="datatable-wrapper datatable-loading no-footer sortable searchable fixed-c

                        <div class="datatable-container">
                            <table class="table datatable datatable-table">
                                <thead>
                                    <tr>
                                        <th>Listing Number</th>
                                        <th>Item Image</th>
                                        <th>Title</th>
                                        <th>Type</th>
                                        <th>Price Option</th>
                                        <th>Amount</th>
                                        <th>Status</th>
                                        <th>Actions</th>
                                    </tr>
                                </thead>
                                <tbody>
                                    <?php foreach ($listings as $item): ?>
                                        <tr>
```

Figure 4.8: Code of the e-waste generator dashboard

Code snippet 2

A critical component of the code focuses on user authentication in the back-end. The code responsible for user authentication, as shown in Figure 4.9, implements standard security protocols to restrict access to specific functionalities of the system to unauthorized individuals.

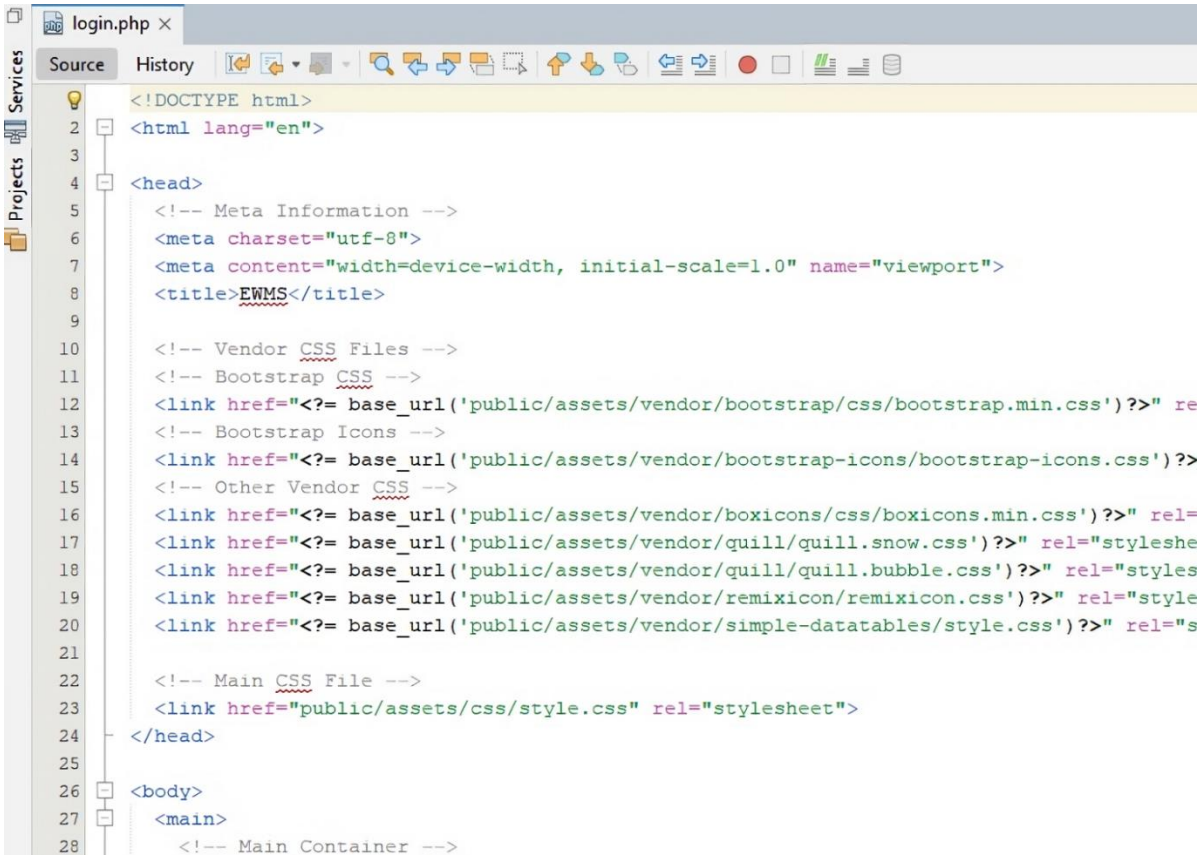


Figure 4.9: Code of the system login page

Code snippet 3

Figure 4.10 shows an HTML form on the 'System Administrator' page for adding new users, using PHP's CodeIgniter 4 framework for structure and server-side validation.

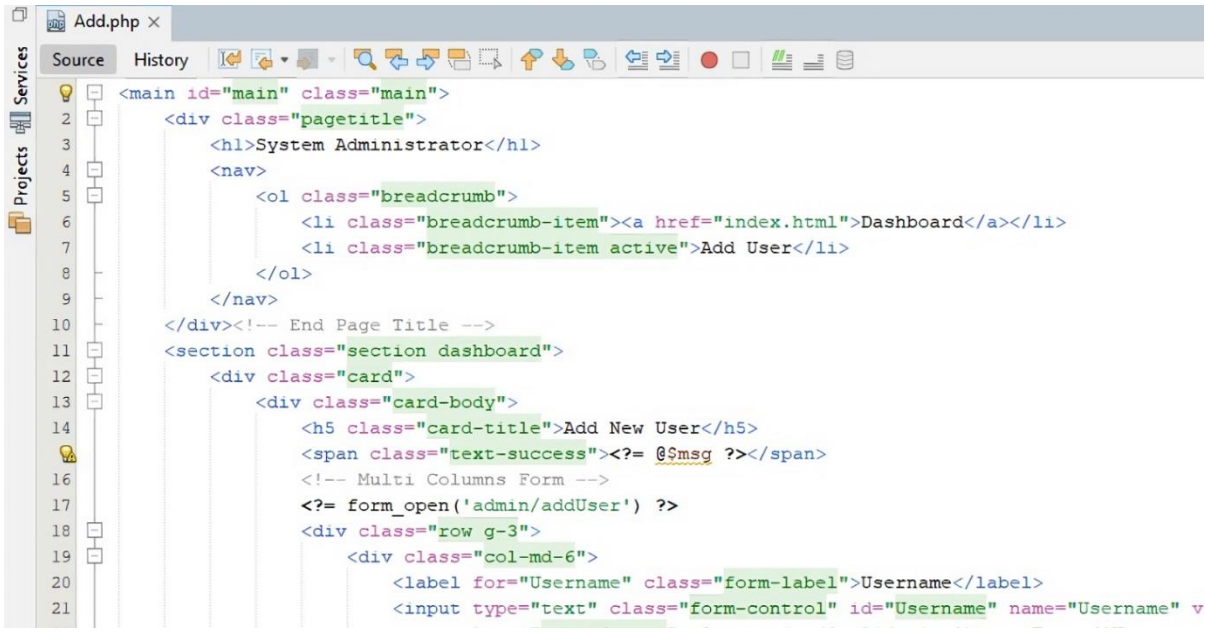


Figure 4.10: Code of the add new user

The chapter thoroughly examines the web-based e-waste management system development process. It provides a comprehensive overview of the hardware and software environment, followed by a detailed examination of the development process, project structure, and vital code segments. The chapter also stresses the significance of employing an iterative approach to guide the project through its stages, resulting in a flexible and responsive development process.

Chapter 5 - Testing and Evaluation

5.1. Introduction

The development of a web-based e-waste management system, or any similar system, requires a testing and evaluation process that is more reliable. It includes diverse testing methodologies employed to align the technical specifications, user requirements, and expected functionality of the system accurately. It also emphasizes assessing system functionality, dependability, performance, and security to guarantee its readiness for real-world implementation.

Software testing is the main activity of evaluating and executing software to discover errors. It is the process where the system requirements and system components are exercised and evaluated manually or by using automation tools to find out whether the system is satisfying the specified requirements and the differences between expected and actual results are determined. (Hooda and Singh Chhillar, 2015).

Testing e-waste management system requires multiple approaches. Each module and interface must be carefully examined because the system serves e-waste generators, collectors, recyclers, government regulatory agencies, and system administrators. This chapter describes the methodical approach to test various components to ensure the system functions seamlessly and satisfies design and development requirements.

5.2. Software Testing Methodologies

The design and development of the web-based e-waste management system involves a thorough and systematic approach to software testing. It ensures the durability, effectiveness, and ease of utilization. Testing techniques are used throughout the software development life cycle (SDLC) for developing a test case, detecting a fault, debugging an error and maintaining its reliability (Shuaibu et al., 2019).

The testing methodologies utilized for the e-waste management system are categorized into functional testing and non-functional testing.

5.2.1. Functional Testing

The purpose of functional testing in the e-waste management system is to ensure that every feature functions according to the specified requirements. The validation of the system's behaviour across different scenarios is crucial to ensure the accurate implementation of all functionalities.

1. **Unit testing:**

In unit testing, separate components or modules are tested in the e-waste management system. It comprises user registration, e-waste listing, e-waste bidding, pickup scheduling, and report production. A framework compatible with the development stack generates automated unit tests for each module. Tests ensure that each module functions appropriately and that changes in one do not affect others.

2. **Integration testing:**

Integration testing investigates module interactions after unit testing. E-waste management system modules like e-waste collection requests and inventory management must be integrated. Integration tests verify data flow and module interaction. These tests ensure error-free communication between the front and back ends and that the integrated system functions as intended.

3. **System testing:**

System testing evaluates the e-waste management system against its comprehensive requirements. The completely integrated system is tested to ensure it meets requirements. System testing simulates operational conditions to test the entire system. This comprises database interactions, network communications, and appropriate hardware, software, and system interfaces. This phase ensures system readiness for real-world deployment.

5.2.2. Non-Functional Testing

Non-functional testing evaluates system performance, security, and usability to ensure functionality.

1. **Usability testing:**

The system's interface and usability are evaluated. Representatives such as e-waste generators and government regulatory agencies participate in testing sessions. Their feedback and interactions enhance system usability.

2. **Compatibility testing:**

System functioning is evaluated across browsers and devices. To ensure consistency, Chrome, Firefox, and smartphones, as well as desktops, are tested.

3. **Security testing:**

Security testing is comprehensive since user data is sensitive. Security scanning, penetration testing, and risk assessment prevent unauthorized access and data breaches.

4. **Performance testing:**

This testing evaluates system performance under varied demand levels. There is load testing for real-world conditions, stress testing for limitations, and scalability testing for adaptable performance.

5.3. Test Plan Development

The test strategy for the web-based e-waste management system is planned and detailed, covering functional and non-functional testing. All critical system functions and user responsibilities are covered in the test plan. The following tables represent essential system component test strategies.

Test plan for user registration process

Table 5.1 outlines the testing tasks, approaches, expected results, and priorities for validating the user registration process. It ensures that all users, including e-waste generators, collectors, recyclers, and regulatory agencies, can safely register and access the system.

Table 5.1: Test plan for user registration process

No.	Task	Testing approach	Expected result	Priority
1	Register without data	Attempt registration with empty fields	Display "All fields are required" message	High
2	Validate email format	Enter invalid email format	Display "Invalid email format" message	High
3	Duplicate email check	Use an already registered email	Display "Email already exists" message	Medium
4	Password strength check	Enter a weak password	Display "Password too weak" message	Medium
5	Successful registration	Enter all valid registration details	Redirect to confirmation page with " Successfully registered" message, and redirect to home page	High

Test plan for e-waste listing process

Table 5.2 details the test cases for validating the functionality of listing, modifying, and removing e-waste items by users. It covers tasks such as submitting listings, uploading images, and entering location details to ensure the accuracy and completeness of the listing process.

Table 5.2: Test plan for e-waste listing process

No.	Task	Testing approach	Expected result	Priority
1	Submit complete listing	Fill and submit form with valid data	Confirmation of successful listing creation	High
2	Submit incomplete listing	Submit form with missing fields	Error message indicating missing fields “all fields required”	High
3	Upload image	Upload an image file for the listing	Image uploaded and displayed with listing	Medium

4	Incorrect quantity format	Enter non-numeric values in 'Quantity'	Error message for “invalid quantity format”	High
5	Price option selection	Select 'Free' or 'Expected' and provide amount if required	Listing displays correct price option	Medium
6	Location details	Enter pickup location and google link	Listing shows the correct location	High

Test plan for bidding process

Table 5.3 focuses on testing the functionality related to bidding and scheduling e-waste pickups, as well as managing appointments. It includes tasks such as submitting bids, viewing submitted bids, and accepting or rejecting bids to ensure a smooth and efficient bidding process.

Table 5.3: Test plan for bidding process

No.	Task	Testing Approach	Expected Result	Priority
1	Submit valid bid	Fill and submit the bidding form with valid data	Successful submission confirmation	High
2	Submit incomplete bid	Submit the form with missing fields	Error message for missing required fields	High
3	View submitted bids	View all bids for a specific item	Display all bids with details	Medium
4	Accept a bid	Accept a bid for an item	Selected bid marked as 'Accepted'	High
5	Reject a bid	Reject a bid for an item	Selected bid marked as 'Rejected'	Medium

These test plans validate system functionality and ensure a consistent user experience across different modules. The prioritization of test cases is based on the criticality of each function to the overall system operations and user interactions.

5.4. Implementation of Test Cases

Individual test cases

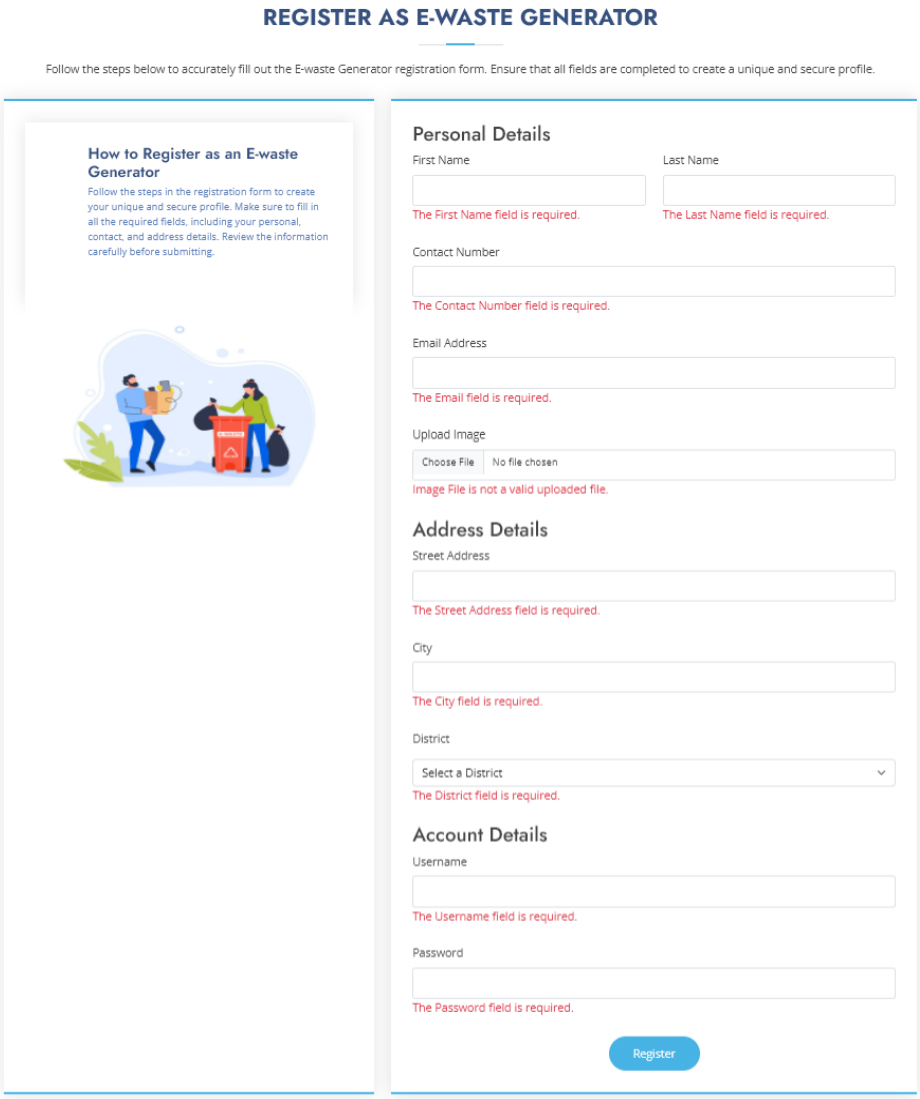
For the web-based e-waste management system, we have created individual test cases to ensure each functionality works as expected. These test cases focus on core functionalities like user registration, e-waste listing review, and bidding for e-waste.

Test case for user registration process

Table 5.4 provides a detailed test case for validating the user registration process, ensuring that the system allows only valid registrations with all required fields completed.

Table 5.4: Test case for user registration process

Testing Case No.	EWMS_TC01
Name	User registration
Description	The system should only allow valid user registration with all required fields filled.
Preconditions	The user must access the registration page of the EWMS.
Assumptions	The user has a stable internet connection and a properly functioning web browser.
Steps of the test case	a. Navigate to the EWMS registration page. b. Attempt to register without filling out any fields. c. Click on submit button without inputting data into any fields.
Expected outcomes	

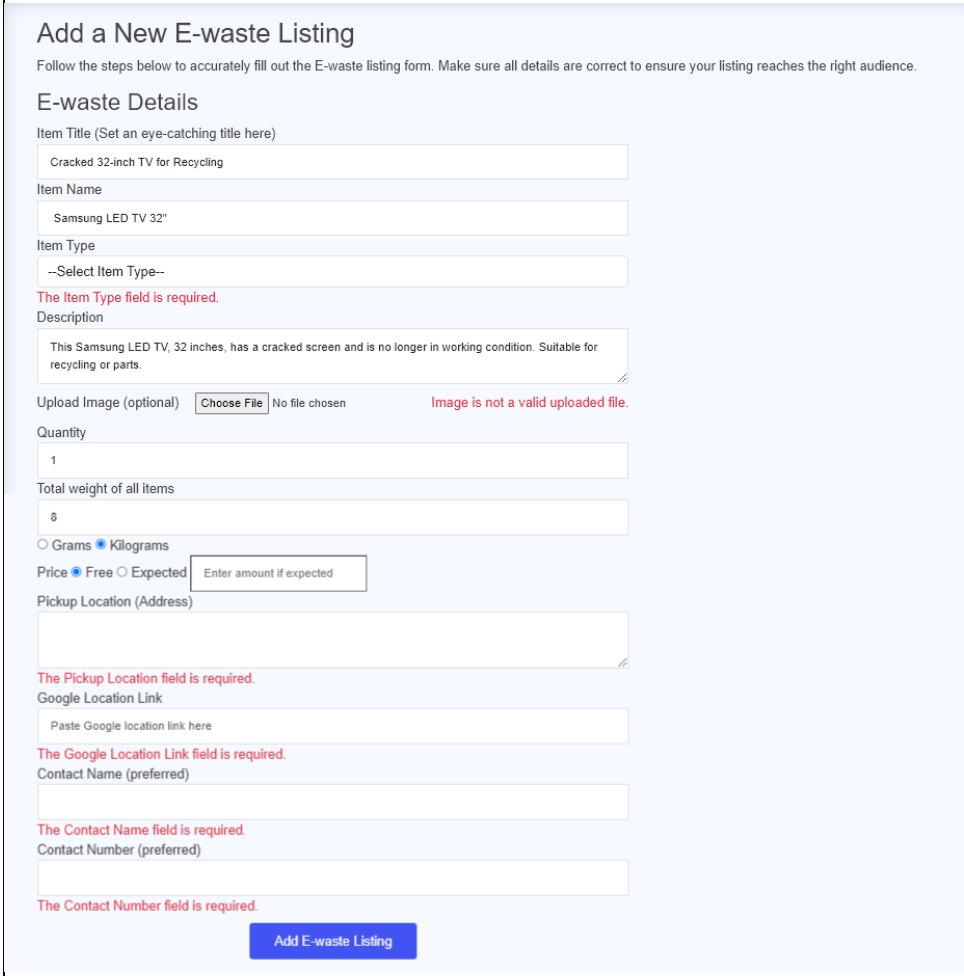
Testing status Success	

Test case for e-waste listing process

Table 5.5 outlines the test case for submitting an incomplete e-waste listing, verifying that the system displays an error message when required fields are missing.

Table 5.5: Test case for submit incomplete e-waste listing process

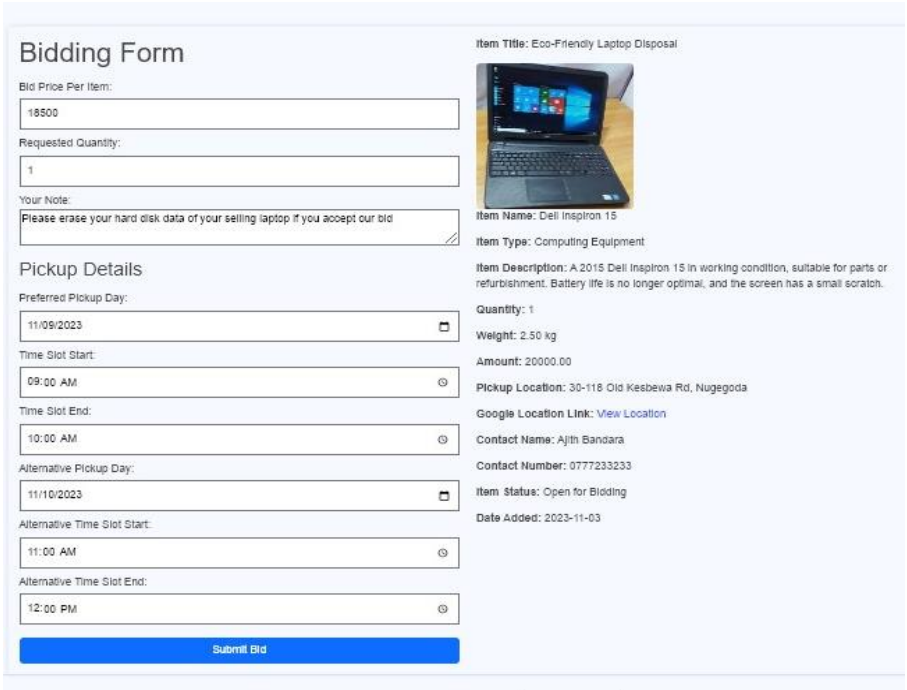
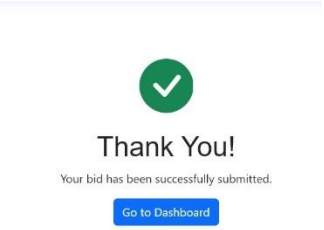
Testing Case No.	EWMS_TC02
Name	Submit incomplete e-waste listing
Description	The system should display an error message when attempting to submit an e-waste listing form with missing required fields.

Preconditions	The user must access the e-waste listing page of the EWMS system.
Assumptions	The user has a stable internet connection and a properly functioning web browser.
Testing Steps	a. Navigate to the EWMS e-waste listing submission page. b. Fill out the form but leave some required fields empty. c. Click on the “Add e-waste listing” button without completing all required fields.
Expected outcomes	a. "All fields are required" message. 
Testing status	Success

Test case for submitting valid bid process

This table 5.6 details the test case for submitting a valid bid in the e-waste bidding process, ensuring the system accepts bids with all required fields filled and confirms successful submission.

Table 5.6: Test case for e-waste bidding process

Testing case no.	EWMS_TC03
Name	Submit valid bid
Description	The system should accept a bid with all required fields
Preconditions	The user must access the bidding page of the EWMS system.
Assumptions	User has a stable internet connection and a properly functioning web browser
Testing steps	a. Fill out the bidding form with valid information b. Submit the form 
Expected outcomes	Successful submission confirmation message 
Testing status	Success

Each test case has been specifically designed to cover the system's essential functions, ensuring all features operate as intended and meet user demands. As each test executes, the system's readiness and areas that need improvement will be displayed.

5.5. Usability Testing and User Feedback

Approach to usability testing

Usability testing was performed to ensure that the EWMS is user-friendly. The approach involved thorough questionnaires and user interaction scenarios that simulated system use. These scenarios covered diverse functionalities, from user registration to e-waste processing and management.

Creation of questionnaire

E-waste generators, collectors, recyclers, and government regulatory agencies were invited to participate in the feedback process by completing an online questionnaire. This questionnaire aimed to gather practical insights into the system's usability, efficiency, and user satisfaction. Structured around rating-scale questions, it delved into critical aspects such as ease of use, navigation, functionality, and overall satisfaction, providing a comprehensive framework for respondents to evaluate their experience with the system.

User interaction scenarios

Users were asked to perform a series of tasks on the system, replicating typical actions they would perform in real-world scenarios. Registering on the platform, listing e-waste, scheduling collections, managing inventory, accessing reports etc.

Analysis of user feedback

Feedback was collected and categorized into five main aspects for detailed analysis:

1. **Appearance:**

The analysis of user feedback concerning the system's appearance, as shown in Table 5.7 and illustrated in Figure 5.1, indicates a positive response. The majority of users, 35, strongly agreed that the system's interface is visually appealing, while 24 users simply agreed. A small fraction, only one user, remained neutral, and there were no responses in the disagree or strongly disagree categories. This suggests that the system's visual design and aesthetic appeal are well-received by most users.

Table 5.7 Summarized answers of appearance (Numerically)

	Q1	Q2	Q3	Q4	Total	Percentage
Strongly Agree	9	9	9	8	35	58.33%
Agree	5	6	6	7	24	40%
Neutral	1	-	-	-	01	1.66%
Disagree	-	-	-	-	-	-
Strongly Disagree	-	-	-	-	-	-

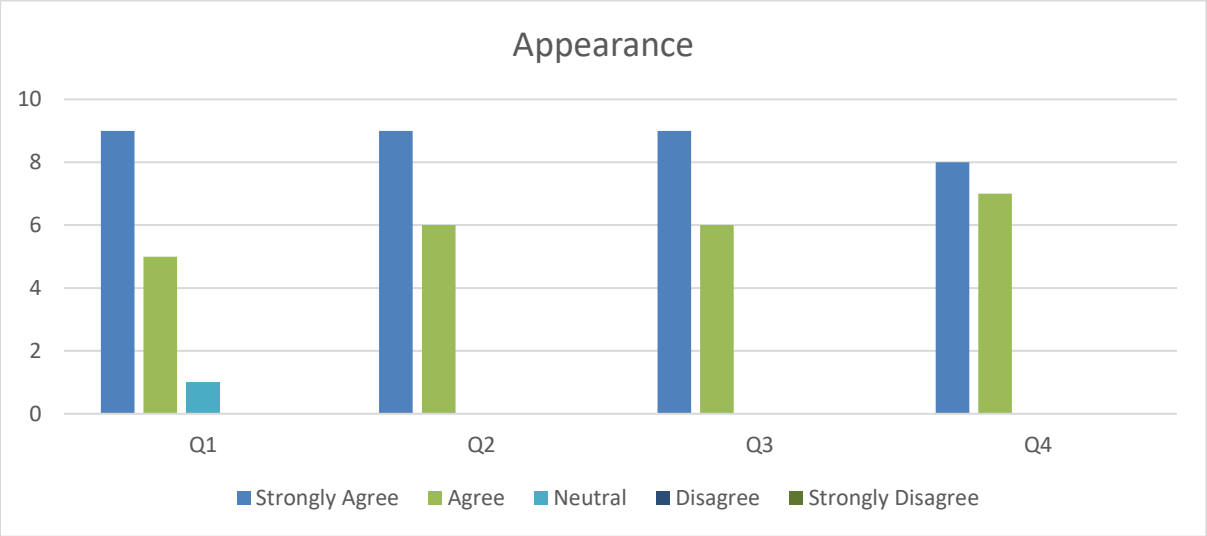


Figure 5.1: Summarized answers of appearance (Graphically)

2. Usability:

Based on the data provided in Table 5.8 and the visual representation in Figure 5.2, it is evident that the usability of the system gathered positive feedback. 33 users strongly agreed that the system was easy to navigate and interact with, and 25 users agreed with this sentiment. Only two users were neutral, and there were no negative responses. This implies that the system is user-friendly and intuitive, facilitating easy navigation and interaction for most users.

Table 5.8 Summarized answers of usability (Numerically)

	Q5	Q6	Q7	Q8	Total	Percentage
Strongly Agree	8	8	8	9	33	55%
Agree	6	7	6	6	25	41.66%
Neutral	1	-	1	-	02	3.33%
Disagree	-	-	-	-	-	-
Strongly Disagree	-	-	-	-	-	-

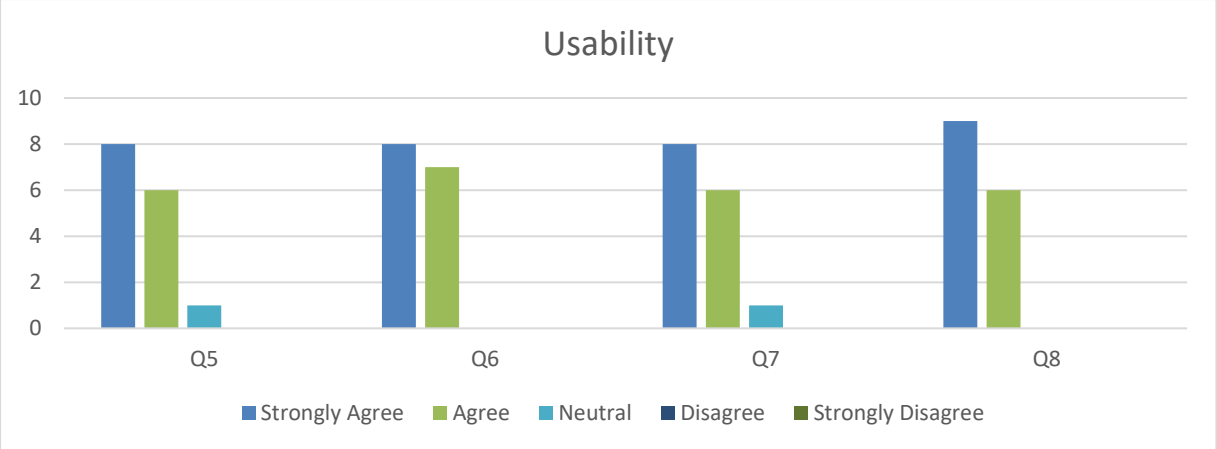


Figure 5.2: Summarized answers of usability (Graphically)

3. Functionality:

The feedback regarding system functionality was predominantly positive, as evidenced by the data in Table 5.9 and Figure 5.3. A majority of users, 40 in total, strongly agreed that the system's features met their needs, with another 20 agreeing. The lack of neutral or negative responses highlights the system's functional efficacy.

Table 5.9 Summarized answers of functionality (Numerically)

	Q9	Q10	Q11	Q12	Total	Percentage
Strongly Agree	8	10	11	11	40	66.66%
Agree	7	5	4	4	20	33.33%
Neutral	-	-	-	-	-	-
Disagree	-	-	-	-	-	-
Strongly Disagree	-	-	-	-	-	-

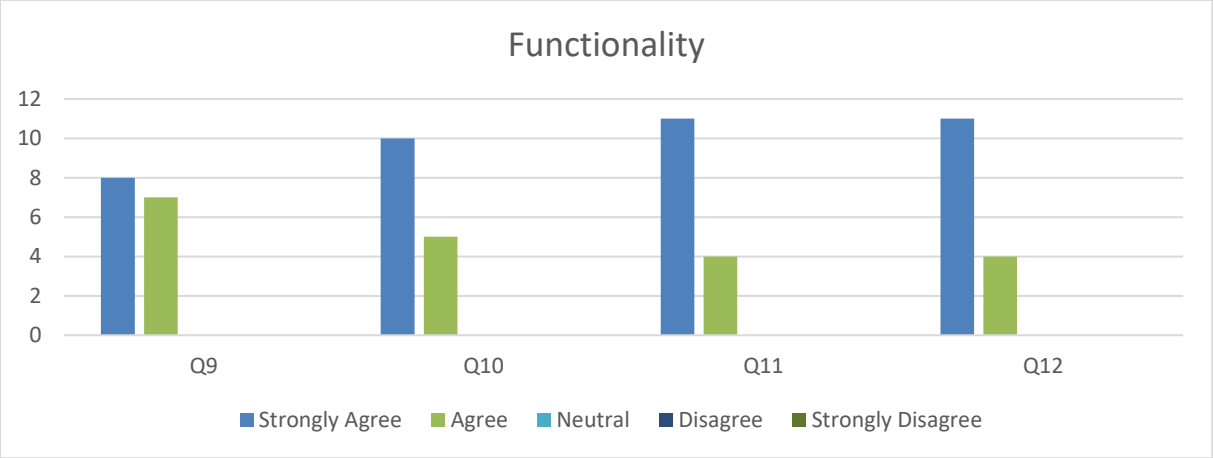


Figure 5.3: Summarized answers of functionality (Graphically)

4. Performance:

The system performance evaluation, as presented in Table 5.10 and Figure 5.4, revealed an overwhelmingly positive response from users. 42 users strongly agreed that the system enhances their productivity and efficiency, while 18 agreed. The lack of neutral or negative responses indicates that the system performs well, contributing to user productivity and efficiency.

Table 5.10 Summarized answers of performance (Numerically)

	Q13	Q14	Q15	Q16	Total	Percentage
Strongly Agree	9	13	8	12	42	70%
Agree	6	2	7	3	18	30%
Neutral	-	-	-	-	-	-
Disagree	-	-	-	-	-	-
Strongly Disagree	-	-	-	-	-	-

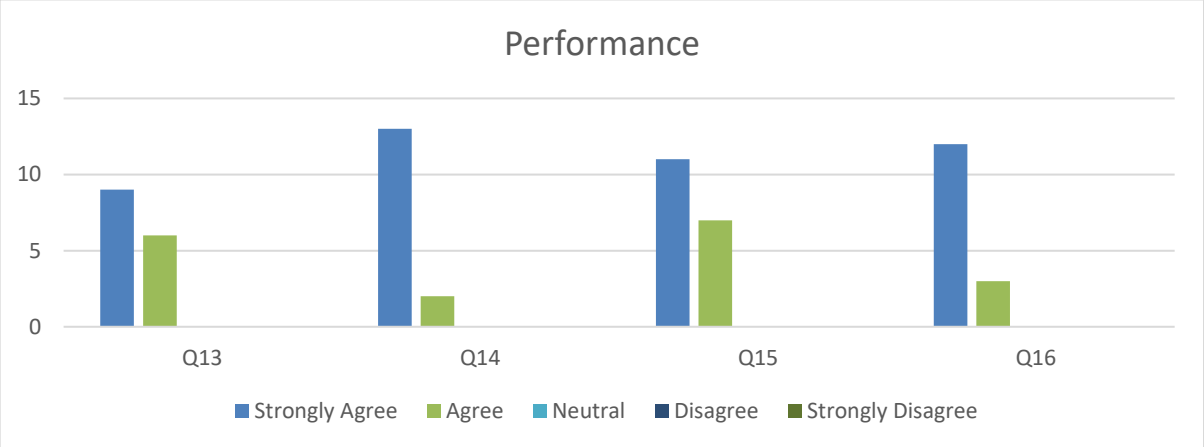


Figure 5.4: Summarized answers of performance (Graphically)

5. Security:

For security, as detailed in Table 5.11 and illustrated in Figure 5.5, user confidence is high. 45 users strongly agreed that the system's data security and privacy measures are adequate, with 15 users agreeing. This strong positive response, with no neutral or negative feedback, demonstrates a high level of trust in the system's security measures.

Table 5.11 Summarized answers of security (Numerically)

	Q17	Q18	Q19	Q20	Total	Percentage
Strongly Agree	10	11	12	12	45	75%
Agree	5	4	3	3	15	25%
Neutral	-	-	-	-	-	-
Disagree	-	-	-	-	-	-
Strongly Disagree	-	-	-	-	-	-

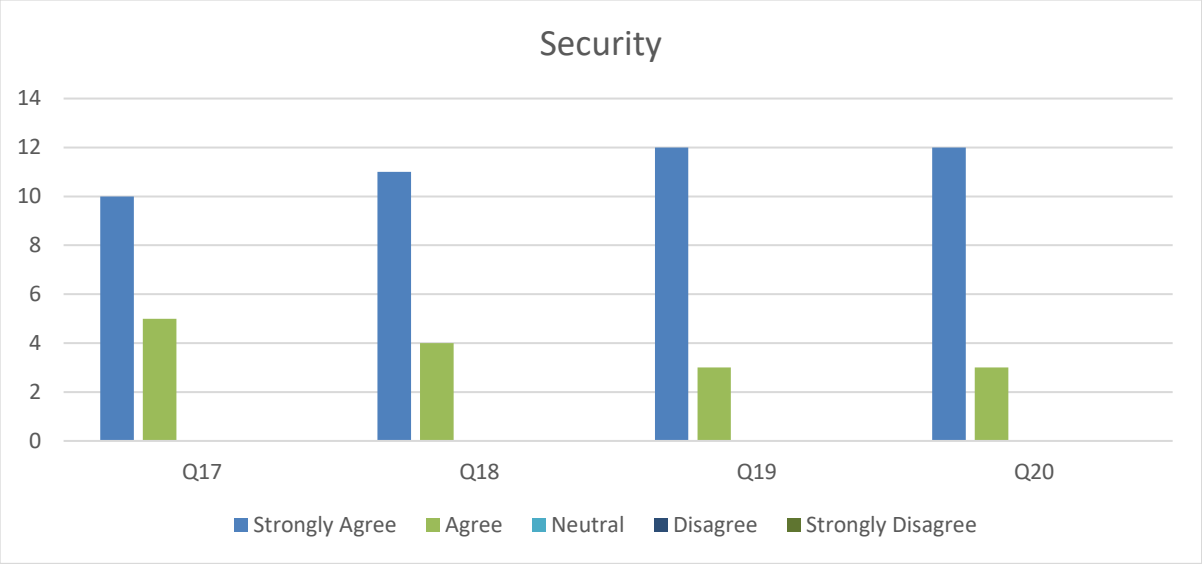


Figure 5.5: Summarized answers of security (Graphically)

5.6. Summary of Feedback Results of the Evaluation

The overall feedback, as outlined in Table 5.12 and Figure 5.6, indicates intense user satisfaction. Responses across Appearance, Usability, Functionality, Performance, and Security were primarily positive, with a majority in the 'Strongly Agree' and 'Agree' categories and minimal neutral or negative feedback. This reflects the system's overall positive reception.

Table 5.12 Overall results of feedback (Numerically)

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Appearance	35	24	1	-	-
Usability	33	25	2	-	-
Functionality	40	20	-	-	-
Performance	42	18	-	-	-
Security	45	15	-	-	-

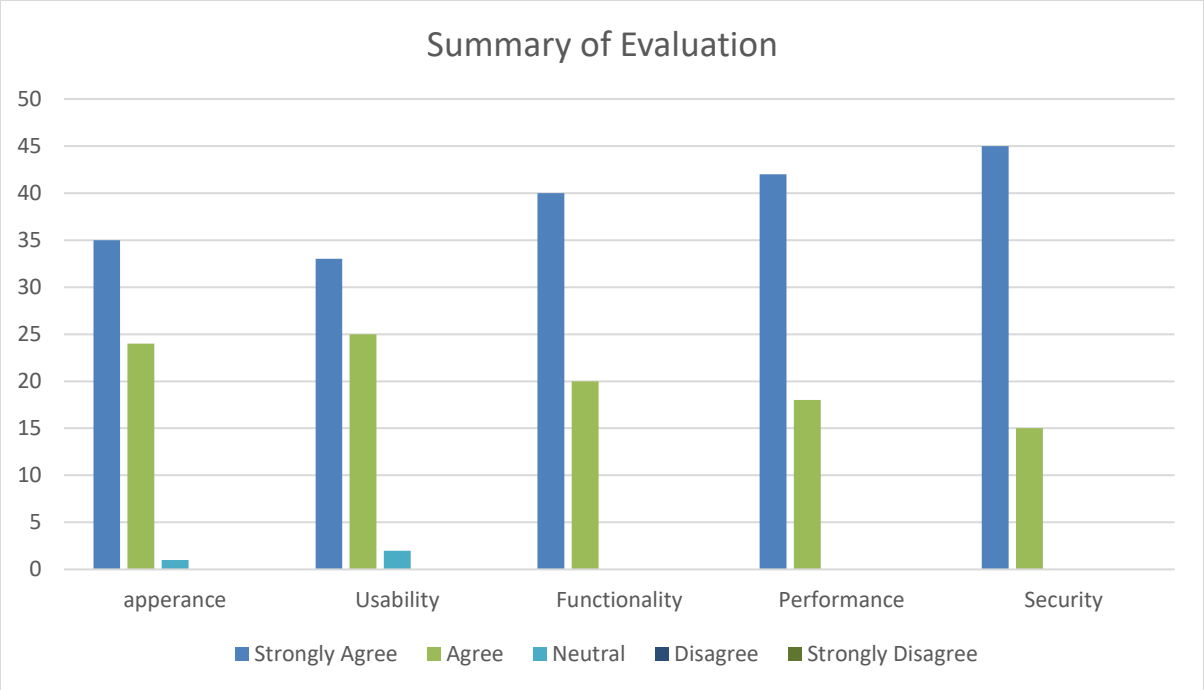


Figure 5.6: Overall results of feedback (Graphically)

Chapter 6 - Conclusion

6.1. Introduction

The completion of this thesis marked the introduction of a new web-based system for managing e-waste in Sri Lanka, tackling the growing problem of e-waste management. This project offers a comprehensive solution to the challenges associated with managing e-waste. It was clear from the beginning that existing systems were not up to the task, lacking both sustainability and the ability to meet the needs of various stakeholders. Therefore, a sustainable approach was needed, one that could minimize environmental impacts while meeting the needs of everyone involved.

The system improves the e-waste supply chain's efficiency by using real-time tracking and monitoring. It effectively deals with issues like poor tracking, report delays, and insufficient communication among stakeholders' issues that have long blocked proper environmental compliance and e-waste management.

An essential feature of this system is its dynamic notification mechanism, which speeds up communication between e-waste management partners. This significantly speeds up the response to e-waste incidents, thus improving the system's efficiency. The system also includes advanced reporting tools that help stakeholders follow regulations and make intelligent decisions by showing e-waste generation trends.

Building this system involved modern technologies like HTML, CSS, JavaScript, PHP, and MySQL. These technologies were crucial in making a solid platform that could grow and was easy to use. Insights were collected from potential users through online surveys, interviews, and observational studies to ensure the system meets high security, scalability, and efficiency standards.

The system's effectiveness and ease of use were confirmed through testing, with both its functions and interface receiving good feedback during user tests. This indicates it has great potential for broad acceptance. Analytics from the testing phase offered insights into how users behave and how the system performs, leading to further improvements.

The potential for broad adoption of this e-waste management system signifies a significant step towards improving the handling of e-waste in Sri Lanka. Additionally, this system has the capacity to serve as a model for comparable initiatives in other developing countries. However,

the effectiveness of this system relies on collaborative efforts among government regulatory agencies, industry stakeholders, and the general public. Through such collaboration, it becomes feasible to comprehensively address the critical issue of e-waste, contributing to environmental protection.

6.2. Achieving the Project Objectives

This project aimed to develop a web-based system to better manage e-waste in Sri Lanka. The objective was to streamline and sustain the processes of listing, collecting, and recycling e-waste. This section demonstrates the system's success in meeting these goals.

Implementation of E-Waste Tracking and Inventory Management: A real-time tracking system for e-waste was established, providing all involved parties, e-waste generators, collectors, and recyclers with immediate updates on e-waste status. This development has made the whole process from listing to recycling and inventory management more efficient.

Ensuring Compliance with Environmental Regulations: The system aids government bodies in upholding environmental laws. It includes features for monitoring e-waste flows, checking the licenses of collectors and recyclers, and watching over their activities. This is crucial for government regulatory agencies to perform their duties effectively, ensuring that environmental standards are met.

Comprehensive Reporting Mechanism: Detailed reports on e-waste management activities are available to all stakeholders, including government regulatory agencies. These reports are essential for managing e-waste effectively, providing insights for strategy development and execution.

Enhanced Communication and Notifications: The system improves communication among e-waste management stakeholders with a reliable notification system. This has dramatically enhanced coordination among e-waste generators, collectors, and recyclers, leading to a more cohesive management approach.

Promotion of a Circular Economy: The system encourages the reuse and recycling of e-waste, aligning with the principles of a Circular Economy. This not only aids in sustainable handling but also supports the recovery of valuable materials, reduces pollution, and fosters economic benefits like resource savings, job creation in recycling, and revenue from recycled materials.

Careful planning, development, and conceptual demonstration have illustrated that web-based solutions can substantially improve e-waste management. Achieving the set objectives has laid a solid foundation for the continuous, sustainable management of e-waste in Sri Lanka, aiding in preserving the environment and fostering a sustainable future.

6.3. Challenges and Learning Opportunities

The development journey of the e-waste management system unveiled several challenges that transformed into significant learning opportunities. Integrating diverse technological elements, including hardware, software, and user interfaces, was a substantial task. These obstacles underscored the necessity for detailed planning and execution.

Technical Complexity: Merging Object-Oriented Programming, Model-View-Controller (MVC) architecture, and advanced database management posed a significant challenge. Achieving seamless operation among these components demanded thorough knowledge and careful management to ensure the system functioned smoothly.

User Adoption: Creating a system easily navigable by all user groups, ranging from e-waste generators to government regulatory agencies, was a critical hurdle. To improve user experience, iterative testing and feedback incorporation became central, helping refine the system's interfaces and functionality for better intuition and accessibility.

Despite these hurdles, the project saw several accomplishments:

Comprehensive Functionality: The system was designed to meet the varied needs of all stakeholders involved in e-waste management. With capabilities for tracking, inventory management, reporting, and bid management, it offers a holistic tool that covers different aspects of e-waste management.

Scalability and Stability: Utilizing frameworks like CodeIgniter 4 and Bootstrap 5 established a strong foundation, ensuring the system's scalability and stability. This positions the system to adapt to future demands and technological progress.

User Satisfaction: The feedback received from user testing was overwhelmingly positive, showing a high level of approval for the system’s functionality, usability, and performance. Such feedback highlights the system’s potential for broad adoption and effectiveness in improving e-waste management practices.

The encountered challenges and the success in overcoming them contributed to the project's achievement and offered priceless insights and experience. These experiences will influence future endeavors in e-waste management and related fields.

6.4. Prospects for Future Enhancements and Work

The e-waste management system presents several opportunities for improvement to boost its efficiency and sustainability. These potential enhancements are prepared to strengthen current functionalities and pave the way for innovations and broader engagement.

Advanced Data Analytics: Implementing data analytics could provide deeper insights into patterns of e-waste generation. Such information would provide decision-makers with the tools to devise more effective e-waste management strategies.

Mobile Accessibility: Mobile apps and system optimization can improve accessibility and convenience, especially for remote users.

Integration with IoT Devices: Adopting Internet of Things (IoT) technology for real-time monitoring could transform the efficiency and transparency of the e-waste management process. IoT could improve the tracking and management of e-waste, from collection points to recycling facilities.

Community Engagement: Amplifying efforts in education and outreach is essential for encouraging community involvement and environmental oversight. Raising awareness about the importance of proper e-waste disposal and recycling can inspire more sustainable habits among the public.

In summary, the web-based e-waste management system designed for Sri Lanka marks a significant advancement in addressing the nation's e-waste-related environmental and social challenges. By overcoming initial obstacles, ensuring user satisfaction, and establishing a basis for future developments, the system stands ready to support sustainable growth and environmental preservation in Sri Lanka and other areas with similar issues. The envisioned future enhancements emphasize the system's capacity to evolve and meet the growing demands, furthering its effectiveness and positive impact on environmental health.

References

Alahakoon, Y., Gunarathne, N., 2022. Paradigm shift in E-waste management: vision for future, First edition. ed. CRC Press, Boca Raton, FL.

Bass, L., Clements, P., Kazman, R., 2013. Software architecture in practice, 3rd ed. ed, SEI series in software engineering. Addison-Wesley, Upper Saddle River, NJ.

Ceylon Waste Management, 2010. Ceylon Waste Management. Available at: https://www.ewaste.lk/ (accessed 6.15.23).

Cleantech, 2003. CleanTech. Available at: https://cleantech.lk/e-waste-management-sri-lanka/ (accessed 6.15.23).

Cooper, A., Reimann, R., Cronin, D., Cooper, A., 2014. About face: the essentials of interaction design, Fourth edition. ed. John Wiley and Sons, Indianapolis, IN.

Dennis, A., Wixom, B.H., Tegarden, D.P., 2021. Systems analysis & design, an object-oriented approach with UML, Sixth edition. ed. Wiley, Hoboken, NJ.

e-Kunu,2007. Dialog Axiata PLC. Available at: http://dlg.dialog.lk/e-kunu?language=ta (accessed 6.16.23).

e-waste recycle,2015.. eWaste Recycle. Available at: https://ewasterecycle.co.uk/ (accessed 6.15.23).

Gunarathne, N. (Ed.), 2015. e-waste Management in Sri Lanka.

Hooda, I., Singh Chhillar, R., 2015. Software Test Process, Testing Types and Techniques. IJCA 111, 10–14. https://doi.org/10.5120/19597-1433

IPEM Group of Institutions, Sethi, A., 2017. A REVIEW PAPER ON LEVELS, TYPES& TECHNIQUES IN SOFTWARE TESTING. ijarcs 8, 269–271. https://doi.org/10.26483/ijarcs.v8i7.4236

Jan, S.R., Shah, S.T.U., Johar, Z.U., Shah, Y. and Khan, F., 2016. An innovative approach to investigate various software testing techniques and strategies. International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Print ISSN, 23951990.

Khan, M., 2011. Different approaches to black box testing technique for finding errors. International Journal of Software Engineering & Applications (IJSEA), 2(4).

Mallawarachchi, H., Karunasena, G., 2012. Electronic and electrical waste management in Sri Lanka: Suggestions for national policy enhancements. Resources, Conservation and Recycling 68, 44–53. https://doi.org/10.1016/j.resconrec.2012.08.003

Norman, D.A., 2013. The design of everyday things, Revised and expanded edition. ed. Basic Books, A Member of the Perseus Books Group, New York.

Panduwawala, P., Samarakoon, M., 2020. Electrical and Electronic Waste Management in Sri Lanka.

Ranasinghe, W.W., Athapattu, B.C.L., 2020. 13 - Challenges in E-waste management in Sri Lanka, in: Prasad, M.N.V., Vithanage, M., Borthakur, A. (Eds.), Handbook of Electronic Waste Management. Butterworth-Heinemann, pp. 283–322. https://doi.org/10.1016/B978-0-12-817030-4.00011-5

Shibly, F.H.A., Thelijjagoda, S.S., 2015. Development of a Web Based Electronic Waste Management System: A Study with Special Reference to Recycling Companies in Sri Lanka. FESYMPO 20. https://doi.org/10.31357/fesympo.v20i0.2562

Shuaibu, I., Musa, M., Ibrahim, M., 2019. Investigation onto the Software Testing Techniques and Tools: An Evaluation and Comparative Analysis. IJCA 177, 24–30. https://doi.org/10.5120/ijca2019919685

Sommerville, I., 2011. Software engineering, 9th ed. ed. Pearson, Boston.

Taley, D.S. and Pathak, B., 2020. Comprehensive study of software testing techniques and strategies: a review. Int. J. Eng. Res, 9(08), pp.817-822.

Appendix A – System manual

E-waste management system

Recommended browsers

The stable versions of recommended browsers are as follows.

Google Chrome: Version 109 was released on January 10, 20231

Mozilla Firefox: Version 109.0 was first offered to Release channel users on January 17, 20232.

Microsoft Edge: Version 109 was scheduled for release the week of January 12th, 20233

Safari: The details about the version of Safari in January 2023 are not explicitly mentioned in the search results.

System URL:

To access the EWMS, enter http://localhost/ewms/web in the address bar of your web browser.

Requirements of web services

Apache Server: Version 2.4.58 was the latest available version

MySQL: Version 8.0.32

PHP: PHP 8.3

XAMPP: Version 8.2.12

Installation Steps:

Install and configure the XAMPP server.
Start Apache and MySQL services via the XAMPP Control Panel as shown in Figure A.1.

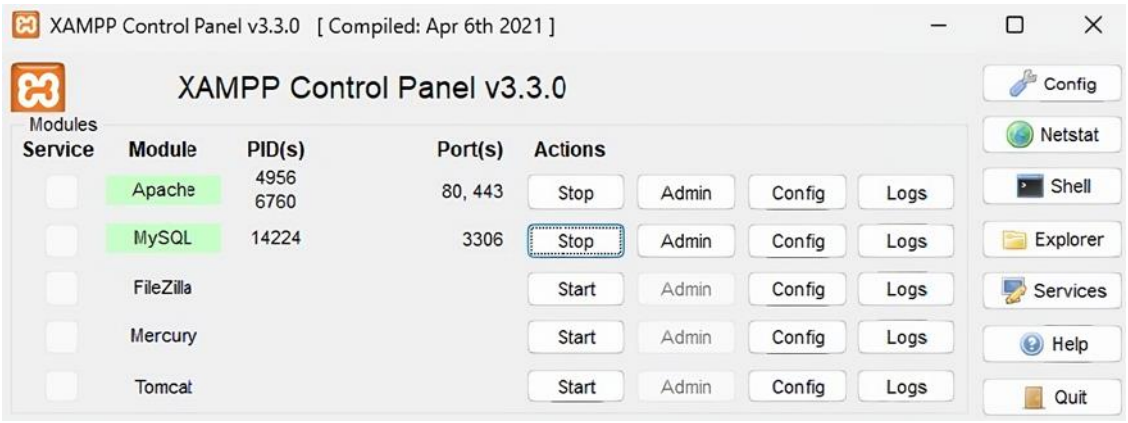


Figure A.1: XAMPP control panel

Create a new database named "ewms" in MySQL (Figure A.2).
Import the provided SQL file to set up the initial database structure

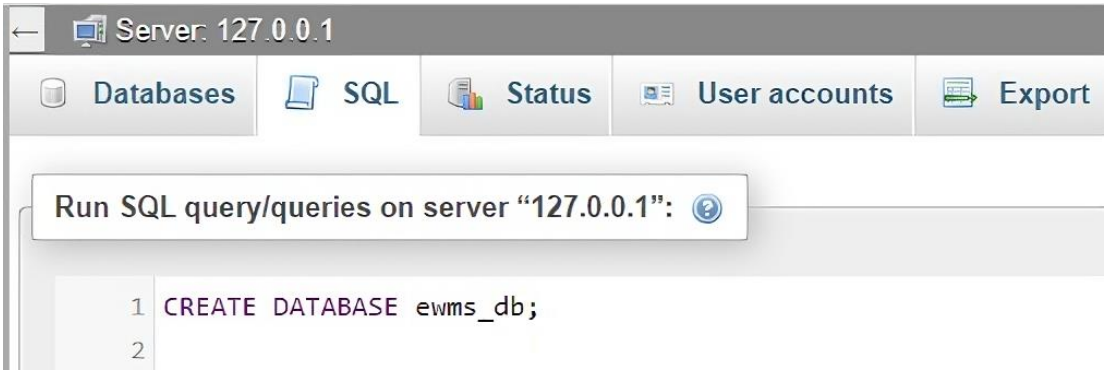
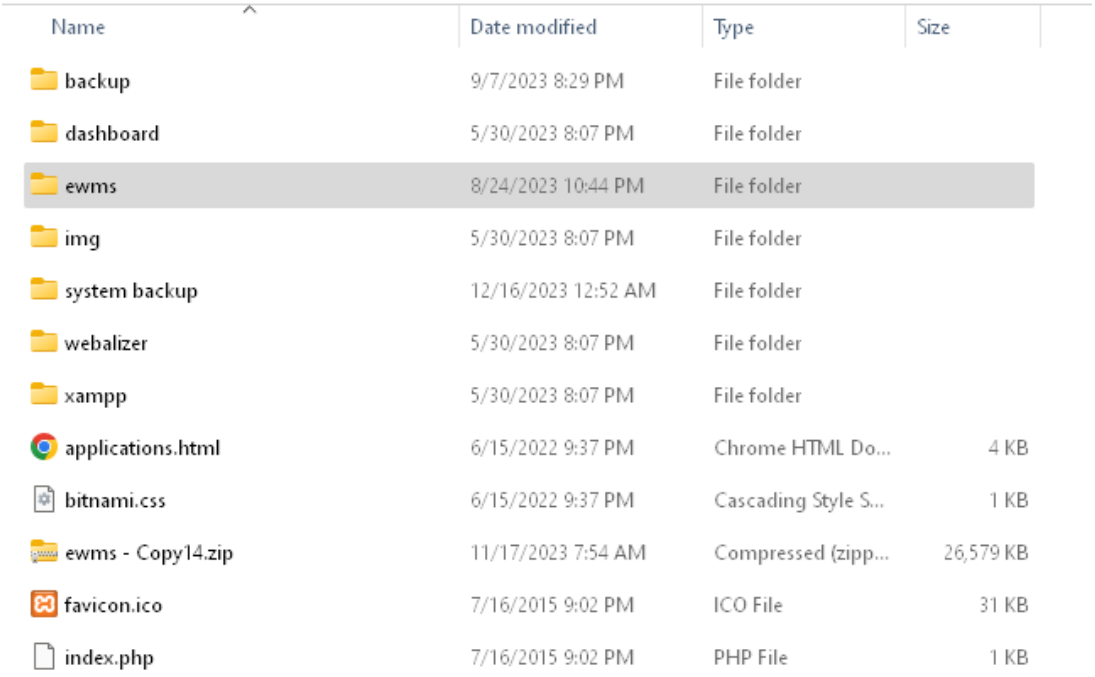


Figure A.2: SQL query to set up the database

.

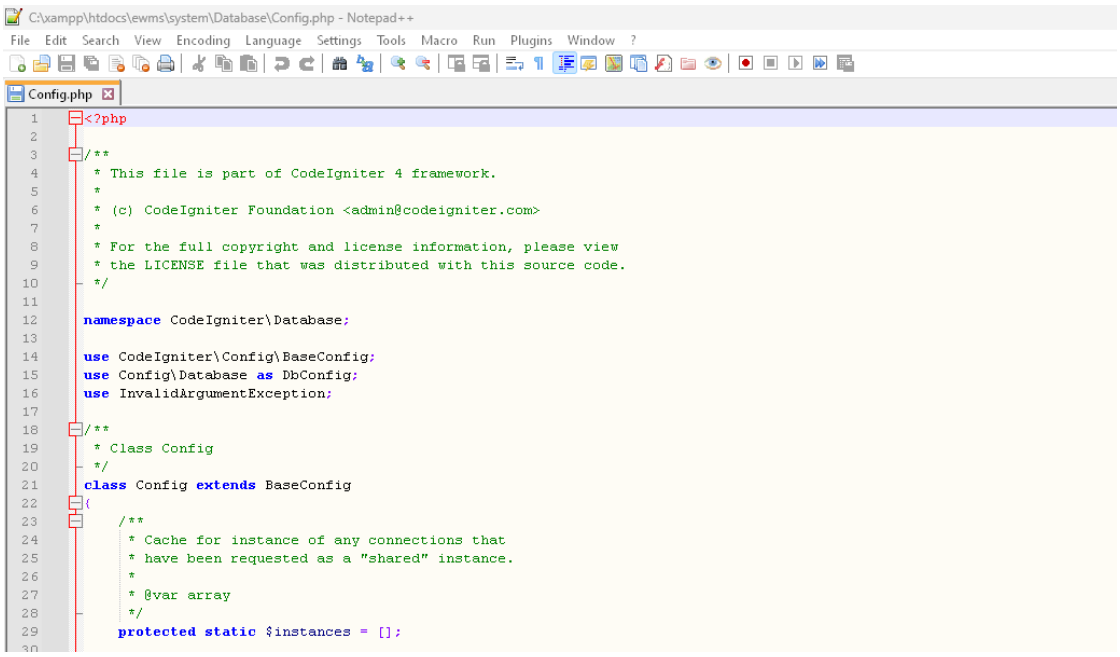
Clone or copy the EWMS application files into the 'htdocs' directory of XAMPP (Figure A.3).



Name	Date modified	Type	Size
backup	9/7/2023 8:29 PM	File folder	
dashboard	5/30/2023 8:07 PM	File folder	
ewms	8/24/2023 10:44 PM	File folder	
img	5/30/2023 8:07 PM	File folder	
system backup	12/16/2023 12:52 AM	File folder	
webalizer	5/30/2023 8:07 PM	File folder	
xampp	5/30/2023 8:07 PM	File folder	
applications.html	6/15/2022 9:37 PM	Chrome HTML Do...	4 KB
bitnami.css	6/15/2022 9:37 PM	Cascading Style S...	1 KB
ewms - Copy14.zip	11/17/2023 7:54 AM	Compressed (zipp...	26,579 KB
favicon.ico	7/16/2015 9:02 PM	ICO File	31 KB
index.php	7/16/2015 9:02 PM	PHP File	1 KB

Figure A.3: EWMS application files in the 'htdocs' directory of XAMPP

Figure A.4 shows configuration of config.php file with appropriate database connection details.



C:\xampp\htdocs\ewms\system\Database\Config.php - Notepad++

File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?

Config.php

```
<?php

/**
 * This file is part of CodeIgniter 4 framework.
 *
 * (c) CodeIgniter Foundation <admin@codeigniter.com>
 *
 * For the full copyright and license information, please view
 * the LICENSE file that was distributed with this source code.
 */

namespace CodeIgniter\Database;

use CodeIgniter\Config\BaseConfig;
use Config\Database as DbConfig;
use InvalidArgumentException;

/**
 * Class Config
 */
class Config extends BaseConfig
{
    /**
     * Cache for instance of any connections that
     * have been requested as a "shared" instance.
     *
     * @var array
     */
    protected static $instances = [];
```

Figure A.4: config.php file with appropriate database connection

Access the system by navigating to http://localhost/ewms/web in a web browser (Figure A.5).

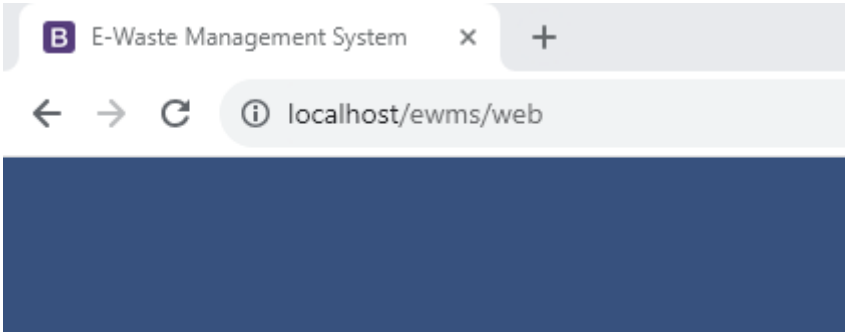


Figure A.5: Access the system by navigating to localhost

Appendix B – Design and implementation

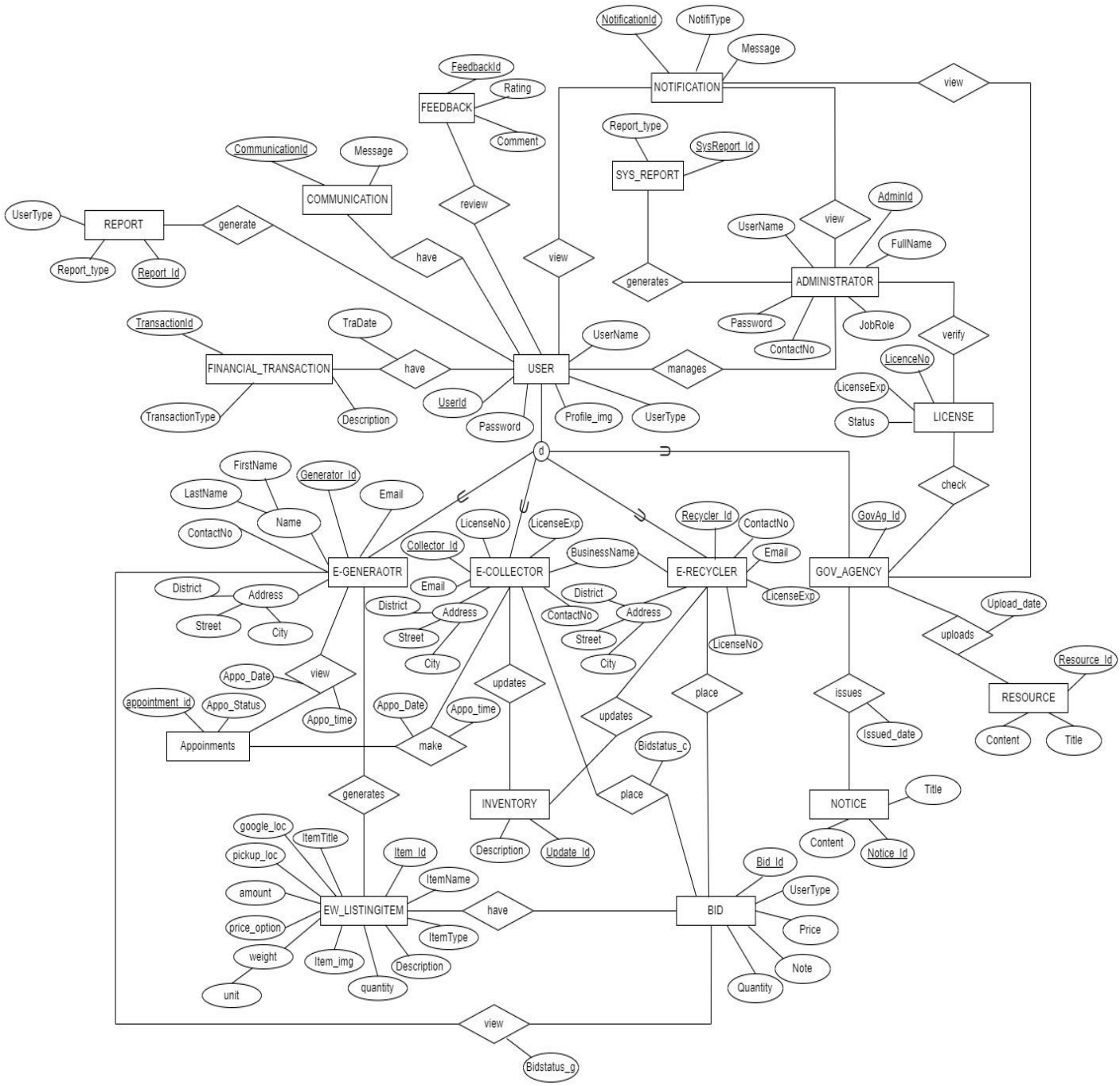


Figure B.1: ER diagram for EWMS database

Appendix C – User documentation

E-Waste Management System (EWMS)

1. Registration Form (Generator/Collector/Recycler/Government Regulatory Agency)

Access http://localhost/ewms/web in a web browser. As shown in Figure C.1 home page will display.

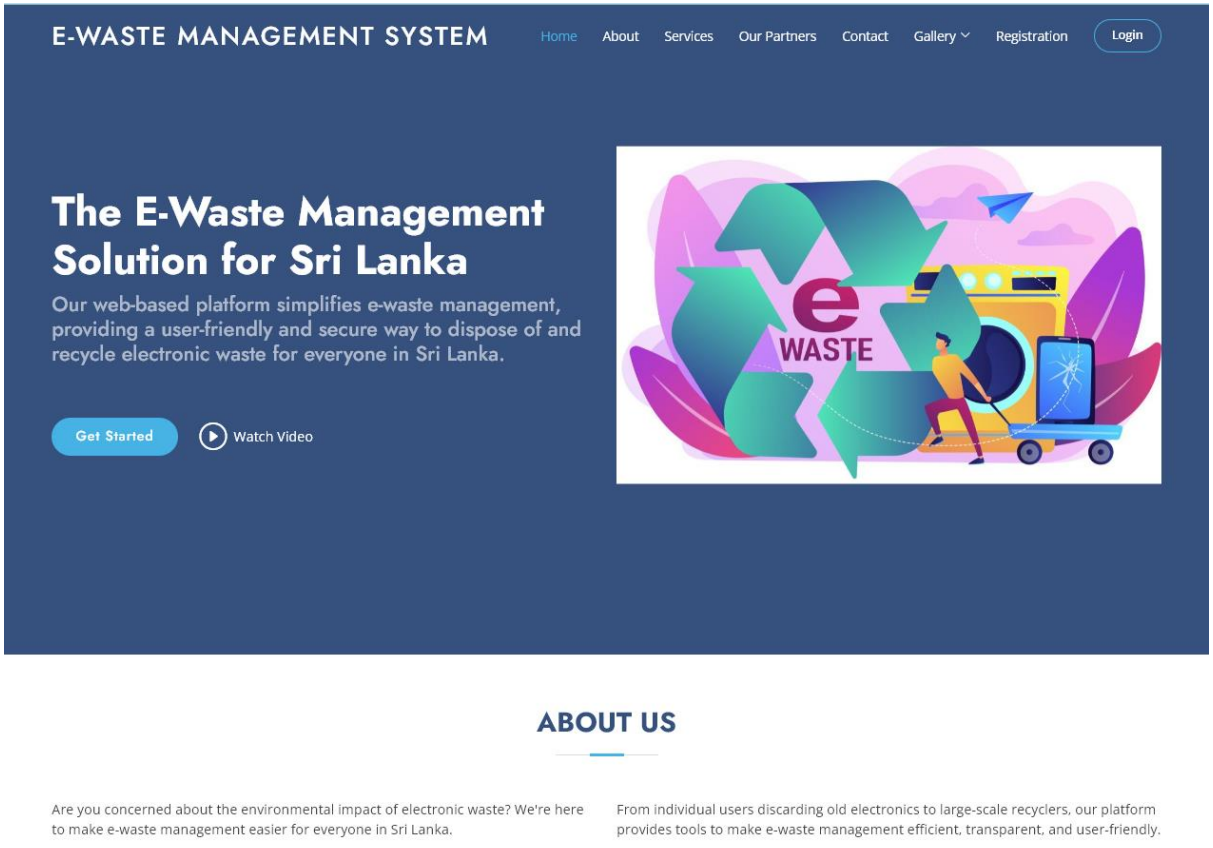


Figure C.1: Home page of EWMS

Choose the appropriate user role for registration. Figure C.2, C.3 and C.4 shows following users who are not currently registered with this system are given the opportunity to register.

As an e-waste generator

As an e-waste collector

As an e-waste recycler

As a government regulatory agency

Fill in the required information and submit the registration form.

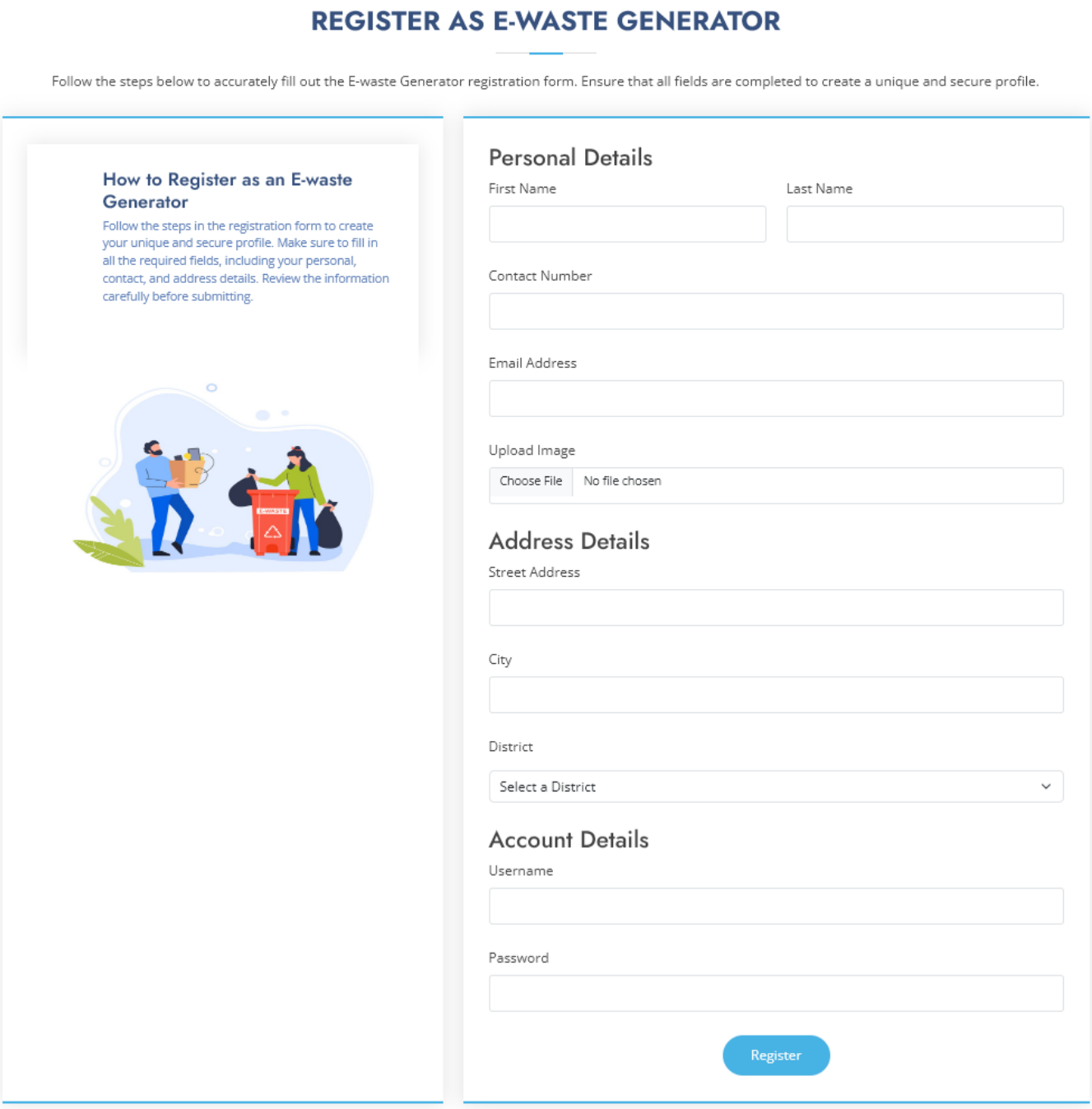


Figure C.2: Registration form for e-waste generator

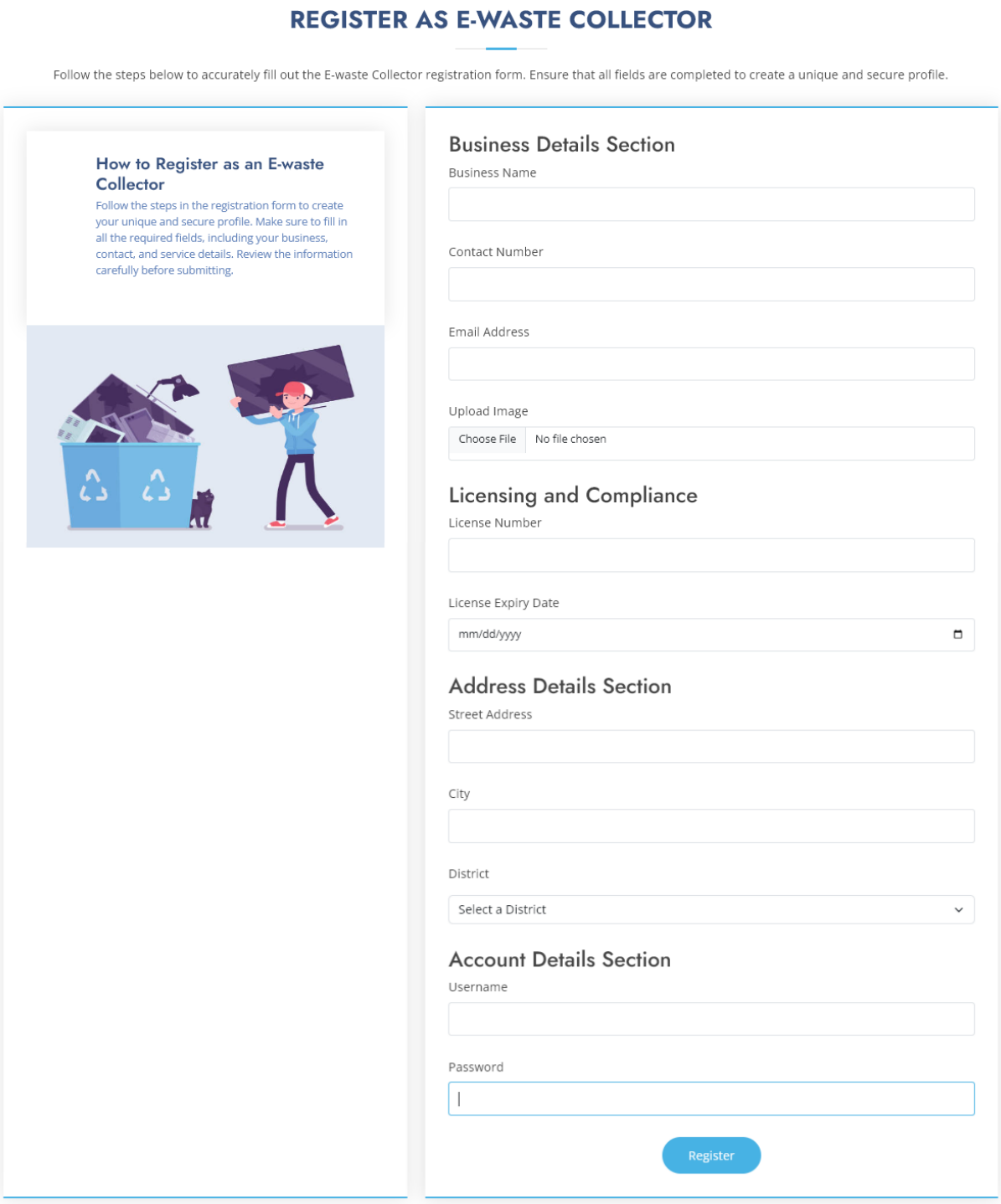


Figure C.3: Registration form for e-waste collector

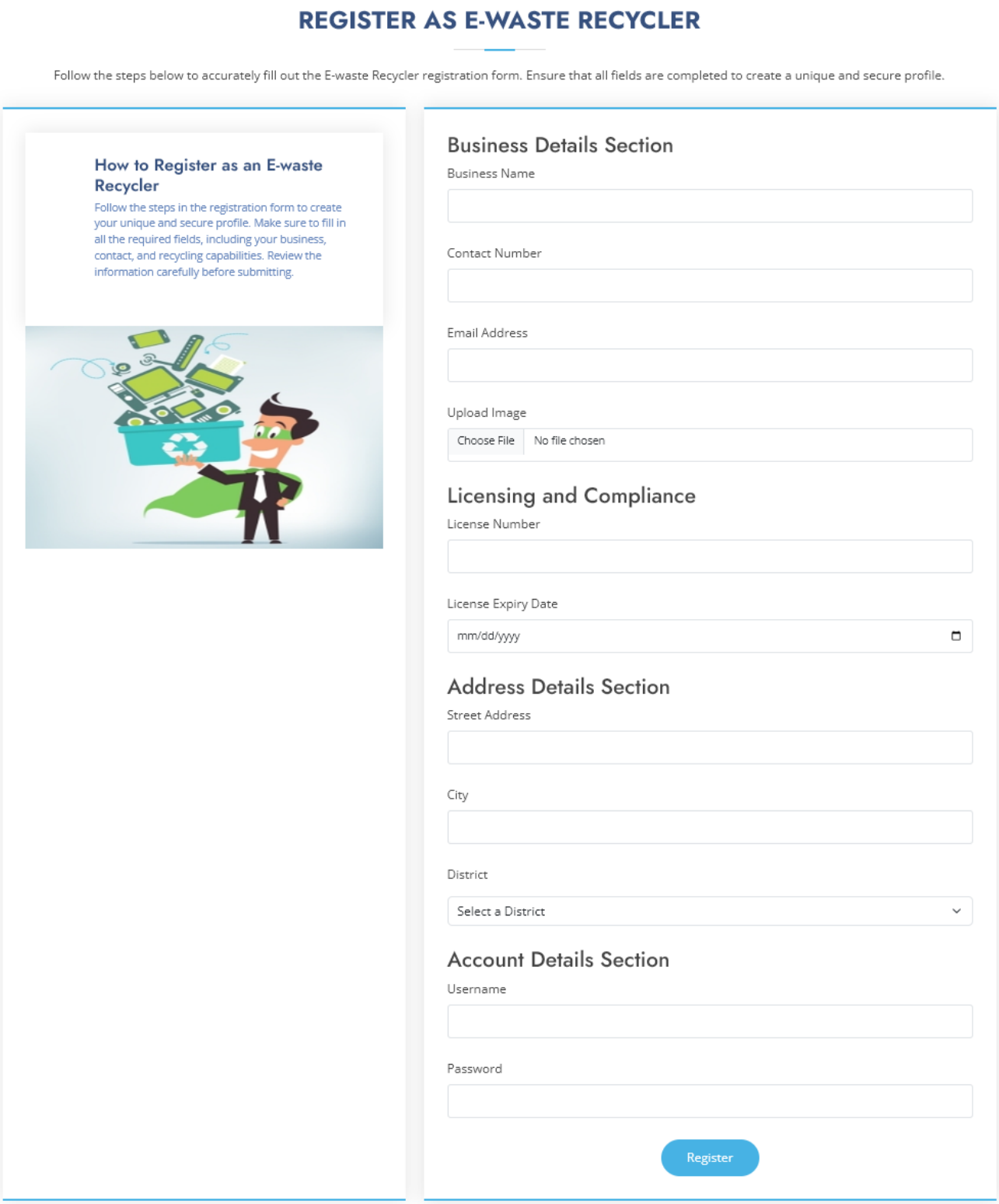


Figure C.4: Registration form for e-waste recycler

Login Form:

Click on the Login button in the upper right corner of the home page. Enter your username and password in the login form (Figure C.5) to access your user dashboard.

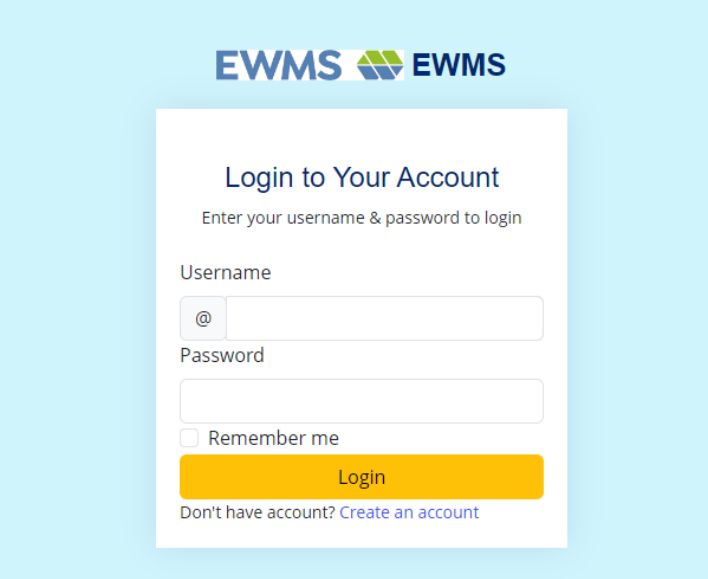


Figure C.5: EWMS system login form

Dashboard:

After logging in, the main dashboard displays, with functionalities accessible via the left menu bar. The dashboard layout varies based on the user role. The primary functionalities are accessible via the left menu bar. Depending on the user role, the main dashboard changes, and the left menu bar also change. Figure C.6 shows the dashboard of e-waste recycler.

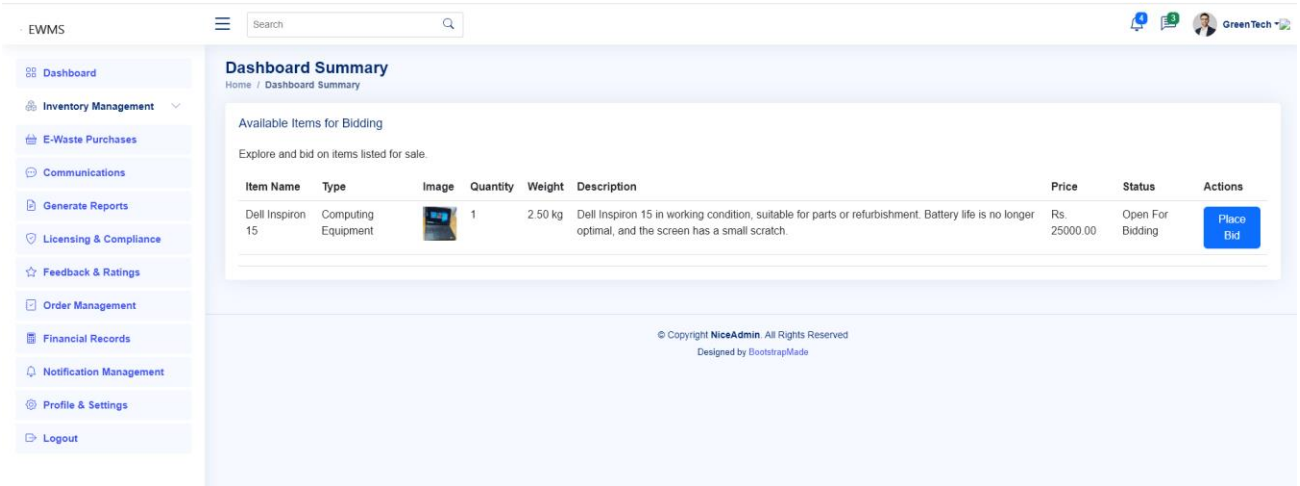


Figure C.6: Dashboard of e-waste recycler

E-Waste Listing (For Generators):

Navigate to the e-waste listing section. Add new e-waste items with descriptions, photos, and specifications as shown in Figure C.7. Monitor and manage your e-waste listings.

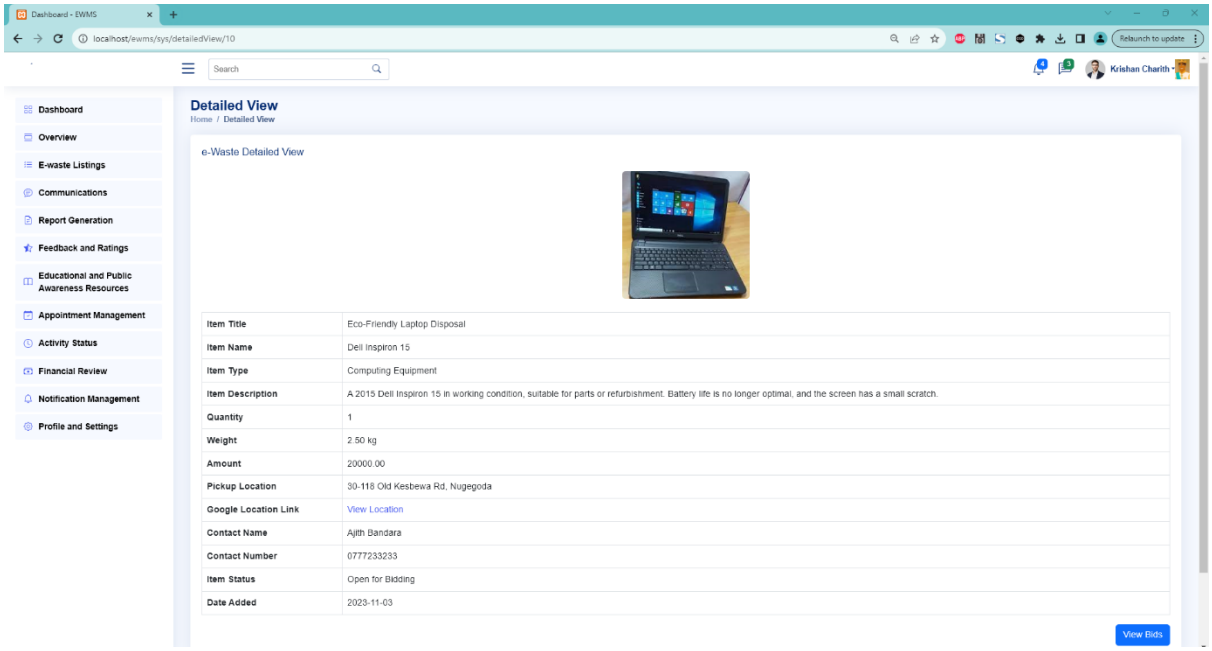


Figure C.7: E-waste listing added in the EWMS

E-Waste Bidding (For Collectors):

View available e-waste listings from generators. Place bids on e-waste items. Manage your bids and interact with generators (Figure C.8).

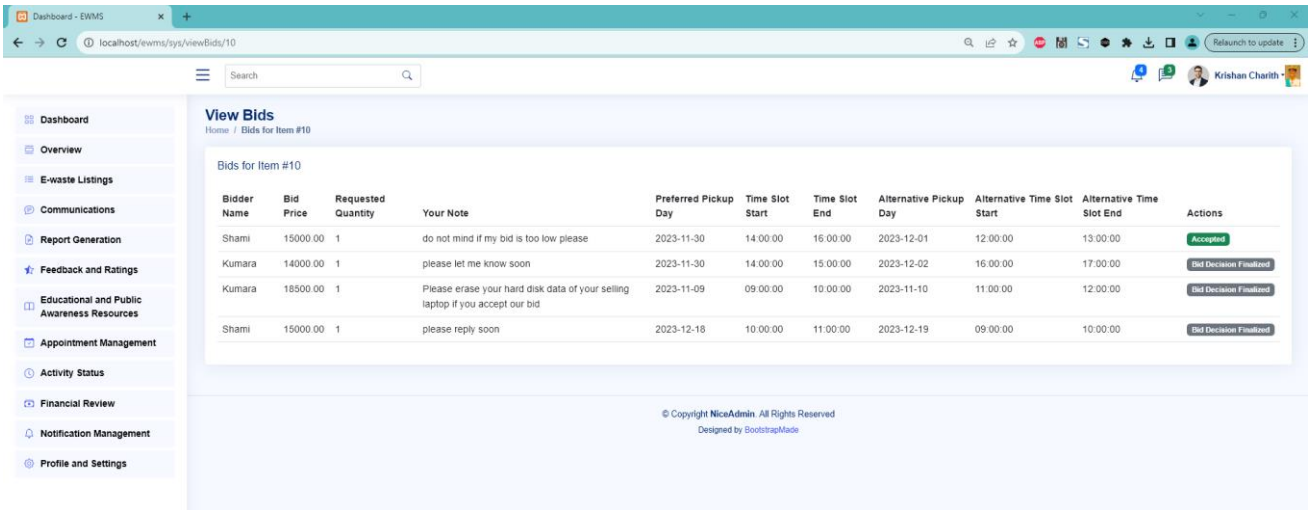


Figure C.8: E-waste bidding placed in the EWMS

User Role Functionalities:

Administrator: System oversight, user account management, report generation.

E-Waste Generator: Listing e-waste, managing bids, tracking transactions.

E-Waste Collector: Bidding on e-waste, scheduling pickups, inventory management.

E-Waste Recycler: Purchasing e-waste, managing recycling inventory.

Government Regulatory Agency: Regulatory oversight, compliance tracking, report generation.

Appendix D - MIS Report

E-Waste Generator

E-Waste Listing and Financial Overview Report

For: PC Tech Solutions

Reporting Period: September 2023

1. Monthly Listing Overview

Monthly Listing Overview: September 2023

Total Listings Count for September 2023: **15**

Category and Type Breakdown:

Category	Number of Listings
Mobile & Personal Devices	3
Computing Equipment	2
Audio & Video Equipment	1
Gaming & Entertainment Systems	0
Office Electronics	2
Batteries	1
Household Appliances	2
Lighting	1
Cables & Connectors	0
Miscellaneous Electronics	0

Listing Status Insights:

Status	Count
Total Listed	12
Active	5
Completed	5
Cancelled	1
Deleted	1

Figure D.1: Monthly Listing Overview for E-Waste at PC Tech Solutions in September 2023

Figure D.1 provides a detailed overview of e-waste listings for PC Tech Solutions during September 2023. The report indicates a total of 15 listings spread across several categories, including Mobile & Personal Devices, Computing Equipment, and Office Electronics, among others. Additionally, it offers insights into the listing statuses, distinguishing them into active, completed, canceled, and deleted categories.

2. Bid Analysis Summary for September 2023

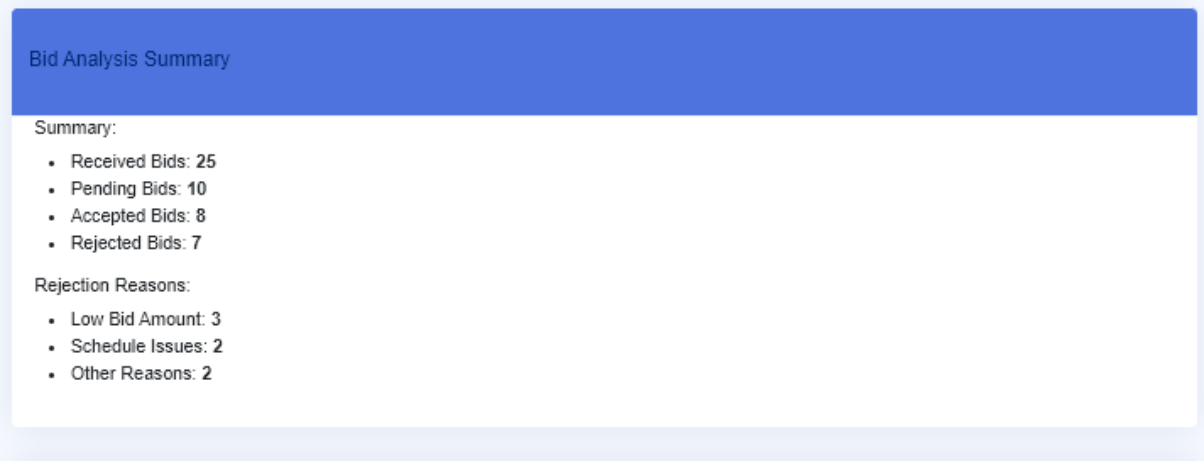


Figure D.2: Bid Analysis Summary for September 2023

Figure D.2 presents a comprehensive summary of the bid analysis for PC Tech Solutions in September 2023. The analysis reveals that the company received a total of 25 bids for its e-waste listings. Out of these, 10 bids are still pending, indicating ongoing negotiations or decisions. The company accepted 8 bids, demonstrating successful agreements between PC Tech Solutions and the bidders. However, 7 bids were rejected due to various reasons, including low bid amounts and scheduling issues, highlighting the challenges in the bidding process. This bid analysis provides valuable insights into the effectiveness and efficiency of PC Tech Solutions' e-waste management and sales strategy.

3. Overall Listings and Income Analysis:

Overall Listings and Income Analysis (January - September 2023)

Month	Total Listings	Total Income (Rs.)
January	12	Rs. 108,000
February	14	Rs. 126,000
March	13	Rs. 117,000
April	15	Rs. 135,000
May	11	Rs. 99,000
June	16	Rs. 144,000
July	14	Rs. 126,000
August	13	Rs. 117,000
September	15	Rs. 135,000

Figure D.3: Overall Listings and Income Analysis (January - September 2023)

Figure D.3 offers an in-depth analysis of the overall listings and income for PC Tech Solutions from January to September 2023. The analysis illustrates the monthly fluctuations in both the number of listings and the generated income, showcasing a pattern that highlights the company's operational efficiency and market performance throughout the nine months. This data not only reflects the company's ability to generate revenue from e-waste management but also indicates the seasonal or market-driven changes in the demand for e-waste disposal and recycling services.

E-Waste Collector

E-Waste Collection and Financial Overview Report

For: GreenTech Collecting

Reporting Period: September 2023

1. Collection Activity Analysis:

Collection Activity Analysis: September 2023

Pickup Summary for September 2023: **30 Collections**

Number of e-waste generators served: **10**

E-Waste Category Analysis:

Category	Number of Collections
Mobile & Personal Devices	3
Computing Equipment	2
Audio & Video Equipment	1
Gaming & Entertainment Systems	0
Office Electronics	2
Batteries	1
Household Appliances	2
Lighting	1
Cables & Connectors	0
Miscellaneous Electronics	0

Figure D.4: Collection Activity Analysis for GreenTech Collecting in September 2023

Figure D.4 showcases GreenTech Collecting's efforts in e-waste collection throughout September 2023, with a total of 30 pickups. It highlights the company's service to 10 different e-waste generators and breaks down the collections by category, including Mobile & Personal Devices, Computing Equipment, and Office Electronics. The analysis offers insights into the types of e-waste most commonly collected, underscoring the company's focus and efficiency in managing diverse e-waste categories.

2. Bid Winning Rate Overview:

Bid Winning Rate Overview: September 2023

Overall Bid Winning Rate for September 2023:

Sent Bids	Won Bids	Win Rate (%)
120	45	37.5%

Category-wise Bid Winning Rate:

Category	Sent Bids	Won Bids	Win Rate (%)
Mobile & Personal Devices	30	12	40%
Computing Equipment	25	9	36%
Storage & Media Devices	20	6	30%
Audio & Video Equipment	22	10	45.5%
Gaming & Entertainment Systems	10	5	50%
Office Electronics	20	5	25%
Networking Equipment	15	3	20%
Batteries	11	6	54.5%
Household Appliances	10	6	60%
Lighting	20	13	65%
Cables & Connectors	10	7	70%
Miscellaneous Electronics	8	6	75%

Figure D.5: Bid Winning Rate Overview for September 2023

This Figure D.5 offers a comprehensive overview of bid-winning rates for September 2023, including both overall and category-wise success rates. The overall bid winning rate stands at 37.5% for the month, with a detailed breakdown by category showing variations in success across different types of e-waste. Categories like Cables & Connectors, and Miscellaneous Electronics exhibit the highest win rates, providing insights into the competitive landscape and effectiveness of bid strategies.

3. Inventory Management Insights:

Inventory Management Insights: End of September 2023

Total Items in Inventory: **150**

Highest Stocked Category: **Computing Equipment (40 Items)**

Lowest Stocked Category: **Lighting (10 Items)**

Category-Wise Inventory:

Category	Number of Items
Mobile & Personal Devices	25
Computing Equipment	40
Storage & Media Devices	15
Audio & Video Equipment	20
Gaming & Entertainment Systems	10
Office Electronics	18
Networking Equipment	12
Batteries	15
Household Appliances	22
Lighting	10
Cables & Connectors	8
Miscellaneous Electronics	5

Figure D.6: Inventory Management Insights as of End of September 2023

Figure D.6 presents a summary of inventory management insights for GreenTech Collecting as of the end of September 2023. It reports a total of 150 items in inventory, with Computing Equipment being the highest stocked category and lighting the lowest. The category-wise inventory breakdown further elucidates the distribution of e-waste items, aiding in strategic planning and operational decisions for the company.

E-Waste Recycler

E-Waste Recyclers Comprehensive Analysis Report

For: EcoRecycle Hub

Reporting Period: September 2023

1. Inventory Management and Recycling Efficiency:

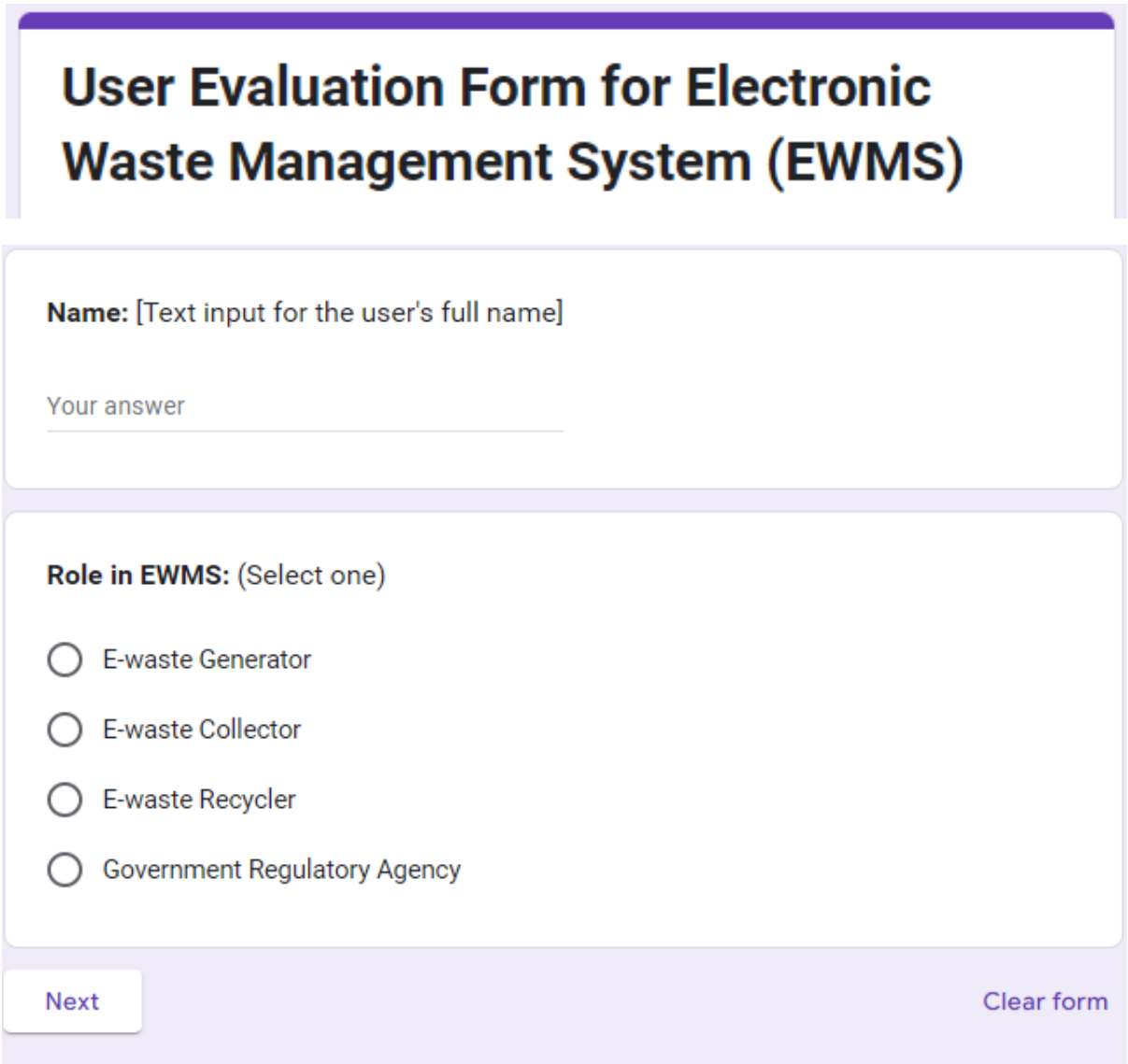
Inventory Management Insights: End of September 2023

E-Waste Category	Purchased Item Sets	Recycled Set Quantity	Recycle Reports submissions
Mobile & Personal Devices	50	25	5
Computing Equipment	80	40	21
Storage & Media Devices	30	15	9
Audio & Video Equipment	40	20	8
Gaming & Entertainment Systems	20	10	7
Office Electronics	36	18	11
Networking Equipment	24	12	5
Batteries	30	15	4
Household Appliances	44	22	15
Lighting	20	10	3
Cables & Connectors	16	8	11
Miscellaneous Electronics	10	5	6

Figure D.7: Inventory Management and Recycling Efficiency for EcoRecycle Hub in September 2023

Figure D.7 provides a detailed analysis of EcoRecycle Hub's recycling endeavors for September 2023, illustrating the inventory management of purchased and recycled e-waste items across different categories. The report highlights the number of items purchased, quantities recycled, and the submission of recycle reports, indicating the operational efficiency and recycling impact of EcoRecycle Hub across a broad spectrum of e-waste categories.

Appendix E - User Feedback Questionnaire



User Evaluation Form for Electronic Waste Management System (EWMS)

Name: [Text input for the user's full name]

Your answer

Role in EWMS: (Select one)

- E-waste Generator
- E-waste Collector
- E-waste Recycler
- Government Regulatory Agency

Next

Clear form

Appearance

Overall visual appeal of the EWMS interface

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Effectiveness of color schemes and graphics

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Readability of text and font size

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Layout and design intuitiveness

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Usability

Ease of navigating through the system

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Clarity and helpfulness of instructions and prompts

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Ease of learning how to use the system

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Effectiveness of search and filter functions

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Functionality

Accuracy and reliability of system processes

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Completeness of features required for e-waste management

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

System's ability to handle diverse e-waste management tasks

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Effectiveness in meeting user-specific needs (based on role)

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Performance

Response time and speed of the system

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Integration and compatibility with other software/tools

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Reliability of real-time updates and notifications

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Efficiency in processing and updating e-waste listings

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

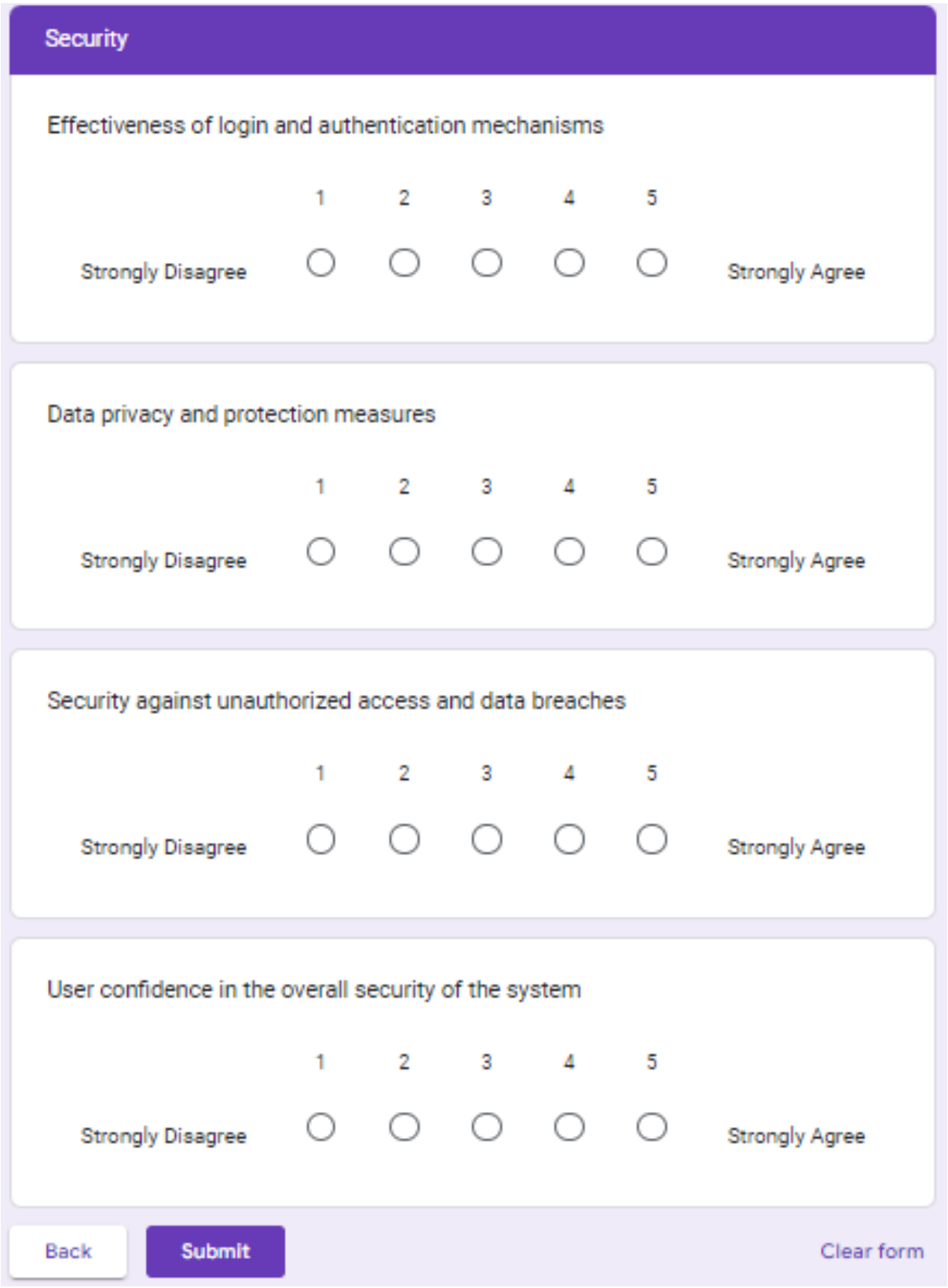


Figure E.1: User feedback questionnaire