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An Analysis of Waste Management Systems to produce a web-based system to help in the collection, transportation and dumping of waste.
(Eco-Waste Solutions Company Limited case study).

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Abstract

This report presents an in-depth analysis of waste management systems to develop a comprehensive web-based solution to facilitate the collection, transportation and dumping of waste. Focused on addressing the specific needs of Eco-Waste Solutions Company Limited, this case study delves into the challenges and opportunities within waste management, emphasizing the importance of technological advancements in enhancing efficiency and sustainability. Through thorough research and evaluation of existing waste management practices, this report outlines the key functionalities and features necessary for the development of an effective web-based system. By leveraging innovative technologies and best practices, the proposed solution aims to streamline waste management processes, improve operational efficiency and contribute to environmental sustainability.

Preface

As we stand at the forefront of an era defined by environmental consciousness and sustainable practices, the imperative for effective waste management solutions has never been more pronounced. This preface sets the stage for the exploration into the creation of a web-based waste management system tailored to meet the needs of Eco-Waste Solutions Company Limited. Within these pages, it embarks on a journey to dissect the intricacies of waste management, leveraging insights from industry expertise, technological innovation and real-world case studies. The project not only addresses the challenges faced by Eco-Waste Solutions but also contributes to the broader discourse on sustainable waste management practices.

Acknowledgement

In crafting this report, I find myself compelled to express my gratitude to those whose support and guidance have been instrumental in shaping this project.

Above all, I express my gratitude to my supervisor MR. SYLVAN DOGBEY for his unwavering guidance and mentorship throughout this project.
I am also indebted to MR. Nii Hammond for his valuable contributions during the conceptual ideation of this project.

Lastly, I extend my sincere appreciation to my family who have supported and encouraged me throughout this journey. Their unwavering support has been a source of strength and motivation, and I am truly grateful for their presence in my academic and professional life.

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1. Introduction

1.1. Background

The evolution of waste collection systems throughout history has played a key role in addressing challenges that threaten public safety, environmental sustainability and rural/urban development. One notable example is the transformation of waste management practices in 19th-century London, where the Great Stink of 1858 catalyzed change. The terrible stench emanating from sewages and overflowing landfills prompted urgent action, leading to the development of revolutionary waste solutions. The lessons learned from such historical challenges continue to shape today's modern approach to developing sustainable waste management systems to support thriving civilizations.

As populations grow and consumption patterns change, the volume and complexity of waste generated have escalated, posing a significant threat to public health, environmental integrity and socioeconomic stability. It falls upon waste management companies such as **Eco-Waste Solutions Company Limited** to grapple with this mounting challenge, as it is tasked with the responsibility of collecting, transporting and dumping waste in vast quantities, all while still ensuring proper procedures and laws are followed.

In response to these pressing problems, the development of new waste management systems has become imperative. However, creating a waste management system with the power of software to tackle such challenges is very difficult.

This is because, a waste management system refers to a coordinated set of practices, processes, infrastructure and policies designed to handle and dispose of waste safely. This system encompasses various stages such as the generation/generator, collection, transportation and disposal.

1.2. Current System

The problem with **Eco-Waste Solutions Company Limited's** current systems is that it relies heavily on manual processes despite the advancements in technology, which could be used to simplify some of its tasks. The manual system involves human labour at all stages of waste management, from collections to disposal and even for its business processes such as keeping records, data management, billing and payment processing, fleet management, customer communications and regulatory compliances.

Furthermore, record keeping is a fundamental aspect of waste management operations, which ensures accurate documentation and tracking of various activities. Workers known as **clerks**, are responsible for maintaining records related to waste collection schedules, quantities and types of waste collected, as well as customer information and service requests. These records are managed using paper-based systems, requiring manual data entries and organizing. To meet legal requirements,

paper documents such as permits, licenses and environmental assessments are manually managed with the current system.

The system also extends to the maintenance and repair of equipment used in the waste management operations. Workers are responsible for conducting regular inspections and addressing any issues or malfunctions that arise. This hands-on approach ensures that equipment such as collection vehicles remains operational and efficient.

1.3. Aims of the Project

The project proposes a novel web-based application to address historic challenges in eco-waste solutions. It aims to centralize waste collection processes, tackling four key issues: digitalizing data for real-time access and security, optimizing routes with GPS, enforcing regulatory compliance and enhancing worker communication and customer convenience. This approach promises streamlined operations, reduced errors and improved efficiency as shown in **Figure 1**.

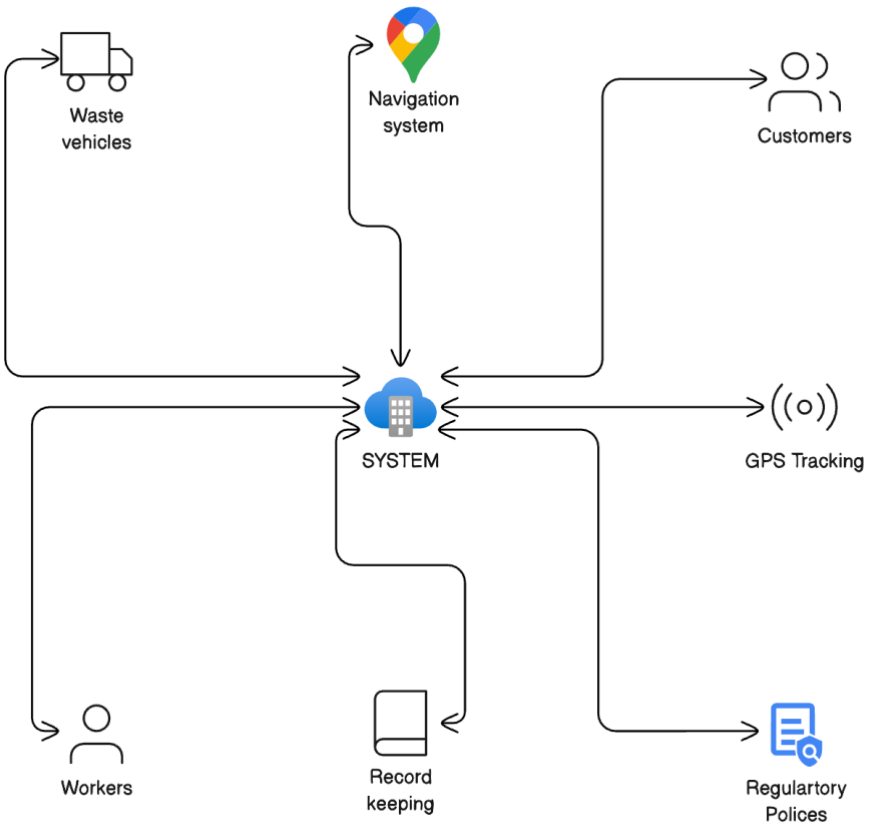


Figure 1 – A centralized hub as the proposed waste management system

1.4. Objectives

The key goals identified as essential to the project are:

1. **Conduct a Systematic Research** [Week 1-2]
    - Research waste management systems to understand their benefits, problems and why it's important
    - Examine the unique challenges confronting waste management stakeholders' issues
    - Investigate recent developments in waste management technologies to discern emerging trends and potential innovations
    - Analyse case studies and empirical data to identify successful waste management strategies and best practices adopted by different regions or industries.

2. **Analysis** [Week 3-4]
    - Identify specific business needs and expectations of Eco Waste Solution Company through a stakeholder analysis (rich picture)
    - Utilize various techniques such as Questioning to gather insights into requirements
    - Translate the business requirements into functional specifications for the waste management system using Moscow.
    - Create diagrams to illustrate the product ideated.

3. ***Design*** [Week 5-6]
    - Create a high-level conceptual model outlining the structure, components and interactions of the system. (wireframes and fidelity Prototype)
    - Define the database schema to organize and store waste management data efficiently, ensuring scalability and performance.
    - Determine the relationships between different data entities and enforce constraints to maintain data integrity and consistency.
    - considerations for data privacy and security measures implemented within the database schema design

4. ***Implementation*** [Week 7-8]

- Develop administrative and other users' functionalities to support user roles and permissions within the system
- Implementing a robust login with encryption and log monitoring
- specific security measures implemented to mitigate potential security threats and ensure data confidentiality and integrity
- Integrate the MySQL database with the user interface components to enable seamless data interaction and presentation

5. ***Testing*** [Week 9-10]

- Conduct database testing to ensure data integrity, reliability and performance
- Test all functionality to verify accuracy, reliability, and compatibility with the system
- Perform different testing standards to assess usability, accessibility, and responsiveness.
- Iterate on testing results to identify and resolve problems or discrepancies, refining the system for optimal performance

6. **Evaluation and Conclusion** [Week 10-11]

- Provide a summary of the key findings and outcomes of the project, highlighting achievements and insights gained.
- Offer recommendations for future improvements, enhancements, and extensions based on the project's findings and experiences.
- Conclude the project by reflecting on the journey, lessons learned, and implications for the field of waste management.

1.5. Approach

Many methodologies and frameworks assist software engineers in structuring their work to produce complex systems. As a result of this, they provide a roadmap for the entire development process, from the initial planning to deployment and maintenance.

Agile Scrum is the chosen methodology for this project. What is this methodology? It is a framework that prioritises adaptability and delivering value incrementally (Hidalgo, 2018).
The project was divided into short iterations or sprints, each lasting two weeks. During each sprint, tasks were identified, prioritized, and worked on based on their complexity and importance to **MoSCow**.

1.5.1. The Project Life Cycle Using Agile Scrum.

1. **Initiation**: The project begins with an initiation phase where the product vision, goals and scope are defined. Various data collection methods are used on stakeholders to gather requirements and create a prioritized backlog of user stories and requirements.

2. **Creating Backlogs**: Detailed and prioritized backlogs ensure that specific features and functionalities of the waste management system are clearly outlined based on **MOSCOW** and the **80/20 rule**. **Prototyping** is also done at this stage. This provides a roadmap for development and guides efforts throughout the project.

3. **Timelines and Milestones**: The project timeline was divided into multiple sprints (**timeboxes**), each focused on delivering specific features and requirements. Milestones were established at the beginning of each sprint, providing clear goals and objectives to be worked towards. Regular reviews and retrospectives were conducted at the end of each sprint to evaluate progress and identify areas for improvement.

4. **MVP Approach (Minimum Viable Product)**: Prioritizing the development of a Minimum Viable Product enabled the delivery of a

functional version of the system sooner. By focusing on essential requirements in the **must-have** first, the MVP approach allows for iterative improvements and faster development.

5. **Test-Driven Development (TDD)**: Implementing this practice involves writing tests before implementing features, ensuring the reliability and robustness of the codebase. By systematically writing tests to validate functionality, TDD helps in the early detection and resolution of defects in the development cycle, fostering more resilient and maintainable software.(Raicevic, 2023)

1.5.2. Why Agile Scrum? (Justification of this Methodology)

The decision to implement Agile Scrum for this project wasn't made in a vacuum. Several factors played a key role. Various methodologies were explored before finally settling on this methodology. Below is a deep dive into the reasoning behind using Agile Scrum and how it aligns with the goal of developing a waste management system for Eco- waste solutions limited.

1) **Its Flexibility and Adaptability**: Its approach allows for complex systems such as a waste management system to undergo frequent iterations and adjustments based on feedback from supervisors, industry experts, and stakeholders. This enables quick responses to requirements and helps prevent deviations (Drury-Grogan, 2013).

2) **Iterative Development**: The nature of iterative development in Agile scrum, aligns well with developing a waste management system, where requirements may evolve as the project is tested and refined. As a result of breaking the project into manageable pieces and working on it incrementally, the percentage of delivering a valuable product, that meets stakeholders' needs and requirements is high (Darrell Rigby, 2016).

2. Literature Review

This Chapter serves as a foundational exploration into the realm of waste management, contextualizing the significance of the project at hand. By critically evaluating past and present research within the field, this chapter aims to justify the project's unique contribution. Thus, this introductory chapter lays the groundwork for the subsequent exploration and analysis within the field of waste management.

2.1. Approach to Literature Search

In conducting the literature review, a systematic approach was employed to identify and evaluate relevant sources that informed our research on waste management systems. We utilized a variety of sources and search strategies to ensure comprehensiveness and rigour in the review process **(See Appendix A**).

The literature search used academic repositories such as PubMed, Scopus, Web of Science and Google Scholar which provided access to peer-reviewed journals and conference proceedings through a comprehensive list of keywords and search terms extracted from preliminary readings, which were utilized in the literature review process

Table 1

Keywords of Literature Review		
Sustainable waste	Waste history	Waste technologies
Waste regulations	Smart waste	Waste collection
Urban Waste Management	Environmental Impact	Ghana waste management

Additionally, we consulted relevant books and reports from reputable organizations such as the Environmental Protection Agency (EPA) World Bank and the UOG library.

Through this process, we identified a series of articles that addressed the environmental and social implications of waste management practices in urban settings, providing valuable insights for our research. A detailed selection criteria is available in **Appendix A**

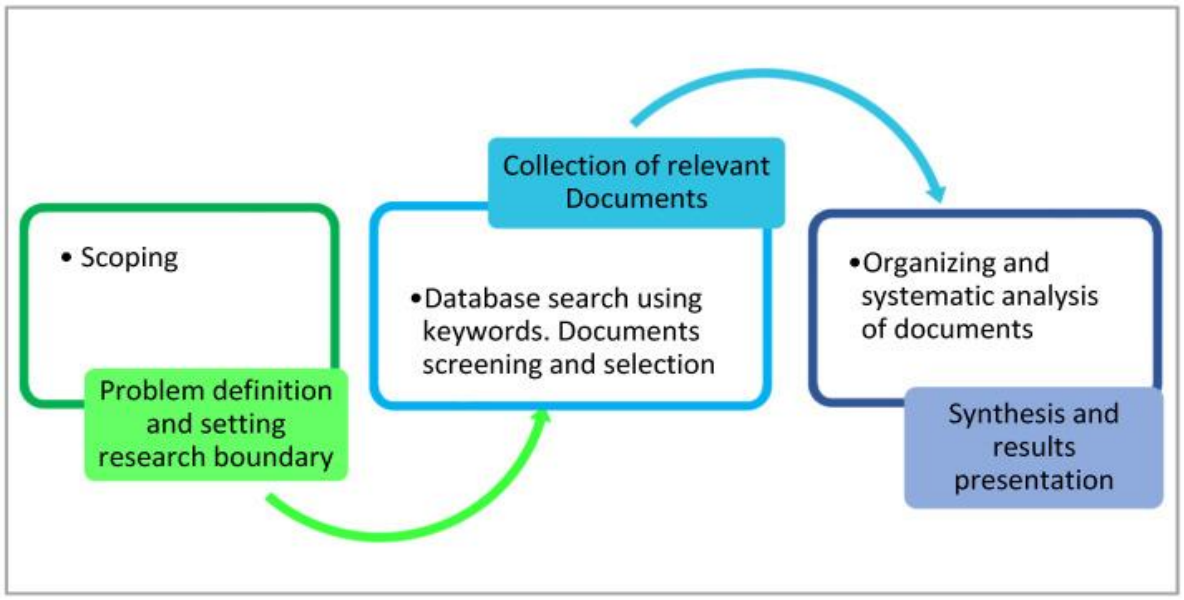


Figure 2 -Approach Used in Literature Research

2.2. History of Waste Management Systems

Waste management systems have been integral to human societies since ancient times. The Dung beetle exemplifies early natural waste disposal mechanisms, suggesting that prehistoric humans likely recognized the benefits of efficient waste management. Ancient civilizations in Mesopotamia, and Egypt implemented basic waste disposal methods, while Rome and Athens had designated waste collection areas. The Middle Ages saw structured waste regulations in some European cities, though practices remained primitive (Gephart, 2010).

The Industrial Revolution marked a significant shift, with urbanization and industrialization spurring increased waste generation. Municipal waste collection and incinerators emerged in the 19th century, with the invention of the garbage truck revolutionizing collection methods in the early 20th century. Advancements continued into the mid-20th century, with the introduction of sanitary landfills, recycling programs and wastewater treatment plants, driven by environmental awareness and legislation (Barles, 2014).

However, In the 1950s and 1960s, waste management in Ghana was primarily focused on basic collection and disposal methods, with little regard for environmental impact. However, as urbanization accelerated in the latter half of the 20th century, particularly in cities like Accra and Kumasi, the need for more structured waste management systems became increasingly evident. In light of increasing waste and environmental concerns, the Ghanaian government and various organizations began implementing initiatives to improve waste management practices. One significant milestone in Ghana's waste management history occurred in the 1980s with the establishment of the Waste Management Department (WMD) under the Ministry of Local Government and Rural Development. The WMD played a key role in coordinating waste management activities nationwide and promoting sustainable waste management practices (NATIONAL REPORT FOR GHANA, 2010).
Throughout the 1990s and early 2000s, several waste management companies emerged in Ghana, including Zoomlion Ghana Limited and the Waste Management Department of the Accra Metropolitan Assembly which aids municipal authorities in waste collection and disposal.

Recent years have seen further evolution in waste management technologies, with innovations like smart waste bins and sensor-based collection systems enhancing efficiency and sustainability. However, waste management in Ghana remains the same, requiring ongoing infrastructure improvements, effective regulations, and public awareness campaigns.

In conclusion, the history of waste management underscores the importance of proactive measures and collaborative approaches to address waste-related challenges and promote environmental sustainability. Despite advancements, ongoing efforts are necessary to ensure effective waste management practices in Ghana and beyond (Kuitunen, 2003).

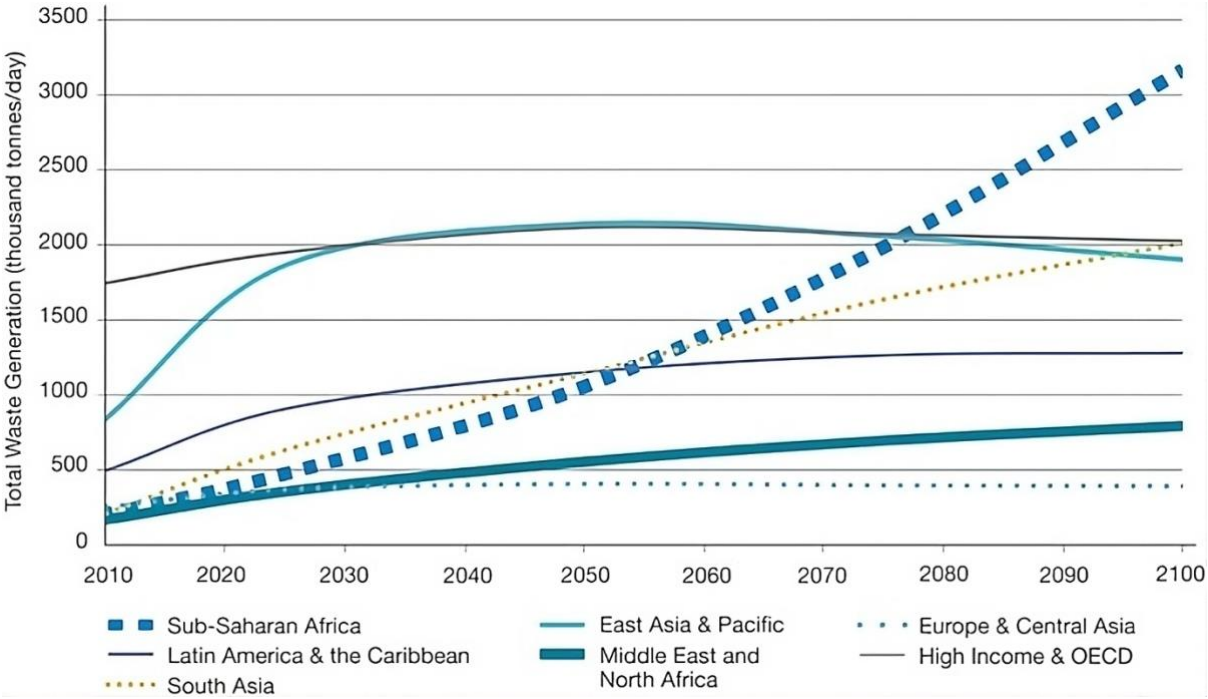


Chart 1 – ***Total Solid waste generated by region***

*This chart by '**Region development in Africa**' article, shows that the Sub-Saharan Region (Ghana's Region) is likely to be generating 3000,000 tonnes of solid waste per day by 2090 (Linda Godfrey, 2019).*

2.3. Understanding Waste Management Systems and its Inefficiencies.

Waste management systems encompass a complex network of processes which involves collection, transportation and disposal of waste materials(Wilson, 2018). However, the effectiveness of these systems varies widely, leading to disparities in outcomes and impacts (Kaza, 2018).

At its core, the challenge of waste management lies in handling ever-increasing waste volumes while minimizing negative impacts on human health, ecosystems and communities. Rapid urbanization, population growth and industrial expansion have exacerbated this challenge by causing a surge in waste generation, putting immense pressure on existing infrastructure and resources (Hoornweg, 2012)

Here are some common types of waste management systems and their problems.

1. **Traditional Waste Collection and Disposal -** This system involves the basic collection and disposal of waste, typically through methods such as landfilling or incineration. Waste is collected from households, businesses and public spaces using conventional waste collection vehicles and transported to designated disposal sites. These approaches result in the loss of valuable resources, pollution of air, soil and water, and has long-term environmental impacts (Y. L. Pan, 2020).

2. **Smart Waste Management Technologies:** Such systems leverage cutting-edge technologies like the Internet of Things (IoT) and sensors to optimize waste collection, monitoring, and resource allocation. These systems enable real-time tracking of waste generation, bin fill levels, and collection routes, allowing for more efficient and data-driven decision-making. However, challenges such as high initial investment costs, interoperability issues, and data privacy concerns may hinder their widespread adoption and effectiveness (Sandro Nižetić a, 2019)

3. **Source Separation and Recycling Programs;** In this system, waste is sorted and separated at the source (e.g., households, businesses) into different categories such as recyclables, organic waste and non-recyclable materials. Offering a more sustainable alternative but can suffer from inefficiencies related to contamination, inadequate infrastructure and low public participation. Without proper education and outreach, communities may struggle to effectively separate recyclable materials, leading to decreased recycling rates and increased waste sent to landfills (Omkar Aphale a, 2015)

4. **Composting and Organic Waste Management;** Organic waste is processed through composting facilities, where it undergoes decomposition to produce nutrient-rich compost, which can be used as soil amendments or fertiliser. This system faces obstacles such as limited access to composting facilities, lack of organic waste diversion programs, and issues with odour and pest control. Inefficient composting practices can result in the loss of organic nutrients and contribute to greenhouse gas emissions (ARGUN, 2017)

2.1. Challenges Faced by Waste Management Companies

Eco Waste Company along with its municipalities and communities encounter a myriad of challenges in their efforts to manage waste effectively.

Firstly, waste management systems suffer from outdated or insufficient infrastructure to handle the growing volume and complexity of waste. This includes inadequate waste collection vehicles, landfill sites and recycling centers. In regions with poor infrastructure (poor Ghanaian communities), waste collection may be irregular or non-existent, leading to waste accumulation in public spaces and increased environmental pollution (Silva, 2019).

Secondly, Waste management services often operate on limited budgets, making it challenging to invest in essential infrastructure upgrades, equipment maintenance and personnel training (Eneji, 2020). Limited funding can also hinder the implementation of innovative technologies and sustainable waste management practices, perpetuating reliance on traditional methods which are often inefficient. This case is more serious in a developing country such as Ghana where Eco Waste Company operates.

Furthermore, compliance with regulations and standards governing waste management practices can pose significant challenges for stakeholders of Eco Waste Company. These regulations may vary widely across jurisdictions and may be subject to frequent changes, making it difficult for the waste management company to maintain compliance while also meeting operational and financial objectives. Regulatory barriers may also inhibit the adoption of innovative waste management technologies and practices. Furthermore, most of these regulations are not well defined and leave room for ambiguity, which creates uncertainty for the stakeholders (Silva L. C., 2023).

Lastly, Urbanization, population growth, and industrial expansion contribute to the escalating volume and diversity of waste generated, placing additional strain on waste management systems. Rapidly growing urban areas face serious challenges in managing municipal waste (construction and demolition debris, and industrial by-products). Furthermore, the lack of proper urban planning strategies continues to make this a challenge for the Eco Waste Company (Hoornweg D. &.-T., 2017).

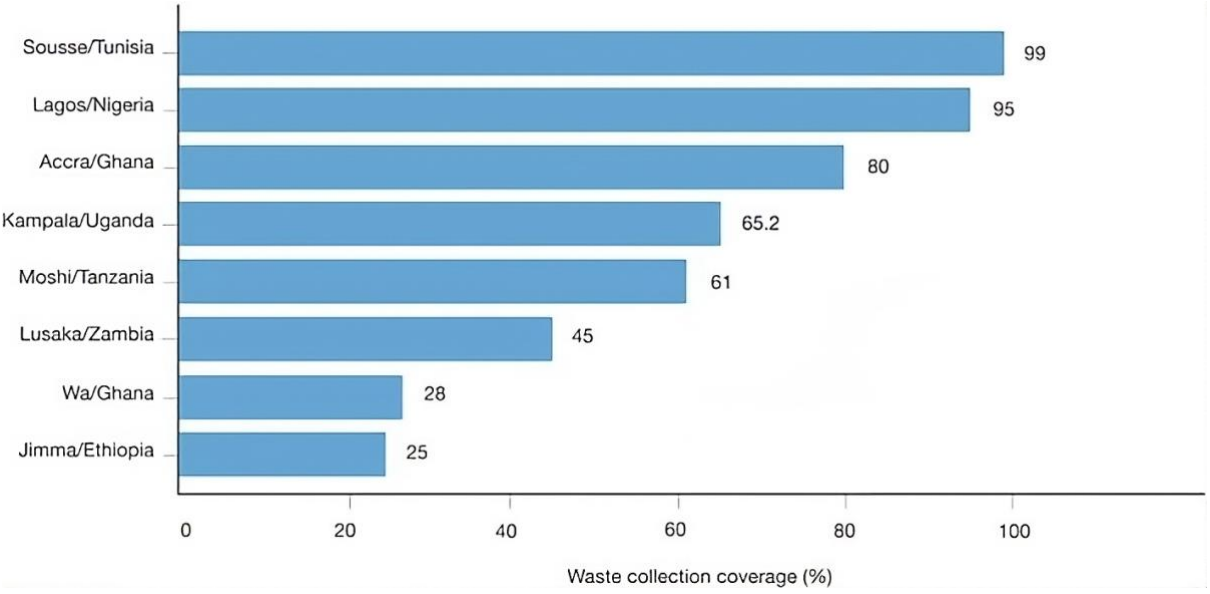


Chart 2 – ***Waste Collection Coverage per Country***

*Chart 2 by '**Region development in Africa**' article, shows that 80% of Accra/Ghana has their waste collected and 28% of WA/Ghana has their waste collected (Linda Godfrey, 2019).*
This supports the argument that in regions with poor infrastructure (WA/Ghana), waste collection may be irregular or non-existent and urbanization in Accra has contributed to large volumes of waste.

2.2. Recent Trends in Waste Management Practices:

In recent years, the landscape of waste management has undergone a remarkable transformation, driven by technological innovations, sustainability and regulatory reforms. This section delves deeper into the multifaceted trends that have reshaped waste management practices:

2.2.1. **Technological Advancements:** The integration of cutting-edge technologies has indeed revolutionized every aspect of waste management, transforming traditional practices into efficient and sustainable processes.

- The adoption of IoT (Internet of Things) integration has been instrumental in the development of smart waste management systems.

- **GPS technology** further augments these systems by providing precise location-tracking capabilities. This ensures the timely and efficient collection of waste across diverse locations, spanning residential, commercial and industrial areas. It also enables optimized routes which reduces fuel consumption and minimizes environmental impact.

- **Automation technologies** have revolutionized waste management operations by streamlining repetitive tasks and reducing reliance on manual labour. It ensures accurate record-keeping and minimizes human error. Moreover, the integration of **computer vision technology** enhances waste sorting capabilities, allowing for automated identification and segregation of different materials based on visual cues. This not only improves sorting accuracy but also bolsters recycling efforts (Lu & Chen, 2022).

- **Software (Web Apps)** has become an integral component of modern waste management systems. These platforms offer stakeholders centralized access to real-time data, analytics tools and communication channels. By leveraging web-based management platforms, waste management companies can monitor collection activities, and track performance metrics. This approach fosters transparency, enhances decision-making and promotes accountability throughout the waste management lifecycle (Eriksson, et al., 2002,).

Table 2. Advantages and Disadvantages of these Technologies

Disadvantages	Advantages	Technology
High maintenance cost	Optimizes waste management processes	**Smart Waste Bins (IoT)**
Uncertainty about the long-term impact on work	Improved efficiency and distinguishing types of waste	**Artificial Intelligence**
Requires initial investment, ongoing maintenance costs.	Enhances routing efficiency, reducing fuel consumption.	**GPS**
Difficulties in verifying the content of the application	Processes automation, real-time data analysis, ease of interaction	**Web based software**

2.2.2. **Industry-Wide Shifts Towards Sustainable Practices:** In response to rising environmental challenges and the urgent need to mitigate climate change, there has been a notable shift towards more sustainable and circular approaches to waste management. This shift is driven by increasing awareness of the finite nature of resources and the imperative to reduce carbon emissions and environmental degradation associated with traditional waste management practices (Cooper, 2017).

There is a focus on pollution from vehicles used to collect and move waste. To tackle this, waste management companies are looking into using electric or hybrid vehicles instead of ones that run on fossil fuels. This helps cut down on greenhouse gases and reduces the reliance on fossil fuels. Additionally, route optimization algorithms and smart logistics solutions are being employed to optimize collection routes, reduce fuel consumption and minimize vehicle emissions (LaGrega, 2010).

2.2.3. **Regulatory Changes and Policy Initiatives:** Regulatory frameworks governing waste management have undergone significant revisions to align with evolving sustainability objectives to address pressing environmental concerns. Governments and regulatory bodies worldwide have enacted stringent measures aimed at reducing landfill dependency, promoting resource recovery, and incentivizing sustainable waste management practices. Legislation mandating extended producer responsibility (EPR) and product stewardship programs has shifted the onus of waste management onto producers, encouraging product design for recyclability and promoting closed-loop supply chains. Additionally, policies incentivizing renewable energy production from waste and imposing landfill taxes have spurred investment in waste-to-energy technologies and alternative waste treatment methods (EU, 2023)

Chart 3 - ***Rising trend in African Countries making new laws to govern waste***

Chart 3 ***'Marine Policy'*** *article, shows the trend of African Countries (Ghana) enacting policies/ bans against plastic waste (Jenna Jambeck, 2017)*

2.3. Analyzing “South Korea's Pay-As-You-Throw (PAYT) System” as a Case Study on Successful Waste Management Systems

“South Korea's Pay-As-You-Throw (PAYT) system” represents a successful waste management strategy aimed at waste reduction through a direct financial connection between waste generation and collection fees. Under this system, residents purchase designated trash bags with varying capacities, incentivizing them to minimize waste generation. Furthermore, waste segregation into distinct categories such as food scraps, recyclables, and general waste encourages responsible disposal practices. Seoul, in particular, has achieved an impressive recycling rate exceeding 65% due to the implementation of PAYT, supported by extensive public education initiatives and a well-established waste management infrastructure.

The success of the PAYT system lies in its ability to provide financial motivation, thereby instilling a sense of individual responsibility for waste management among residents. However, concerns regarding affordability for low-income households underscore the need to address potential social inequities associated with this approach. Additionally, the effectiveness of the PAYT system is bolstered by complementary policies promoting the use of reusable products and establishing producer responsibility.

While directly replicating PAYT may require adjustments to the Eco-Waste Company’s system, its underlying principles offer valuable insights for driving global waste collection efforts. After analyzing the case of South Korea's PAYT system, we can identify key strategies and best practices that contribute to successful waste management outcomes for the Eco-waste management system (Bhada-Tata, What a waste , 2014).

2.4. Conclusion

In conclusion, the journey of this project has been marked by a systematic approach to identifying and addressing the challenges within the waste management domain. Through a comprehensive review of past and current research, the project identified the overarching problem encompassing waste management inefficiencies. The project objectives were carefully formulated to tackle these challenges.

Moreover, the research and investigation conducted were firmly grounded within the context of addressing the identified problem domain. By examining recent trends in waste management practices and exploring technological advancements, the project ensured a holistic understanding of the complexities inherent in waste management systems. Finally, the case study has also shared a different approach to waste management practices which will be taken into account when developing the system.

Moving forward, the insights gained and the solutions developed will serve as a foundation for further advancement in the waste management system.

3. Product Research

This Chapter delves into understanding and reviewing existing waste management systems and extracting insights that will shape the development of the proposed solution. Through meticulous analysis and evaluation, we aimed to design and implement a waste management system that not only meets the needs of the stakeholders but also sets a new standard for efficiency, sustainability and innovation in the field.

Below is a list of 3 similar products;

3.1. WasteHero (Product 1)

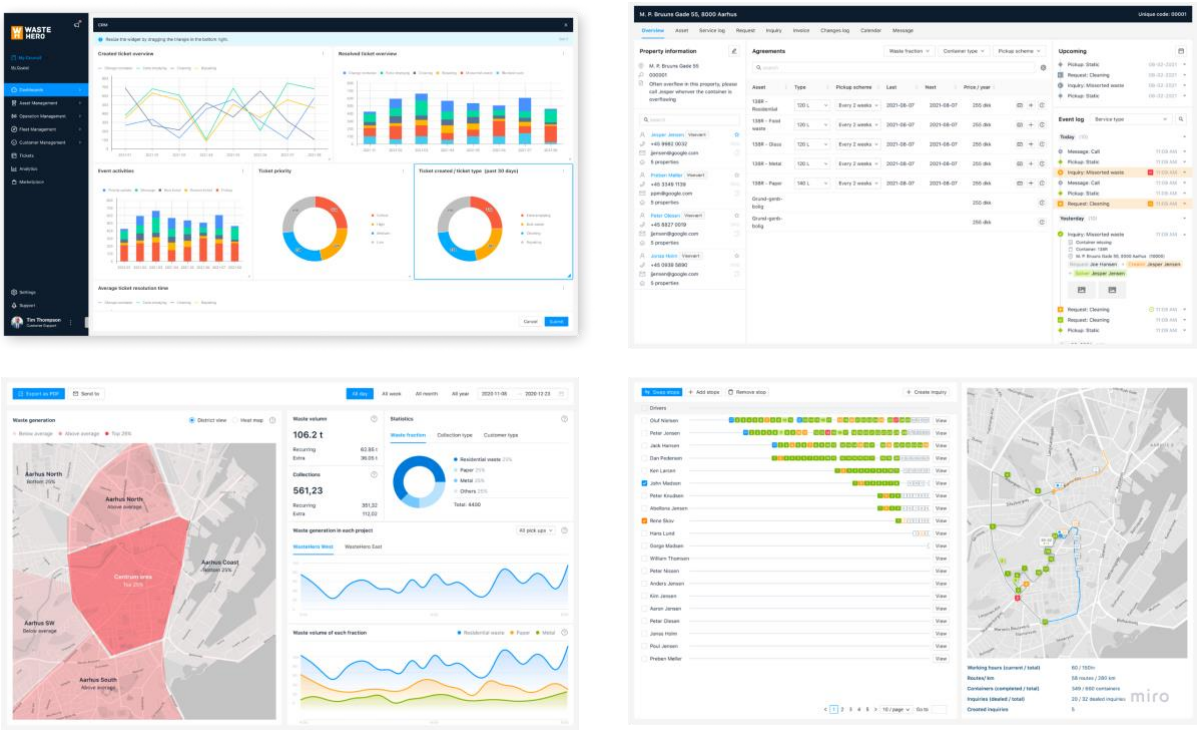


Figure 3

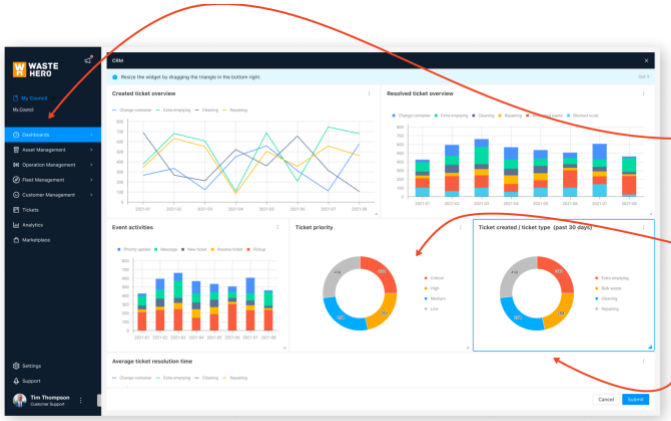
(WasteHero, 2023)

Waste Hero is a waste management software platform that provides modular software and hardware solutions to help waste management organizations digitally transform their operations. It offers features such as route planning, fleet management, asset management and customer service systems. It aims to streamline daily workflows, provide data-driven insights and improve productivity (WasteHero, 2023).

Even though WasteHero is an amazing product, it may be too complex and feature-rich for a small company such as Eco Waste Solution Company. The extensive customization options and integrations could be overkill for the Eco–Waste Solution company with smaller fleets, routes and budgets.

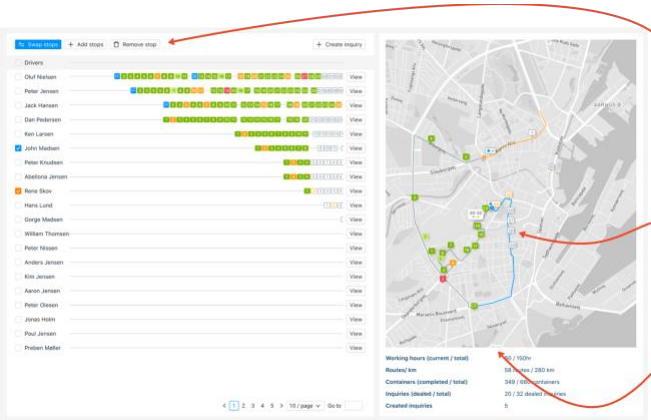
LINK: https://wastehero.io/

3.1.1. Appearance and Functionalities of Waste Hero



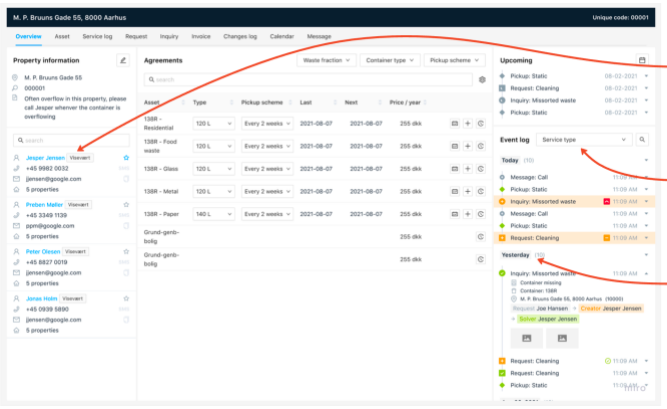
- **Clear hierarchy and labeling:** The information is organized into sections with clear headings like "My Council," "Asset Management," "Customer Management," etc. This makes it easy for users to find the information they need quickly. According to Hick's Law, users take longer to make decisions when presented with more choices. By clearly labeling sections, the dashboard reduces cognitive load.
- **Limited color scheme:** The dashboard primarily uses a blue and white color scheme, which is easy on the eyes and promotes a professional look. Color can be a powerful tool in interface design, but using too many colors can be overwhelming.
- **Card-based layout:** The information is presented in cards, which visually separates different sections and makes it easy to scannable.

Figure 4



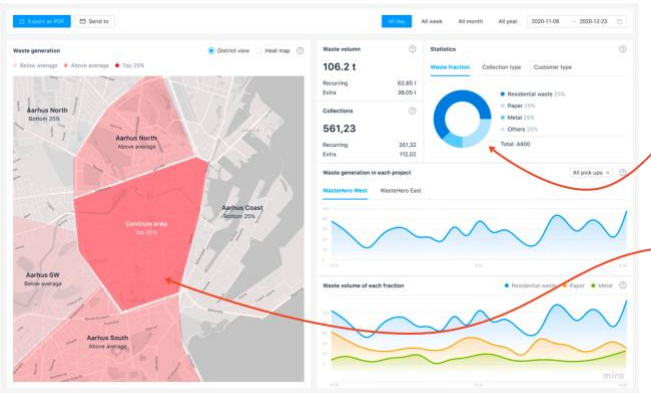
- **Limited Map Controls:** The dashboard likely presents a limited set of map controls to avoid overwhelming users and prioritize the core functionalities of driver tracking and route management. This aligns with the principle of user-centered design, which emphasizes designing interfaces that meet users' needs and avoid unnecessary complexity.
- **Map History :** it consist of a visual element like a timeline or a button allowing users to access past driver locations and routes. This functionality adheres to the user-centered design principle by providing users with information about past activities.
- **Map Placement:** The map appears to occupy a prominent position on the dashboard, likely because it's crucial for functionalities like driver tracking and route management. This placement aligns with the Hick-Hyman Law , which states that users take longer to make decisions when presented with more choices. By placing the map prominently, the dashboard reduces the time it takes for users to find route-related information.

Figure 5



- **User-centered design:** The design prioritizes the needs of the user by making the information clear, easy to find, and easy to understand.
- **Affordance:** The elements on the dashboard afford their functionality, meaning they visually communicate how to interact with them. For instance, buttons look like buttons and text fields look like they can be typed in.
- **Signifiers:** The visual elements signify their meaning. For example, the calendar icon next to "Upcoming" signifies that this section shows upcoming events.

Figure 6



- **Clear Visual Representation:** By leveraging charts and colors, the dashboard presents complex quantitative data in a visually clear and easily digestible manner.
- **Quantitative Reports;** the dashboard uses a combination of visual elements and textual data to effectively communicate quantitative information about waste collection to users. This approach promotes a user-friendly experience and improves data comprehension

Figure 7

3.2. **Lean-path** (Product 2)

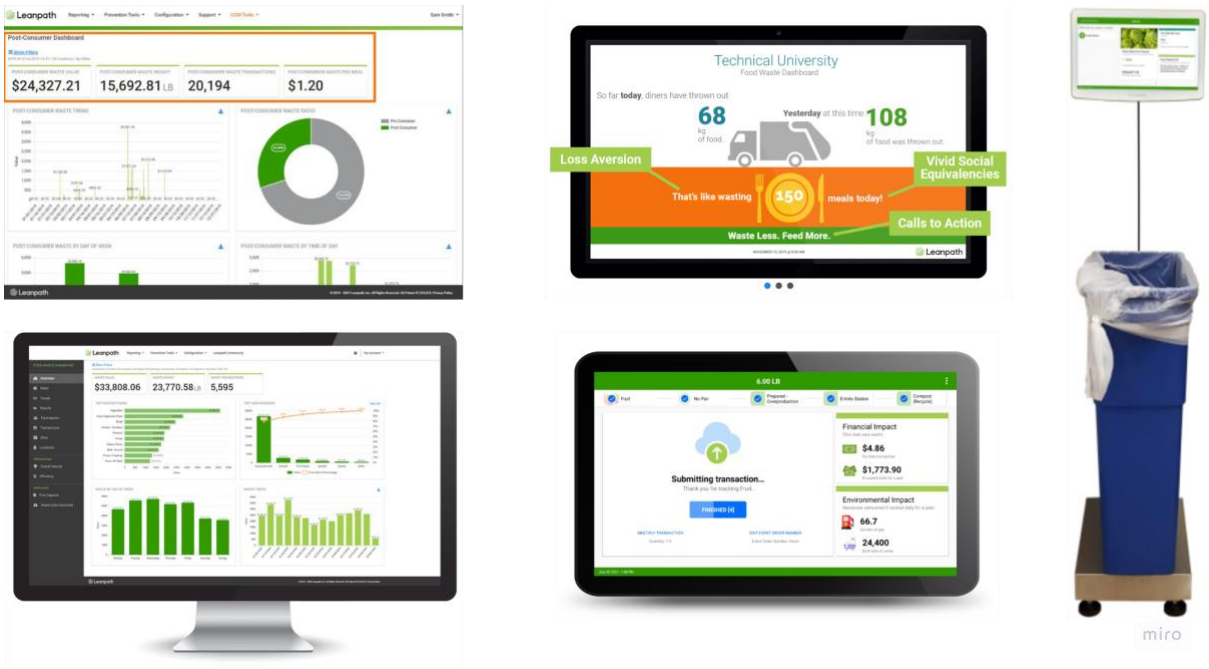


Figure 8

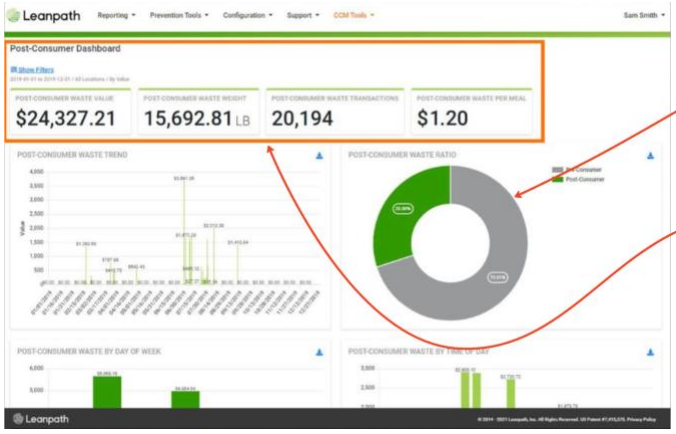
(Leanpath , 2024).

Lean-path is a food waste software application, that allows kitchens to track the amount and reason for food waste, helping them discover opportunities to prevent waste In the future. Leanpath implements a methodical strategy to transform wasteful practices in kitchens, focusing on measurement, identifying causes, and utilizing behavioural techniques. Research indicates that Lean-path enables kitchens to decrease food waste by more than 50% and cut down food purchasing expenses by 2-6%, resulting in a notable 7x return on investment (Leanpath , 2024).

Even though this waste management is very beneficial, it is purposely developed for kitchens only and doesn't have all the needed features for a full waste management system needed for a company like Eco -waste Solutions company.

LINK: https://www.leanpath.com/

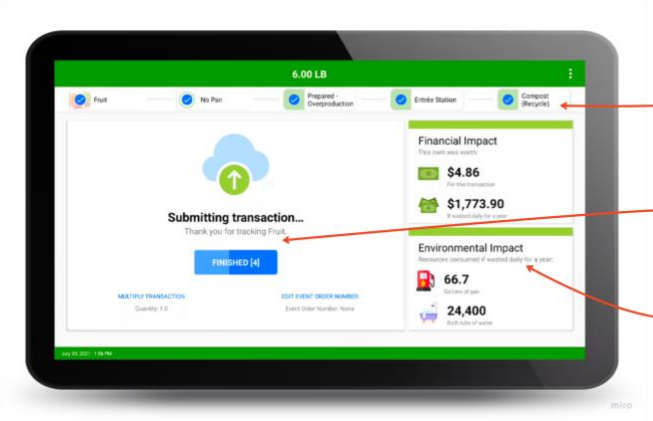
3.2.1. Appearance and Functionalities of Lean-path



- **Data Visualization:** The dashboard prominently features charts like bar graphs and pie charts to represent waste data.Charts can be easier to understand than tables with raw numbers
- **Clean and Uncluttered:** The dashboard uses a white background with minimal elements, reducing visual clutter and making it easy to focus on the data.

miro

Figure 9



- **Progress Bar:** A green bar at the bottom likely represents the completion status of the waste tracking process. This progress bar provides users with feedback on their task completion.
- **Submitting a Transaction:** When a customer or user submits a transaction, they initiate the payment process. This typically involves sending information about the purchase, such as the amount, currency, and payment method, to the system.
- **Terminology:** Waste-related terms like "Overproduction" are displayed, potentially with an option to learn more (indicated by the blue question mark). This balances providing key information with offering additional details for those who want it.

miro

Figure 10

- **Focus on Waste Data:** The screen displays information about the wasted item, its financial and environmental impact, and an event order number for tracking purposes. There are no elements that indicate processing payments, like shopping cart icons, checkout buttons, or references to currency.

miro

Figure 11

3.3. **Waste Accountant** (Product 3)

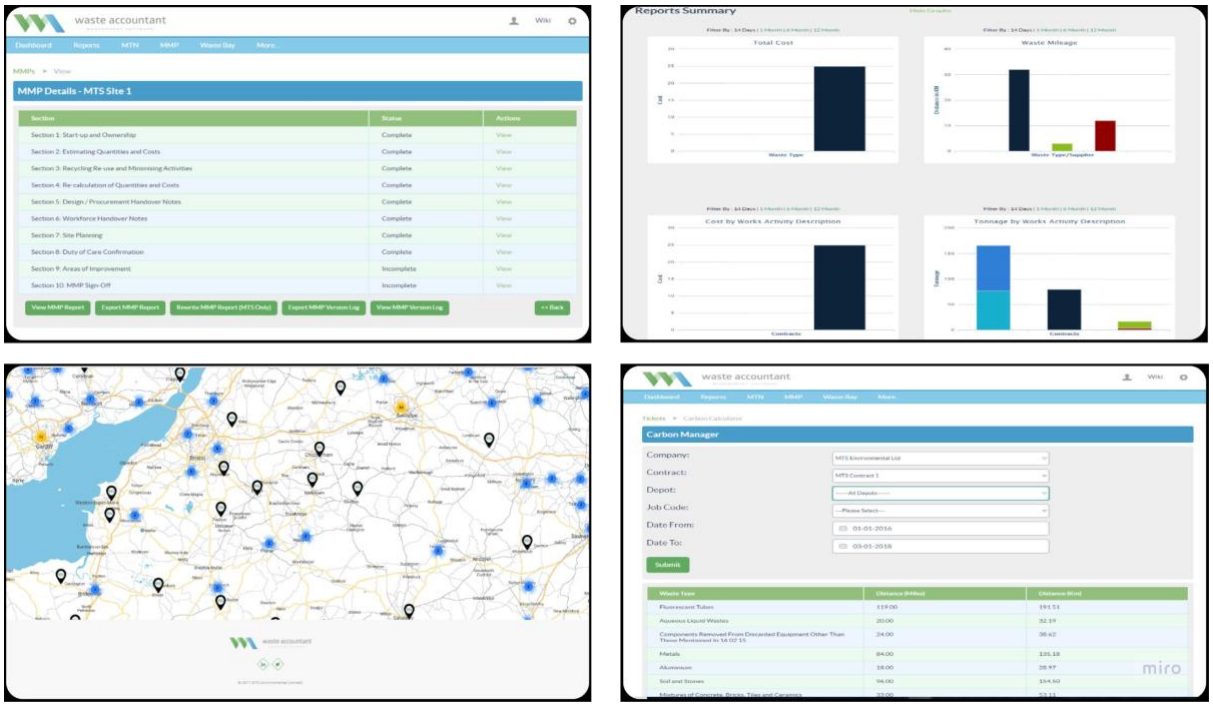


Figure 12

(Waste Accountant, 2017)

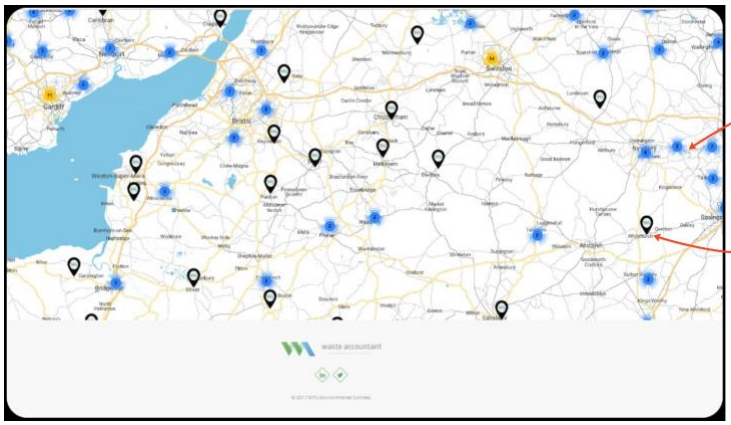
Waste Accountant is a cloud-based waste management system designed to aid companies in reducing their environmental footprint by minimizing landfill waste, decreasing waste transportation, and boosting recycling rates. It facilitates comprehensive waste tracking from generation to disposal, enabling users to enhance their waste management strategies. The software ensures easy data input and secure cloud storage, with reports and analysis tools for cost-saving insights and compliance enhancements (Waste Accountant, 2017).

Notable features include carbon tracking, regulatory waste reporting, and subcontractor data input.

However, Waste Accountant does give companies like Eco-Waste Solution company the ability to have different user roles to use the system. This on the other hand doesn't make the system very secure even though it uses cloud databases.

LINK: https://www.wasteaccountant.com/

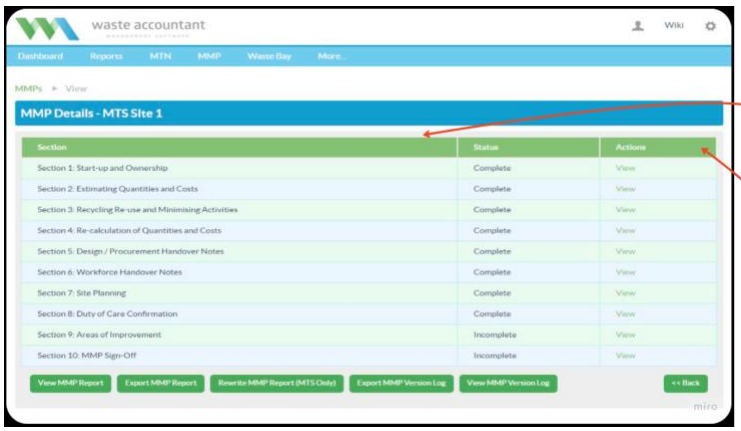
3.3.1. Appearance and Functionalities of Waste Accountant



- **Limited animations or motion graphics:** While not visible in this image, it avoids excessive animations or motion graphics which help prevent cognitive overload for users.
- **Banners Points:** Large banner elements are used to highlight locations on the map.

miro

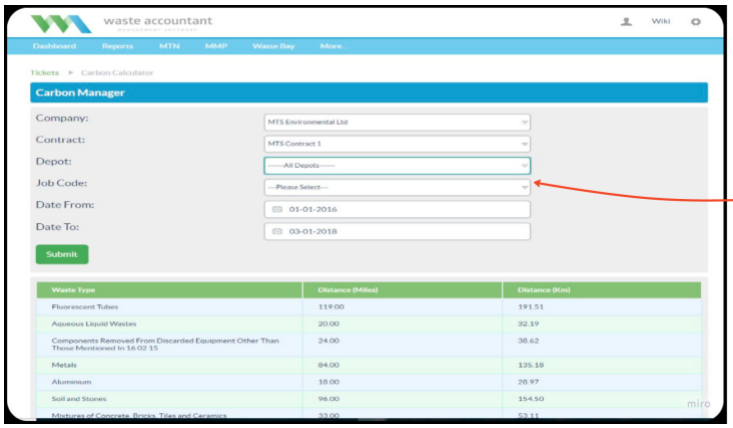
Figure 13



- **Tables:** The dashboard prominently features tables to display data. Tables can be informative way to display information
- **Conditional Formatting:** The tables use conditional formatting to highlight critical information, such as incomplete sections or upcoming deadlines. However, it's important to use conditional formatting judiciously to avoid overwhelming users with too much color variation

miro

Figure 14



- **Input methods:** the form contain input methods such as **drop down menus and date pickers** that will ensure data integrety for the system

miro

Figure 15

3.4. Comparison of Products

The Products are compared based on 3 criteria obtained from the needs of Eco-Waste Solution Company, which were discussed in the **Literature Research**.

Table 3

Criteria	Waste Hero	Lean Path	Waste Accountant
Assistant with Regulatory Compliance	Provides basic compliance features but lacks robust regulatory tools	Focuses on food waste tracking, limited regulatory compliance features	Offers comprehensive regulatory compliance assistance
Scalability	Designed for scalability, suitable for organizations of all sizes	Primarily tailored for kitchen-based operations, limited scalability	Built to scale, accommodating the growth of larger organizations
Technological Improvement	Offers modular software and hardware solutions, emphasizing digital transformation such as GPS and IOT	Integrates innovative technologies to address food waste, but not focused on broader technological advancements	incorporate only a digital map technology for waste management.

3.5. Nielson Heuristic Usability Evaluation

This is a set of 10 principles developed by Jakob Nielsen and Rolf Molich to evaluate the usability of user interfaces. These principles are considered some of the most important guidelines for creating user-friendly and intuitive software (Benaida, 2023).

Table 4

#	Heuristic	Waste Hero	Lean path	Waste Accountant
1.	**Visibility of system status**	The application effectively communicates system status to users through clear feedback mechanisms.	During testing, there was no clear visibility of system status observed, potentially leading to user confusion	Waste Accountant ensures users are informed of system status through intuitive feedback mechanisms.
2.	**Match between system and the real world**	Waste Hero aligns language and icons with real-world counterparts, enhancing user understanding.	Lean path maintains consistency with real-world language, icons, and concepts, facilitating user interaction.	Waste Accountant closely mirrors real-world language, icons and concepts for seamless user experience.
3.	**User control and freedom**	Waste Hero provides users with appropriate buttons and controls, empowering them to	Lean path offers users sufficient control and freedom through intuitive	Waste Accountant ensures users have ample control and freedom to interact with the system, enhancing usability.

		navigate the application efficiently.	interface elements.	
4.	**Consistency and standards**	Waste Hero maintains consistency and adheres to usability standards throughout the platform, contributing to a cohesive user experience.	Lean path adheres to consistent standards across the platform, promoting familiarity and ease of use.	Waste Accountant follows industry standards consistently, ensuring a seamless user experience.
5.	**Error prevention**	Waste Hero's well-designed system effectively prevents major usability-related errors, enhancing user confidence.	No specific error prevention mechanisms were identified during testing, potentially exposing users to usability issues.	Waste Accountant includes robust error prevention measures, minimizing usability-related errors.
6.	**Recognition rather than recall**	Waste Hero's intuitive design minimizes the need for users to recall information,	Leanpath's user-friendly interface reduces cognitive load by presenting	Waste Accountant prioritizes recognition over recall, ensuring users can easily navigate the system without

		enhancing usability.	information in a recognizable format.	relying heavily on memory.
7.	**Flexibility and efficiency of use**	Waste Hero hieratical levels of navigation, makes it flexible and efficient for users with diverse needs.	Leanpath's navigation options are limited, potentially hindering user flexibility.	Waste Accountant's navigation structure may be improved to enhance flexibility and efficiency for users with varying requirements.
8.	**Aesthetic and minimalist design**	Waste Hero's aesthetically pleasing design and minimalist displays contribute to a clutter-free interface, promoting user focus.	Leanpath's simple and clean interface design minimizes distractions, allowing users to focus on essential tasks.	Waste Accountant's focus more on user experience than design elements create an inviting user experience, facilitating user engagement
9.	**Help users recognize, diagnose, and recover from errors**	Waste Hero's error messages aid users in recognizing, diagnosing, and recovering from errors efficiently.	No error messages were encountered during testing, potentially indicating a lack of support for error recognition and recovery.	Waste Accountant includes clear and concise error messages that helps users to resolve issues effectively.

10.	**Help and documentation**	Waste Hero provides limited documentation but offers a feedback section for user input,	Leanpath offers comprehensive documentation to support user needs,	Waste Accountant includes extensive documentation to assist users in navigating the system effectively,

3.6. Conclusion and Findings

In conclusion, this chapter provides a comprehensive review of the existing waste management systems like WasteHero, Lean Path and Waste Accountant, which identified key strengths and weaknesses to inform the development process. Key features and Functionalities that align with the needs of Eco–Waste Solution Company were also discovered.

The comparison of products unveiled areas for improvement and innovation for the proposed project solution. The analysis highlighted the importance of user-friendly interfaces that adhere to Nielsen Norman heuristics. Features like clear error messages, intuitive navigation and real-world terminology will be crucial for user adoption and engagement.

Furthermore, while WasteHero offers extensive features, its complexity makes it difficult to use. Prioritizing features relevant to Eco's scale and operations helps avoid unnecessary functionalities. The proposed system should be adaptable to accommodate Eco's potential growth. Robust compliance features are essential for Eco's operations and should offer comprehensive regulatory reporting tools.

In addition, user role management is crucial; potential security concerns must be addressed. The proposed system must have a visually appealing and minimalist interface, akin to those of WasteHero and Lean Path, which will significantly enhance the user experience and promote system adoption.

Moving forward, the key issues identified in this chapter will be used to enhance the design and implementation of the proposed waste management system. Specifically, it will incorporate robust regulatory compliance features, ensure scalability and usability to accommodate the needs of Eco-Waste Solution Company and integrate cutting-edge technologies to drive innovation and efficiency.

By addressing these key issues, the developed solution will not only meet the requirements of Eco-Waste Solution Company but also set a new standard for efficiency, sustainability, and innovation in the waste management industry.

4. Requirement Analysis

The following Chapter explores how gathered insights from questionnaire surveys and research analysis shape the functional and non-functional requirements of the waste management system. Functional requirements specify system functions, while non-functional ones detail construction and design considerations like performance and scalability. It Further details what has been decided based on stakeholder input and delves into the rigour process of requirement specifications based on MosCow and the 80/20 rule. Analytical techniques used, including Use case diagram and Rich picture are discussed

4.1. Survey Analysis

This approach to data collection offers a systematic and effective way of gathering information from a considerable number of participants. The designed Questions (**Available in Appendix B**) set standardized questions to collect shareholders' opinions about the waste management system and to solicit requirements for the proposed system (Francisa, 2017).

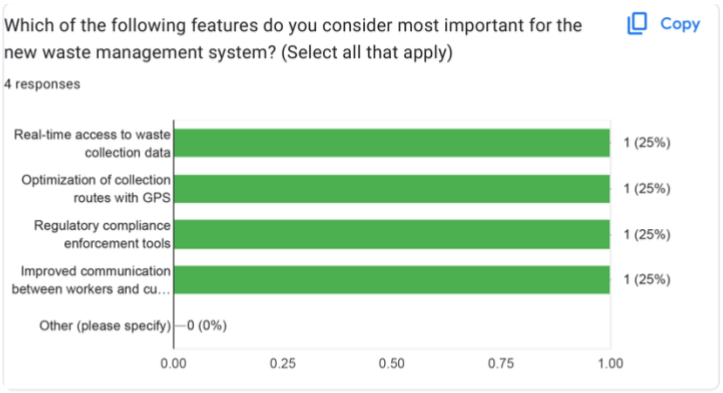
To maintain the integrity and diversity of the data collected, a representative sample of 20 stakeholders from the Eco–Waste Solutions Company was selected to complete the survey questions.
To ensure compliance with the Data Protection Act and other ethical standards, participants were made to fill out a consent form before, proceeding with the questions.

After a thorough analysis of the gathered data, it became feasible to contextualize the findings and extrapolate the relevant user requirements based on the answered survey. This process enabled a deeper understanding of the needs and preferences of the Eco-waste Solution Company.

4.2. Result of Survey

The collected data from the survey was analyzed using Qualitative and quantitative methods. Full Results of the Questionnaire survey are Available in **Appendix C.**

4.2.1. **Qualitative Data Analysis**- involves examining non-numerical data to identify themes, patterns and insights. This provides rich, in-depth insights into stakeholders' perspectives, allowing for an understanding of the complexities and nuances of their experiences and preferences. Example of Qualitative Results in **Figure 16** which shows an equal number of stakeholders all agreeing to the new features.



https://docs.google.com/forms/d/1y8lupYJOIxU_4kFCtmp-WAZhimWK_PxhpQmeW9EaV4A/viewanalytics 2/7

Figure 16 - ***Questionnaire Result for Analysis***

4.2.2. **Quantitative Data Analysis** - involves analyzing numerical data to identify trends, relationships and statistical patterns. This allows for quantifying and measuring aspects of stakeholders' responses, into trends, preferences and behaviours. Example of Quantitative Results in **Figure 17** which shows 75% of stakeholders agree on the importance of real-time access to waste collected data.

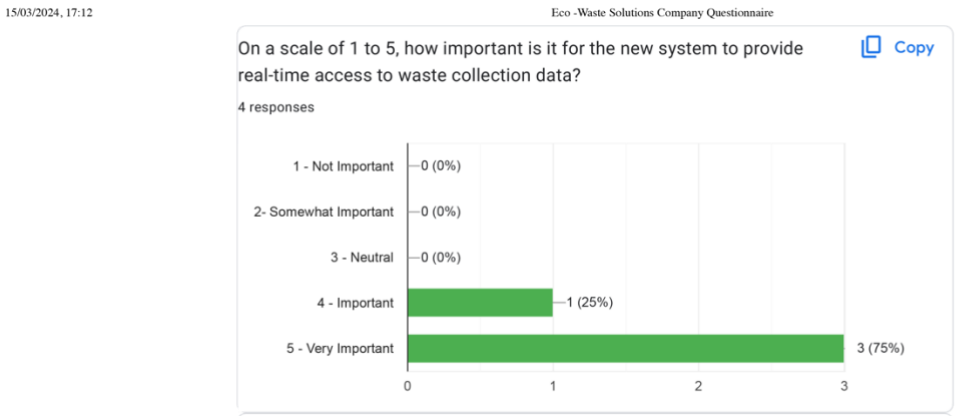


*Figure 17 - **Questionnaire Result for Analysis***

4.3. Business Requirements

Further research has been conducted to gain a deeper understanding of the unique business requirements of the Eco-Waste Solution Company. This additional research aims to delve into specific aspects of the company's operations, waste management practices and organizational structures to get **High-Level Requirements**.

4.3.1. Stakeholder Mapping and Analysis

This is the first step, is to understand the individuals affected by or can influence the project. By analyzing stakeholders' interests, concerns and expectations, insights into their requirements are gained for the waste management system allowing for the prioritizing of requirements based on the importance and impact on different stakeholders (Aligica, 2006).

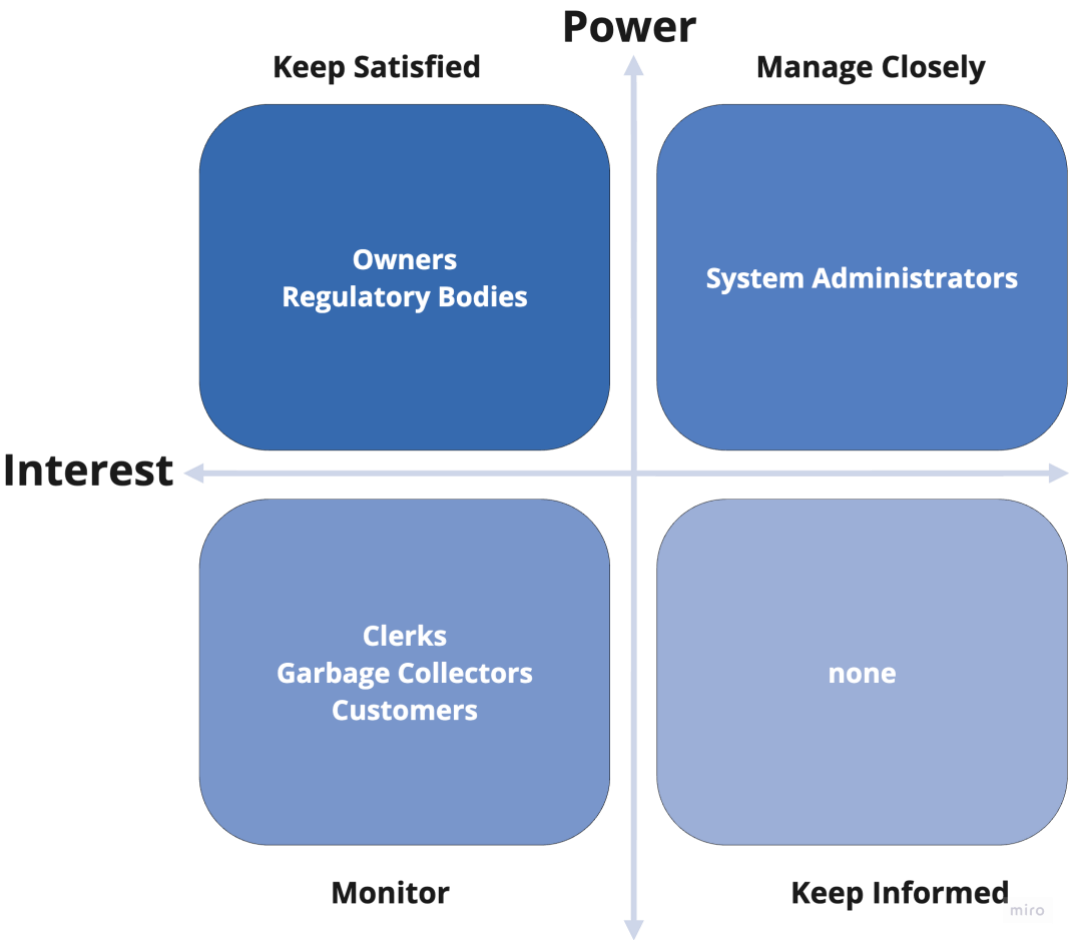


*Figure 18 – **stakeholder mapping for Eco-Waste Solution Company.***

4.3.1.1. Stakeholder Analysis Explanation

1. **Owners:** Their interest and influence continue to be high, reflecting their vested interest in the company's success and decision-making authority

2. **Regulatory Bodies:** They retain high interest and influence, regulating and enforcing environmental laws impacting the company's operations

3. **System Administrators:** They have high power due to their authority over system design, implementation and maintenance. However, they have low interest in certain aspects of the system that do not directly impact their responsibilities, such as customer support or the day-to-day operational tasks of garbage collectors.

4. **Clerks:** they have high interest since they rely heavily on the system to carry out their tasks effectively but do not have significant authority over system-related decisions

5. **Garbage Collectors:** Garbage collectors may have lower power in decision-making regarding system design and implementation but have a high interest in the functionality and usability of the system.

6. **Customers:** While customers may have low power in terms of system design and implementation, they have a high interest in the services provided by the system

4.3.2. CATWOE Analysis

This is a powerful technique used in systems thinking and problem-solving to explore and understand the key components of a problem. The abbreviation “CATWOE” stands for Customers, Actors, Transformation Process, Weltanschauung (or Worldview), Owner, and Environmental Constraints. Each component represents a different perspective or dimension of the problem, and analyzing them helps stakeholders gain a comprehensive understanding of the system and its dynamics (Birgitta Bergvall-Kåreborn, 2004).

1. **Customers –** individuals, households, businesses, municipalities and any industry that generates waste are the customers of Eco–Waste Solutions Company. They are directly affected by the effectiveness of waste collection, transportation and disposal. Customers expect efficient, reliable and environmentally responsible waste management services that minimize pollution and protect public health (AlisonStowell, 2007).

2. **Actors-** Garbage collectors, Clerks and Administrators are the actors in the waste management system. These actors are responsible for executing various tasks such as waste collection, sorting and regulatory compliance.
   Effective coordination and collaboration among actors are essential for optimizing waste management processes and achieving environmental goals (AlisonStowell, 2007).

3. **Transformation process-** This involves collecting, transporting and disposing at a site. It includes activities such as curb side collection, material separation and hazardous waste. The goal of the transformation process is to collect waste generated, maximize resource recovery and mitigate environmental impacts through sustainable waste management practices (AlisonStowell, 2007).

4. **Weltanschauung (Worldview)-** The worldview in waste management systems encompasses societal attitudes, cultural norms, environmental values and regulatory frameworks related to waste. There is currently a growing awareness of the importance of waste reduction, recycling and circular economy principles in addressing global challenges such as climate change, resource depletion and pollution. Stakeholders' worldview influences waste management policies, regulations, investment decisions and public perceptions of waste as a resource or a problem (AlisonStowell, 2007).

5. **Owner-** The owner of the waste management systems is "**Eco Waste Solution Company**". it has the authority and responsibility to design, implement and oversee waste management practices and systems. Owners set strategic objectives, allocate resources, establish performance targets and ensure compliance with regulations to achieve sustainable waste management outcomes (AlisonStowell, 2007)..

6. **Environmental Constraints-** this includes regulatory requirements, technological limitations, financial constraints, public acceptance and resource availability. Regulatory frameworks dictate waste management practices, waste diversion targets, recycling mandates, pollution prevention measures and data protection of its customers. (AlisonStowell, 2007).

4.3.3. Rich Picture

A rich picture is a holistic illustration that incorporates various elements such as stakeholders, processes, resources, interactions and contextual factors within a peculiar environment, to understand the current state of affairs, identify key stakeholders and their perspectives and also uncovering underlying challenges and opportunities (Howard, 1998).

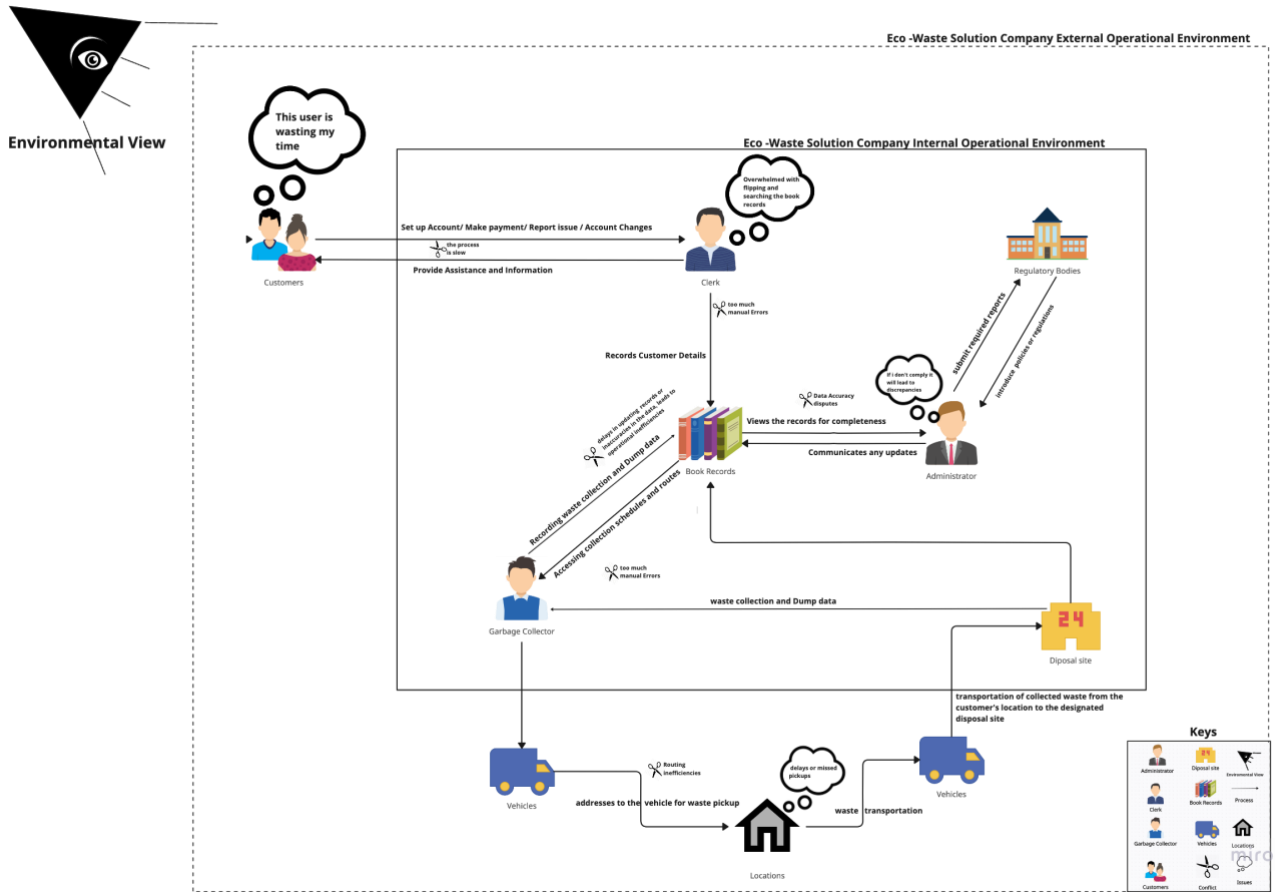


*Figure 19 – **A Rich Picture of Eco-Waste Solution's Environment***

4.3.3.1. Rich Picture Explanation

Figure 19 tries to show the internal and external environment of the Eco-waste solution. The various elements that constitute the picture are mentioned in the key sections. Here is an explanation:

1. **Actors**: These represent the individuals or entities involved in the rich picture. They are:
    - **Administrator** – This person oversees all business operations, ensures all data recorded is correct and follows regulations
    - **Customer**- Engages with Eco-Waste Solution Company for their collection services
    - **Regulatory Bodies**- Makes regulations and standards for waste management, providing oversight and enforcement if necessary

- **Clerk**- this worker is responsible for recording data into the books. They also retrieve and give information to customers and other workers
- **Garbage Collector** - This work is responsible for the collection of waste from designated locations and transporting it to a disposal site.

2. **Issues:** This shows the thoughts and concerns of the actors which provide different perspectives from each person/ actor**.**
    - **Customer concerns:** the process of waiting for clerks to provide assistance or information is too slow.
    - **Clerk concerns:** Gets overwhelmed when flipping and searching for information from the book records
    - **Administrator concerns:** Stressed over the changing regulatory policies and how to comply.
    - **Customer Locations:** Delays or missed pickups of waste.

3. **Conflicts:** This illustrates the tension within processes.
    - In **Figure 19** there is a conflict between the **customer** and the **clerk** because the process is slow.
    - There is also a conflict between **Garbage Collectors** and **Book records** because their operations are affected by data they receive.
    - Conflicts between **Clerk** and **Book** records because there is too much room for manual errors
    - Conflicts between **vehicles** and **locations** because there are routing inefficiencies
    - Conflicts between **Admin** and **Book records** because the data lacks integrity

4. **Environmental View**

The environment represents the broader context in which Eco -Waste Solution operates, including physical, social, economic and regulatory factors that may impact it.

(Howard, 1998).

4.6. Using the MosCow Method to Prioritize Requirements

Based on further research encompassing **Product Research, Survey Results, Stakeholder Analysis, CATWOE analysis, and the Rich picture,** new high-level requirements are formulated for Eco Waste Solutions Company. These requirements are derived from a comprehensive understanding of the company's needs and stakeholder perspectives, aiming to address key challenges and enhance operational efficiency.

Table 5

High Level Functional Requirements	MoSCoW Prioritisation	Justification
1. The system must have databases for Users (including garbage collectors and customers)	**Must Have**	This is essential for user authentication and access control.
2. The system must manage vehicles (add/edit/delete) and assign them to garbage collectors based on operational needs and routes	**Must Have**	Efficient fleet management is crucial for route planning and resource allocation
3. The system must allow garbage collectors to record collected waste and waste disposed.	**Must Have**	This ensures accurate documentation and tracking of waste collection activities
4. Garbage collectors must record fuel logs with proof for tracking fuel usage and expenses	**Must Have**	This ensures accountability and efficient fuel management practices
5. Garbage collectors must access collection points on a map to plan and navigate routes effectively	**Must Have**	This optimizes garbage collection routes and improves operational efficiency
6. Customers must be able to make payments securely via Credit/ Debit cards.	**Must Have**	Enables timely bill settlement for customers
7. Customers must be able to manage their accounts (view service schedules, update account information, and track collection history)	**Must Have**	Customers need self-service options for managing their waste collection services.

8. Users (customers and garbage collectors) must be able to report system or collection issues for prompt resolution.	**Must Have**	This facilitates communication and enables addressing problems
9. The system should monitor GPS locations of vehicles and track them in real-time to identify and address vehicle-related issues promptly	**Should Have**	This enhances operational visibility and allows for faster response to vehicle problems
10. The system should allow sending notifications to all users for disseminating important information promptly (e.g., schedule changes, service updates).	**Should Have**	Efficient communication with users improves transparency and service experience.
11. The system should generate reports to provide insights into waste collection data for informed decision-making	**Should Have**	Data analysis helps optimize routes, manage resources efficiently, and improve overall service delivery
12. Users can receive notifications for upcoming collections, reminders, and other relevant information.	**Could Have**	Improves user experience and keeps them informed.
13. The system could potentially integrate with AI cameras for waste sorting assistance.	**Could Have**	This could enable waste sorting automation for improved efficiency (long-term goal).

4.7. Non Functional Requirements

Table 5

High level Non Functional Requirements	Reasoning
1. **Performance**- The system should be able to handle multiple user requests,	To ensuring optimal performance during peak usage periods
2. **Security** – The system should have robust security features that protect sensitive user data, including encryption of passwords and access control policies	To safeguard sensitive information and prevent unauthorized access or data breaches,
3. **Reliability** - The system should demonstrate high reliability, with minimal downtime and consistency.	To ensure uninterrupted availability of essential functions
4. **Usability** - The system interface needs to be intuitive, ensuring users can navigate easily.	To enhance user satisfaction and productivity
5. **Accessibility** - The system must comply with accessibility standards.	This will make it usable for a wide range of people
6. **Scalability** - The system architecture should be structured to expand effortlessly as both the user base and data volume increase.	To accommodate future growth and expansion of the system
7. **Availability –** The system should be ready and available to operate at all times	To ensure continuous operation of the system,

4.8. Time Boxing

Additionally, time boxing has been applied, incorporating the 80/20 rule to identify the crucial 20% of requirements that deliver 80% of the value or functionality needed by Eco Waste Solutions Company. This strategic approach ensures that essential features are prioritized and implemented within specified time frames, maximizing the project's impact while optimizing resource allocation.

Table 6

MoSCoW	Hours	Days
Must Have	216	9
Should Have	96	4
Could Have	648	27
Won't Have	480	20

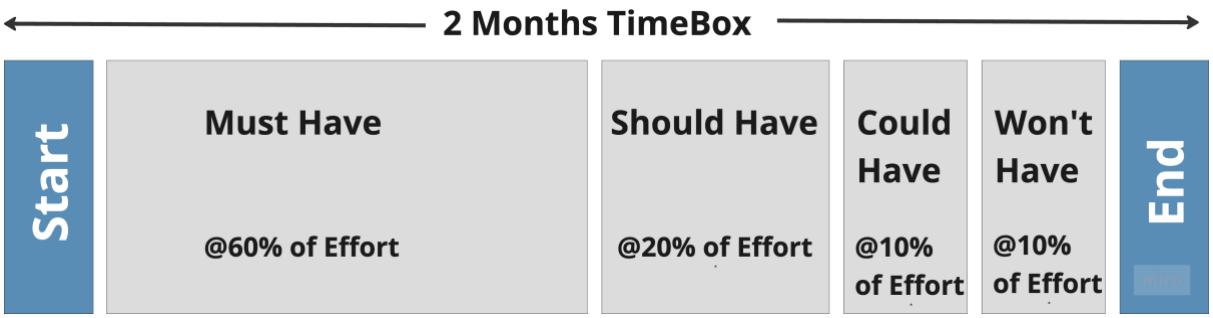


*Figure 20 – **A structured Time Box***

4.9. Use Case Diagram

This diagram offers a broad overview of the interactions between users and the system's functionalities. The actors are the users (Admin, Garbage Collector, Clerk and Customer), who are associated with relevant use cases based on their roles and interactions with the system. This shows how the proposed system works in practice as it shows stakeholders' interactions with the waste management system, guiding system design and development efforts (Waykar, 2015).

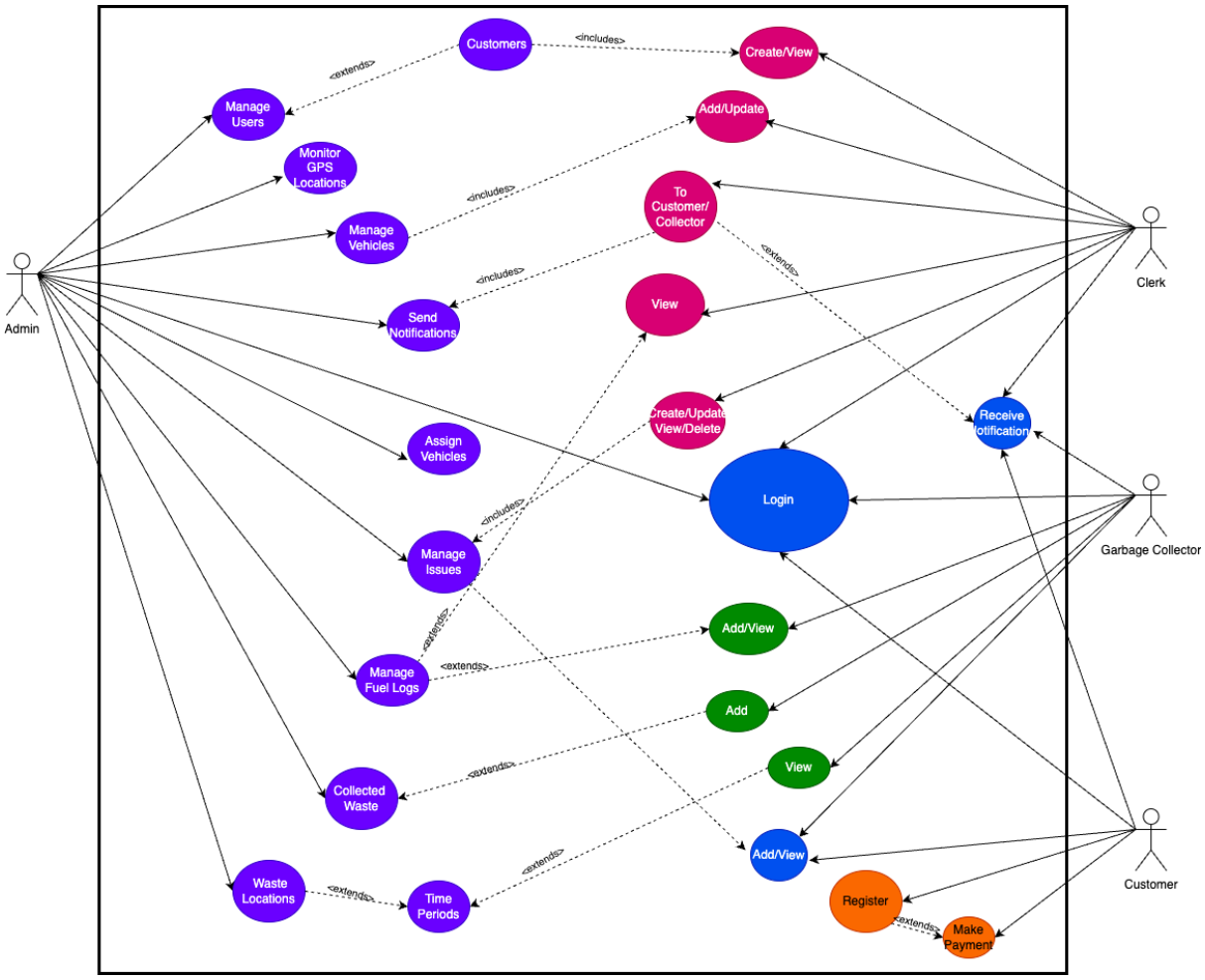


Figure 21 – ***The use case diagram showing all interactions***

4.9.1. Use Case Description

- **Use case scenario - 1**

Table 7

Use Case	Customer Registration
Actors	Customer
Preconditions	The customer is a new user who does not have an existing account in the system.
Basic Flow	1. The customer navigates to the registration page 2. The customer fills the form, makes payment and submits 3. The system validates the registration 4. Registration Complete
Postconditions	A new customer account is created in the system database, allowing login
Exceptions	If an invalid password is entered during registration. The system will show an error message prompting the customer to enter a valid password.

- **Use case scenario - 2**

Table 8

Use Case	Waste Collection
Actors	Garbage Collector
Preconditions	logged In.
Basic Flow	1. The system displays the assigned route information for the day 2. Garbage collector navigates the first collection point. 3. Upon Arrival collector can mark location as collected and record collected data

	4. The database is updated for the collected point as complete 5. Once all collection for the day is complete, collector logs out
Postconditions	Garbage collector completes their assigned route for the day, collecting waste from scheduled locations
Exceptions	The assigned route for the day contains errors or missing information. The garbage collector can report the issue through the system

- **Use case scenario - 3**

Table 9

Use Case	New Location Notification
Actors	Clerk, Garbage Collector, Admin (indirectly)
Preconditions	All parties are logged In.
Basic Flow	1. Clerk add a new location to the system 2. Clerk send a notification to all Collector alerting a new collection point 3. The collector can view the notification and decide on their course of action
Postconditions	A new collection location is added to the system and can be seen by Collectors.
Exceptions	If the garbage collector doesn't receive the notification due system malfunctions, they may not be aware of the new collection. A system administrator might need to

5. Design Development

This chapter explores the creative methods used in developing the waste management system. We discuss user testing, alternative considerations and the rationale behind our design choices. Visual elements like illustrations are incorporated, along with technical designs using accepted notations such as UML diagrams. Navigation structure, with references to the literature review for justification. Appendices contain detailed technical information and visual aids. See **Appendix G** *for system architecture.*

5.1. Design Thinking as a Creative Method

The design process was primarily guided by Design thinking principles, which emphasize **empathy**, **ideation** and **prototyping** to address complex challenges (Pressman, 2018). The chosen methodology (**Agile Scrum**) was used to structure the design sprints (timebox), enabling iterative development which allowed for this process to be broken down into manageable iterations, known as sprints, each focused on delivering specific features. After confirming the selected idea for the project, conducting a comprehensive literature review and understanding the various requirements for the waste management system.

A “**Prototype Site Map**” was used to generate the hierarchy and organization of pages and content. This was done within a limited timeframe, facilitating creative brainstorming sessions.

Upon selecting the most suitable design, wireframes were used to outline each page of the system and then translate it into a high-fidelity prototype using Axure RP10.

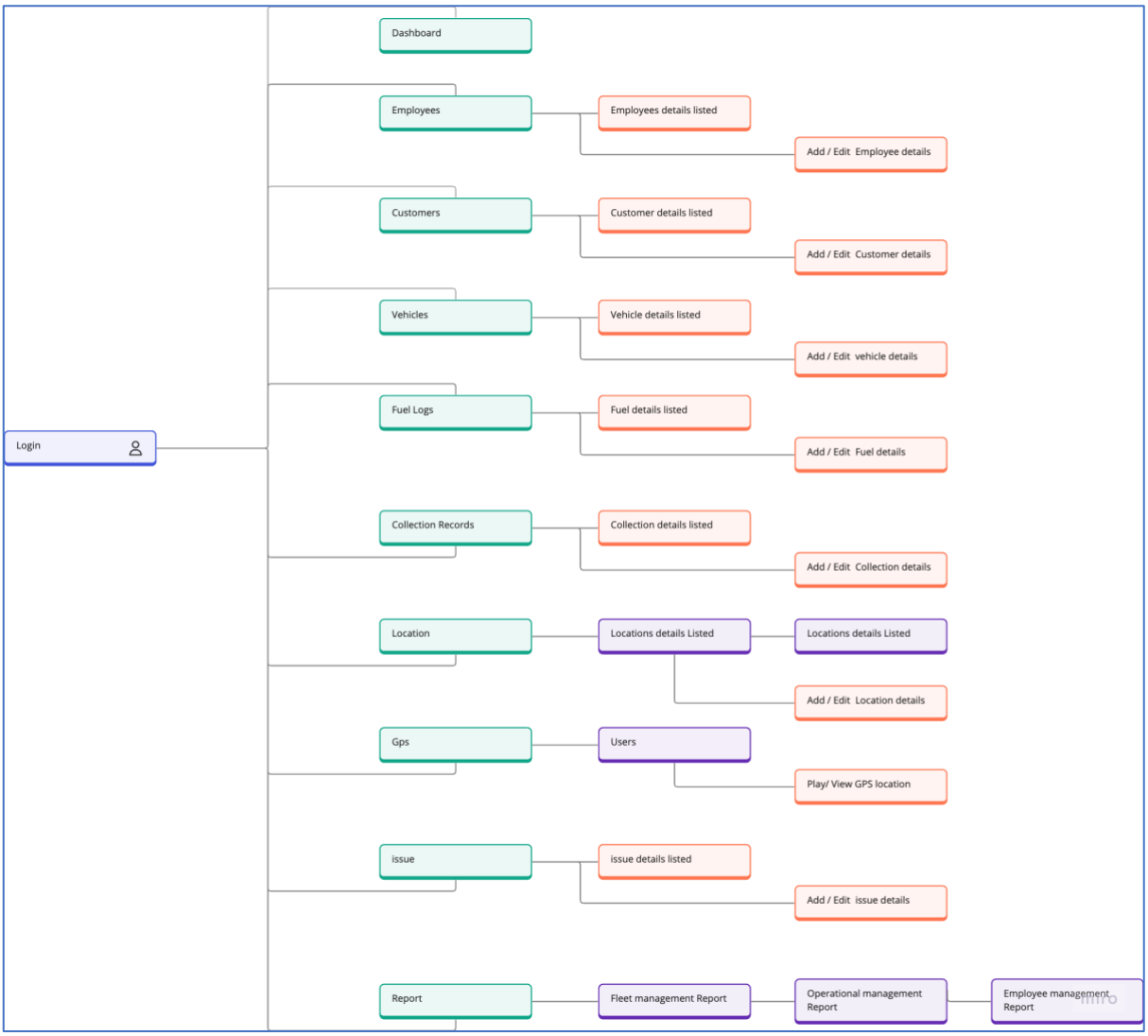


*Figure 22 - **Prototype Site Map***

5.2. Wire Frame

From the **Prototype Site Map** exercise, wireframes are drawn to represent the system's interface with a focus on layout, functionality and information architecture. All wireframes are available in [Appendix D]

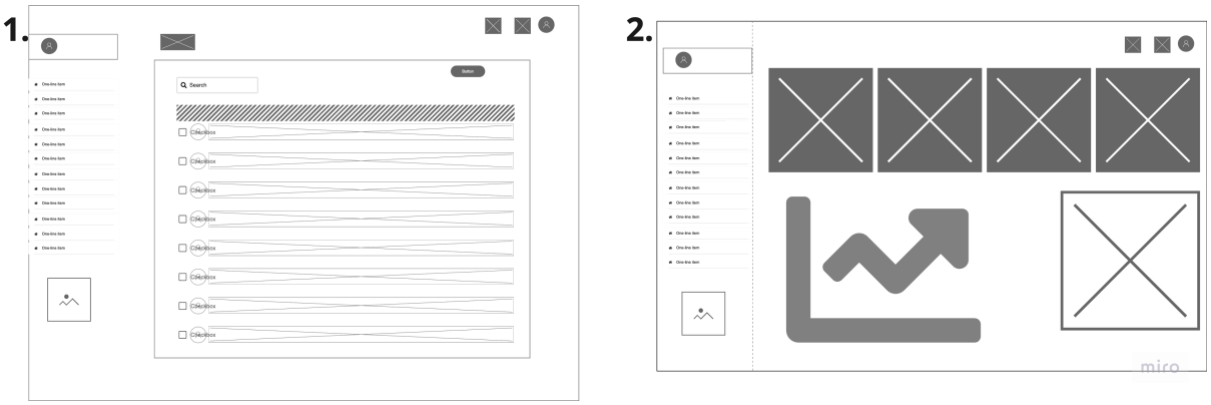


*Figure 23 - **Wireframes***

5.3. Low-Fidelity Prototype and High-Fidelity Prototype

To illustrate the website's development process, this section showcases both low-fidelity and high-fidelity prototypes. The Dashboard page is an example, but complete prototype screenshots are available in [Appendix D]

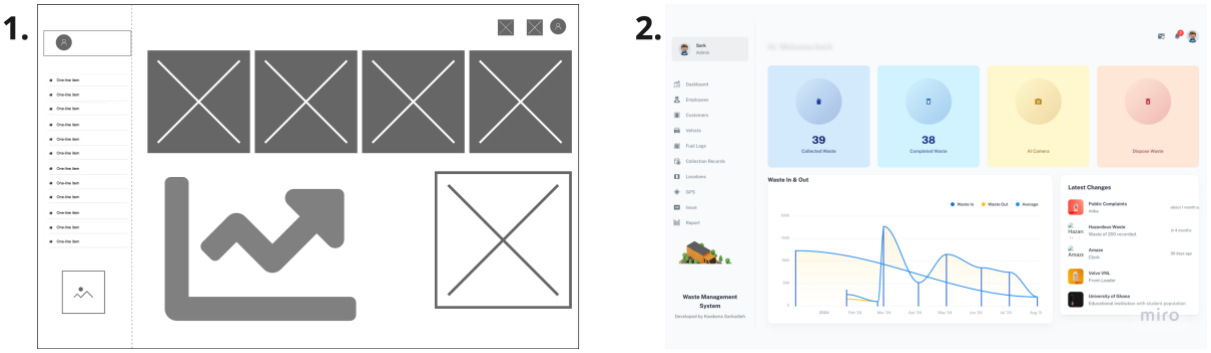


*Figure 24 - **Low Fidelity & High Fidelity Prototype***

5.4. Database Design

In the development of the waste management system, database design plays a pivotal role in organizing and managing critical data. It ensures efficient storage, retrieval and manipulation of information necessary for system functionality

5.4.1. Entity-Relationship Diagram (ERD) Translation

The ERD serves as the blueprint for translating conceptual data models into a physical database schema. Entities, attributes and relationships identified in the ERD are mapped to tables, columns, and foreign key constraints in the database schema (Il-Yeol Song, 1995).

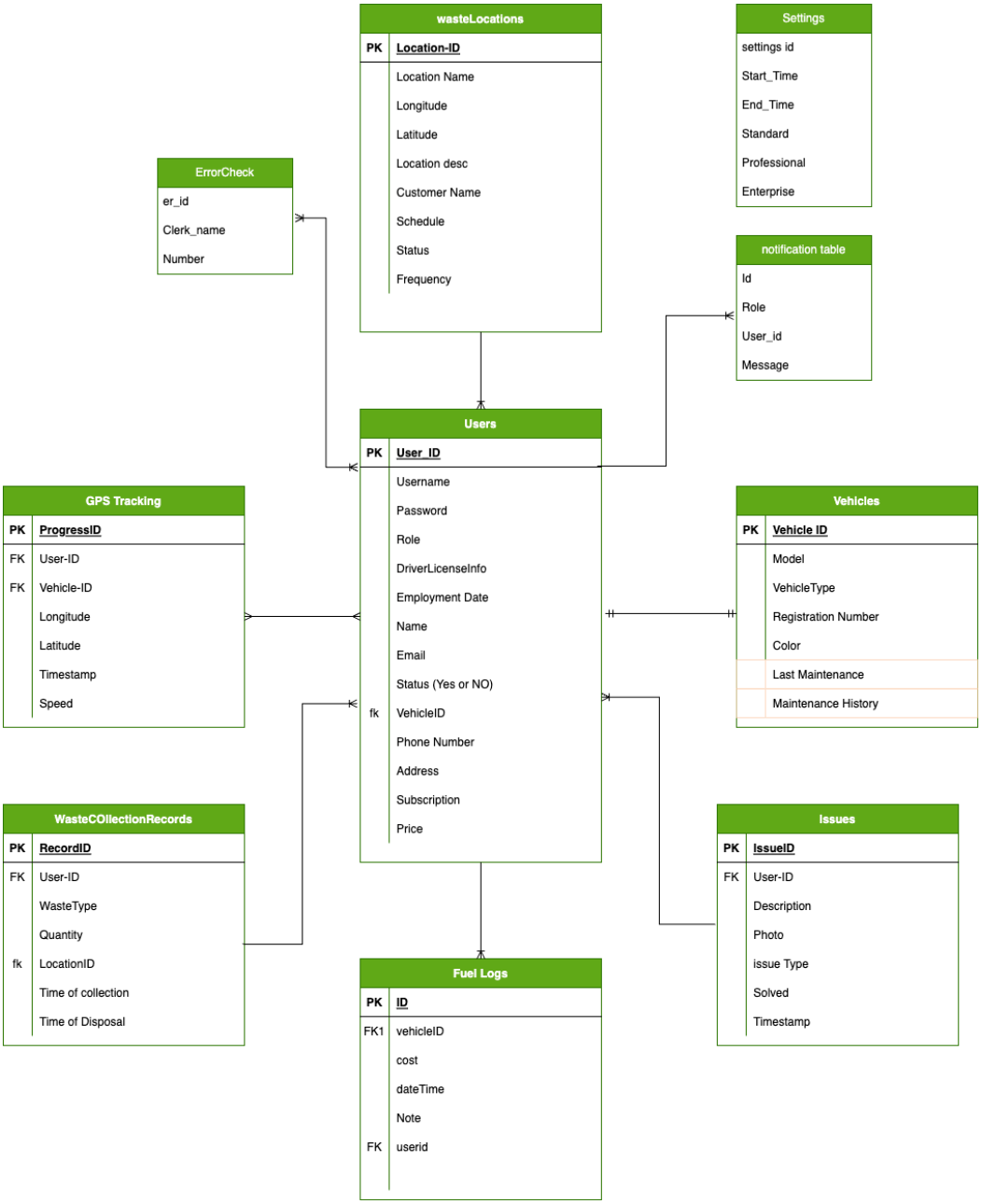


*Figure 25- **ER Diagram***

5.4.2. Class Diagram Design

This serves as a visual representation of the relationships between objects and their class. It also serves as a blueprint for the database structure, providing a clear understanding of how objects interact and what functionalities they possess (Daniela Berardi, 2005)

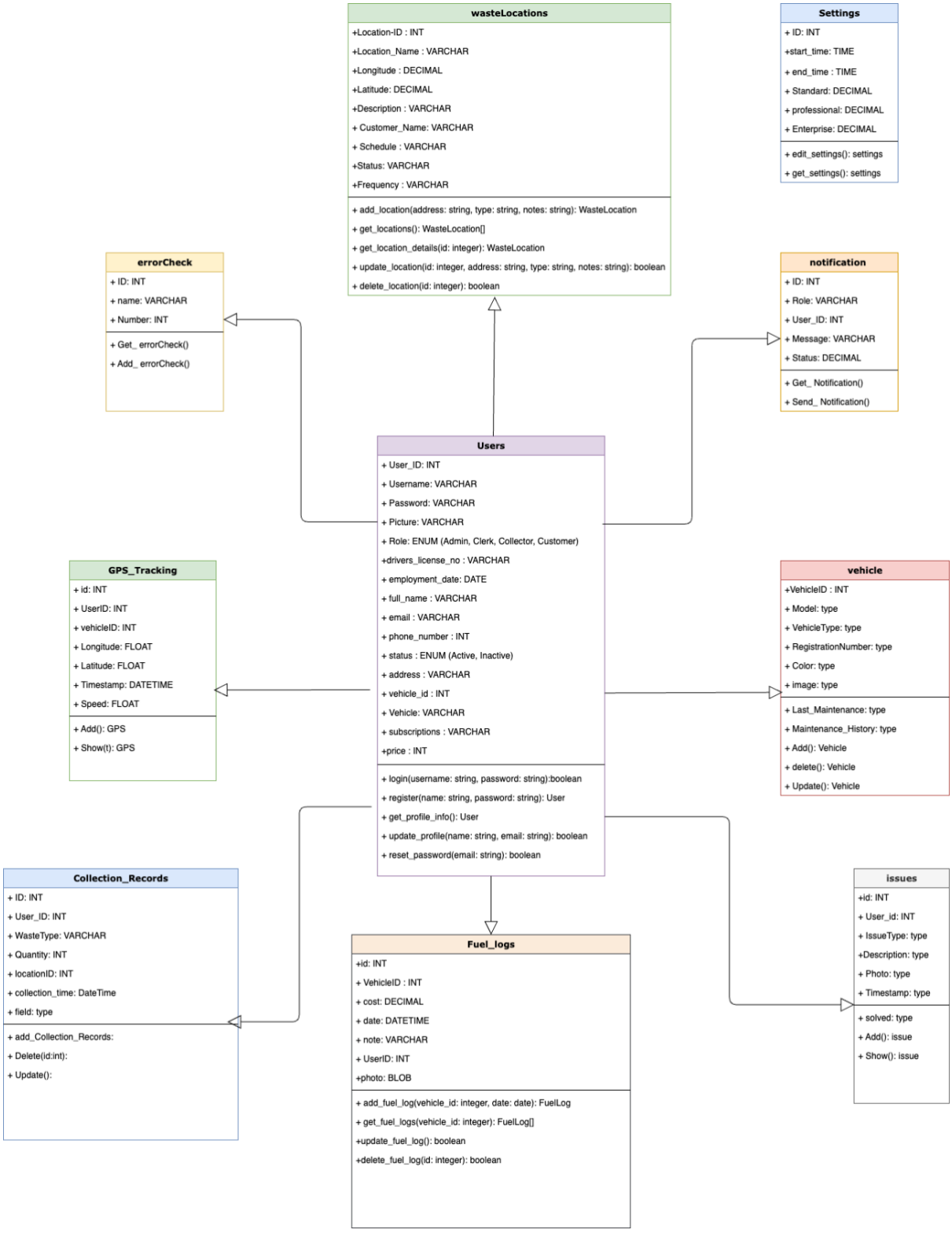


*Figure 26 – **Class Diagra***

5.4.3. Database Constraints and Indexing

Various constraints such as **primary key, foreign key, unique**, and **check constraints** were enforced to maintain data consistency and integrity. Additionally, indexing strategies are employed to improve query performance and optimize data access.

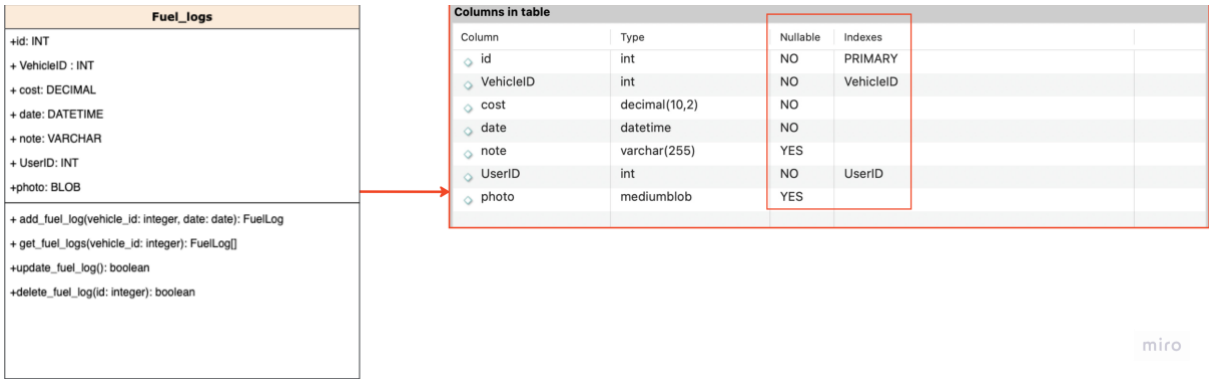


Figure 27

5.4.4. Security Measures

Security is paramount, the database incorporates robust measures such as role-based access control (RBAC), encryption of sensitive data, and auditing mechanisms to monitor database activities and prevent unauthorized access.

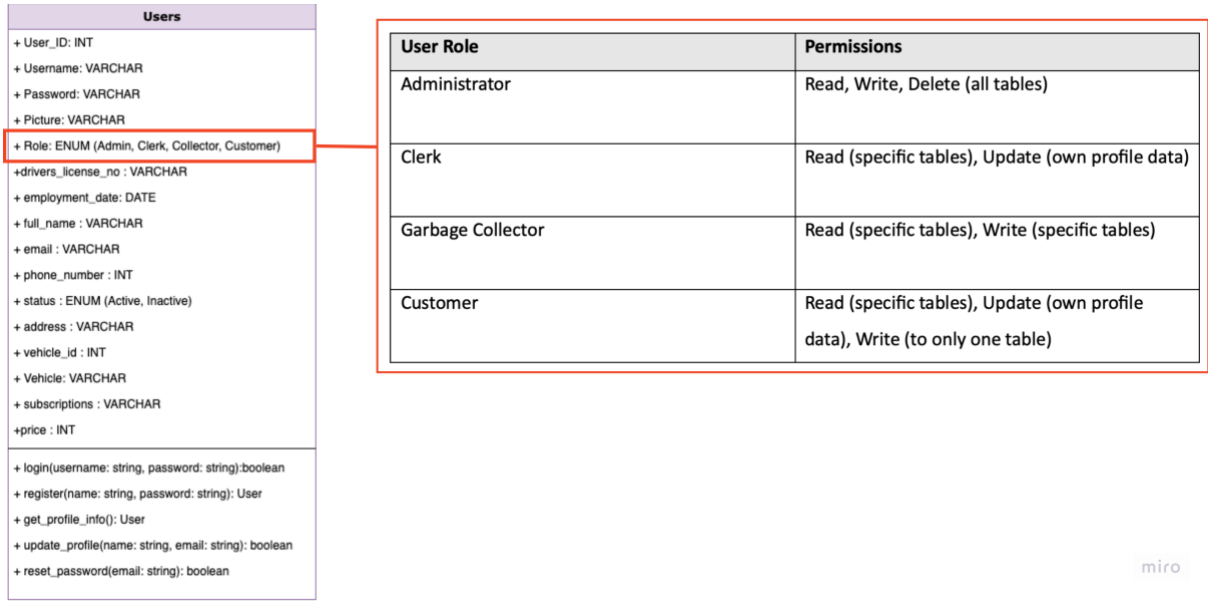


Figure 28

5.4.5. Activity Diagram

This diagram illustrates the sequence of actions carried out by users and the system's response to those actions. It provides a visual representation of the sequential and parallel steps involved in various processes within the system.

Login/ Register Activity Diagram

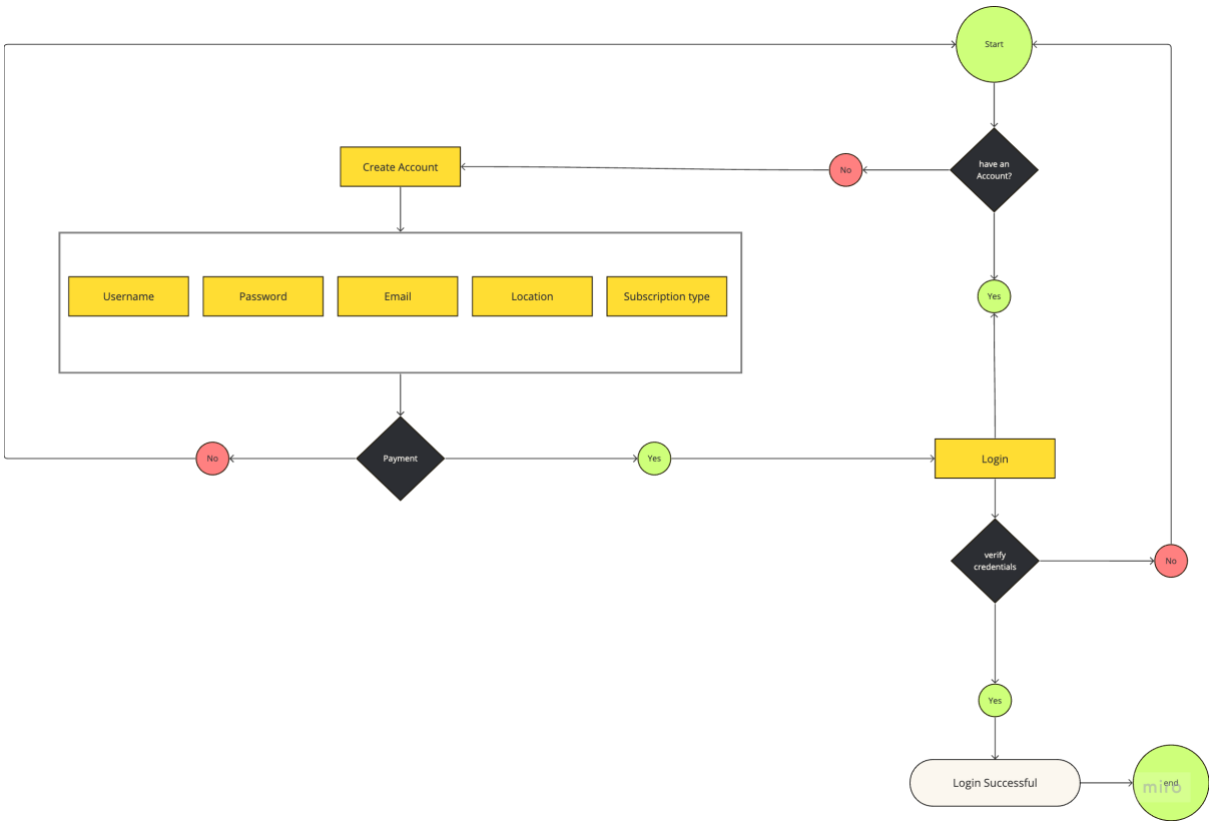


Figure 29 – ***Login / Register Activity Diagram***

6. Technical Project Development

In this chapter, we delve into the practical aspects of implementing the designs outlined in the previous chapters. We explore the steps taken to bring our conceptual designs to life, discussing the strategies, challenges, and technical considerations encountered along the way.

Furthermore, there is a detailed account of the technologies used, the programming languages chosen and the development decisions all justified in **Appendix G**

In summary, My SQL Workbench was set up and activated. It is a versatile web server solution that enables utilizing MySQL for server query operations. Code development primarily occurred using VS-code, a feature-rich editor supporting various programming languages. The website's front end employs React JS, while Node JS drives the backend functionalities, ensuring seamless integration and robust performance.

6.1. Design Implementation

This section dives into the system's practical development, specifically focusing on the "**Must-Have"** functionalities: **User Registration, GPS Navigation** and **Waste Collection**.

For a more comprehensive view of the development process, refer to **Appendix E**, It includes a wider range of screenshots and code snippets.

6.1.1. User Registration

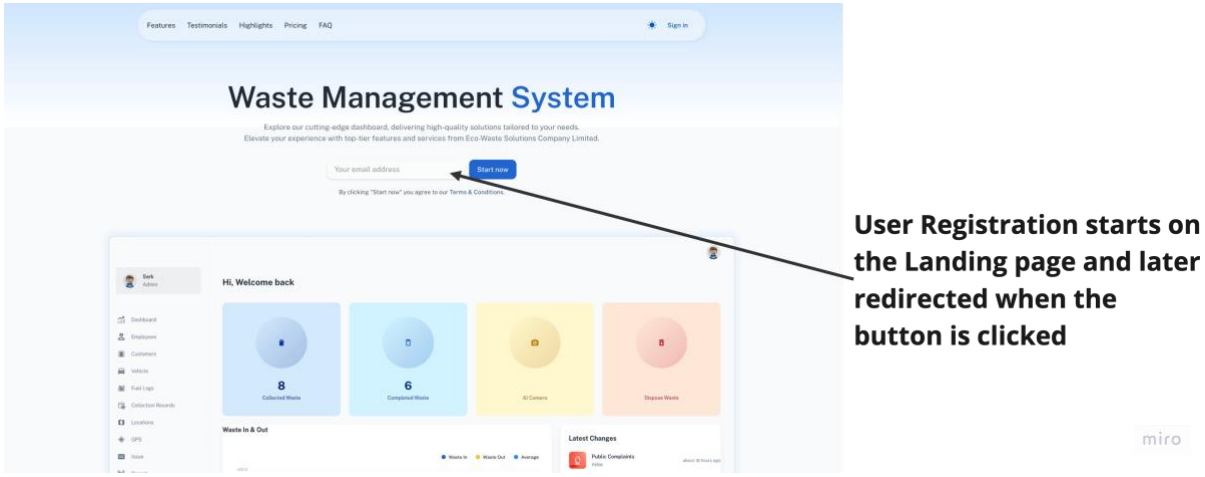


*Figure 30. – **Landing Page***

The registration process starts when "**start now**" is clicked. The user is then redirected to the second page shown in **Figure 31** to continue the process.

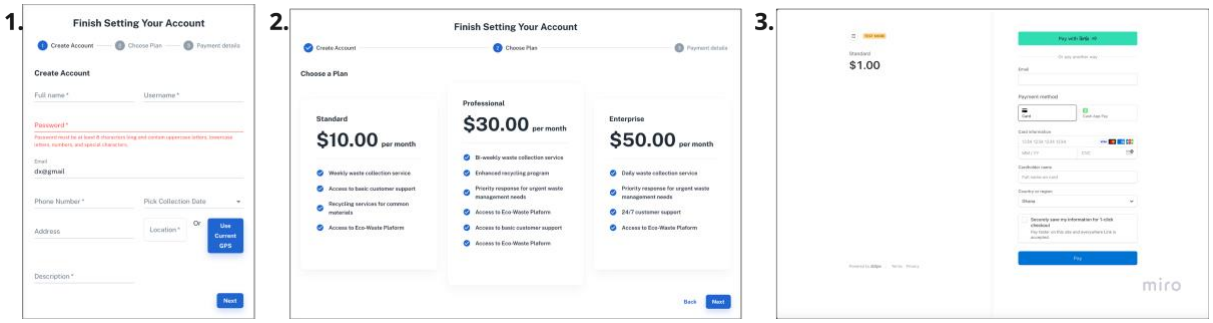


*Figure 31. – **Registration process***

As shown in **Figure 31**, the first image, numbered **1**, ensures that the password is secure, with a strength meter appearing on the screen to guide the user in creating a reliable password. Below is a code snipped that ensures that function.

```
// Define isPasswordComplex function outside useEffect
function isPasswordComplex(password) {
  // Minimum length requirement
  if (password.length < 8) {
    return false;
  }

  // Regular expressions for checking uppercase letters, lowercase letters, numbers, and special characters
  const hasUpperCase = /[A-Z]/.te
  const hasLowerCase = /[a-z]/.te
  const hasNumber = /[0-9]/.test(password);
  const hasSpecialChar = /[!@#$%^&*()_+\-=[\]{};':"\\|,.<>/?]/.test(password);

  // Check if all criteria are met
  return hasUpperCase && hasLowerCase && hasNumber && hasSpecialChar;
}
```

(parameter) password: any

*Figure 32. – **Snippet of code for password constraints***

The user will be sent to the login page after completing the registration process.

6.1.2. GPS Navigation & Tracking

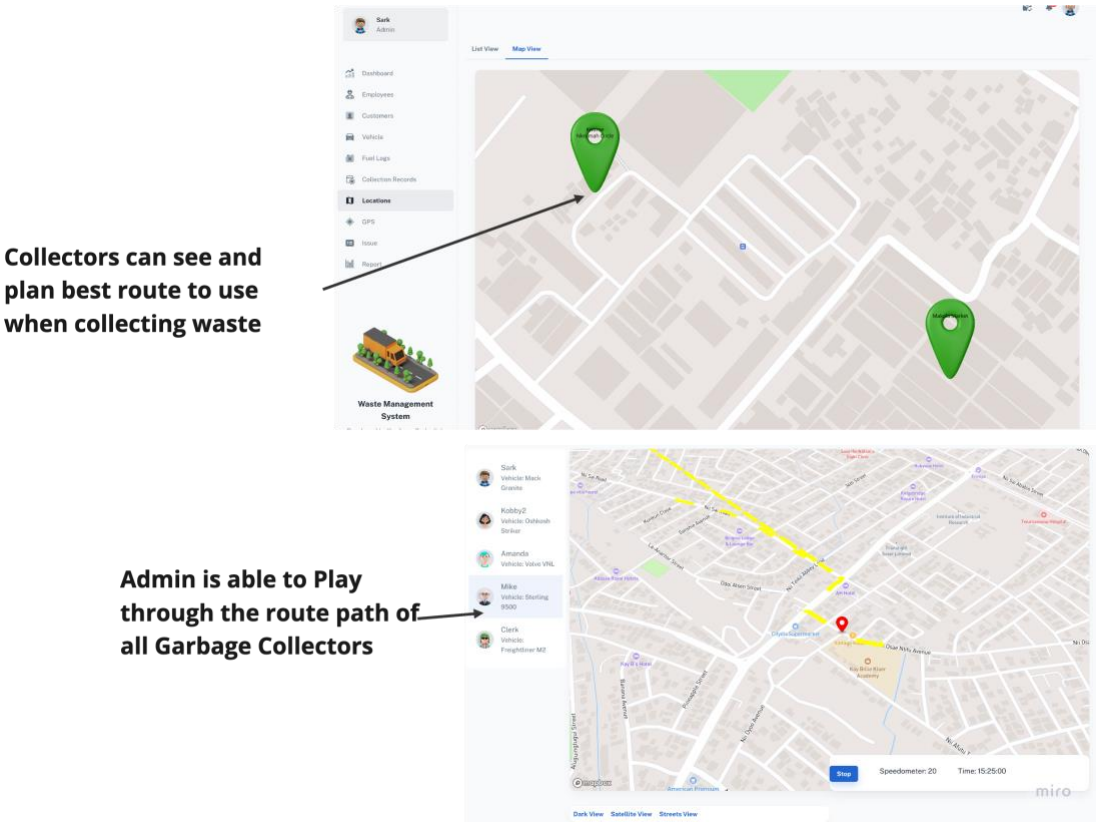


*Figure 33– **GPS tracking page***

As shown in **Figure 33** the GPS page shows all the live locations of the Garbage collectors. Below is a code snippet that makes it possible.

```
//GPS API
const options = {
  enableHighAccuracy: true,
  timeout: 5000,
  maximumAge: 0,
};

function success(pos) {
  const crd = pos.coords;

  // console.log("Your current position is:");
  // console.log(`Latitude : ${crd.latitude}`);
  // console.log(`Longitude: ${crd.longitude}`);
  // console.log(`More or less ${crd.accuracy} meters.`);


  setLongitude(crd.longitude);
  setLatitude(crd.latitude);
  setSpeed(crd.accuracy);
}
```

```
axios.post("http://localhost:8080/addGPS", {
  UserID:  CurrentUserID,
  vehicleID: assignedVehicleID,
  Longitude: Longitude,
  Latitude: Latitude,
  Timestamp: CurrentDate,
  Speed: Speed,
}).then((response) => {
  console.log(response + "help");
  setRegStatus(response.data.message);


});
}
```

*Figure 34. – **code snippet of how the system captures and stores GPS data***

6.1.3. Waste Collection

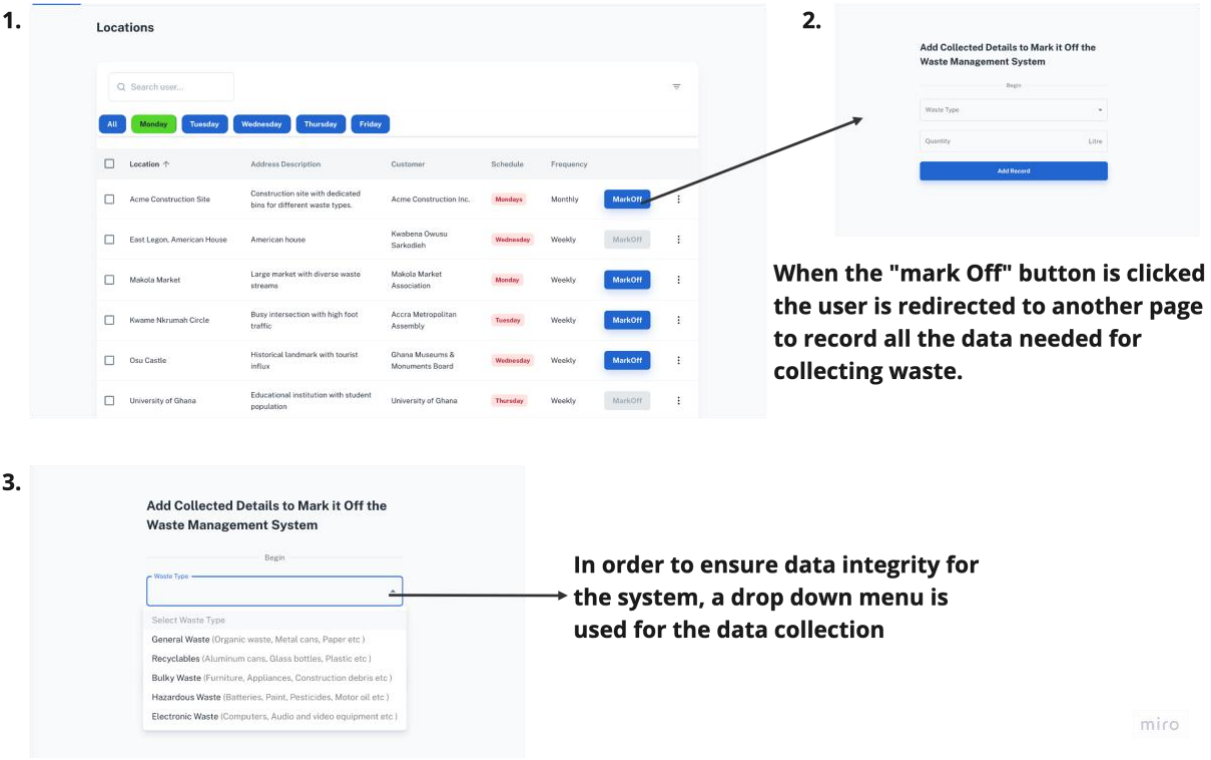


*Figure 35 – **Waste collection process***

From the picture above, the waste collection process starts on the locations page, which shows all the available locations. Picture number 1, shows all non-collected areas Mark-off button in blue and the collected ones in grey. Also, picture numbered 3 uses a drop-down to ensure data integrity, below is a code snippet of how it is carried out.

```
const register = () => {

  axios.post("http://localhost:8080/addCollection", {
      user_id: CurrentUserID,
      wasteType: wasteType,
      quantity: quantity,
      collection_time: CurrentDate,
      locationID: id,
  }).then((response) => {
    console.log(response + "help");
    setRegStatus(response.data.message);

    if (response.data.message === 'Record Added successfully') {
      navigate('/dashboard/location');
    }
  });


  axios.put(`http://localhost:8080/MarkedOff/${id}`);
};
```

```
// Location Status update to grey out Mark Off
app.put("/MarkedOff/:id", (req, res) => {
    const id = req.params.id;

    // Extract values from the request body
    const { Status } = req.body;

    // Log the received data for debugging
    console.log('Received data:', { Status });

    const q = "UPDATE waste_locations SET `Status` = 'InActive' WHERE id = ?";

    db.query(q, [id], (err) => {
      if (err) {
        console.error(err);
        return res.status(500).json({ error: 'Failed to update Status' });
      }

      res.json({ message: 'Update successful!' });
    });
});

//Add Location
```

*Figure 36– **Code Snippet of how collection data is stored in the database***

6.2. Database Creation

The conceptual database designs are used to create actual database tables which hold all the necessary details as shown in **Figure 37**, and then connected to the node server.

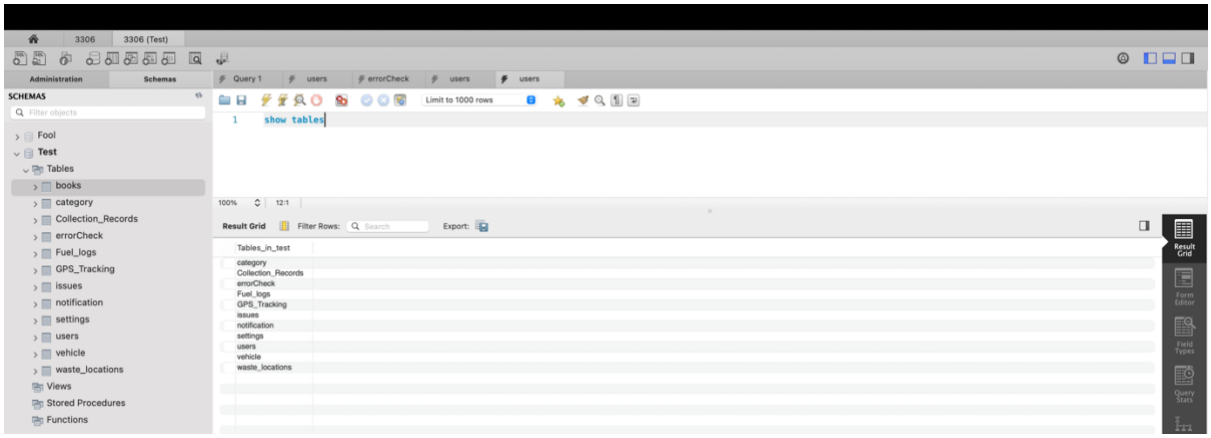


*Figure 37 – **Showing all created tables in MySQL Workbench***

```
const db = mysql.createConnection({
    host: "localhost",
    port: 3306,
    user: "root",
    password: "12345678",
    database: "test"
});

// Function to execute a query using the connection pool
const queryDatabase = async (query, params) => {
    return new Promise((resolve, reject) => {
        db.query(query, params, (error, results) => {
            if (error) {
                reject(error);
            } else {
                resolve(results);
            }
        });
    });
};

app.use(express.json());
app.use(cors());
```

*Figure 38 – **Code snippet to show database connection to Node server***

```
// Define a route to retrieve data for all vehicles
app.get('/vehicleUsage', (req, res) => {
  // Query to retrieve total mileage for each vehicle model
  const query = `
    SELECT
      Vehicle.Model,
      SUM(TripDistance) AS TotalMileage
    FROM Vehicle
    INNER JOIN (
      SELECT
        Vehicle.Model,
        GREATEST(
          (t1.Timestamp - t2.Timestamp) * t1.Speed,
          0
        ) AS TripDistance
      FROM GPS_Tracking t1
      INNER JOIN GPS_Tracking t2 ON t1.vehicleID = t2.vehicleID AND t1.Timestamp > t2.Timestamp
      INNER JOIN Vehicle ON t1.vehicleID = Vehicle.VehicleID
    ) AS MileageData ON Vehicle.Model = MileageData.Model
    WHERE MileageData.TripDistance > 0
    GROUP BY Vehicle.Model;
  `;
```

*Figure 39 - **Using Advanced Queries for system performance***

6.3. Conclusion

Each functionality is prioritized and developed iteratively using the timeboxing technique, ensuring alignment with the High-Level requirements before progressing further.
Additionally, special attention is given to the user interface design, emphasizing seamless interaction guided by Jakob Nielsen's heuristic principles. The user interface is meticulously crafted to enhance the overall user experience, fostering usability and engagement throughout the platform. Advanced coding techniques were employed to optimize performance and enhance user experience.

The research conducted earlier served as a foundation, informing design choices and development strategies. Overall, the implementation phase was a dynamic process characterized by adaptability, creativity and a commitment to delivering a high-quality product

7. LEGAL SOCIAL ETHICAL AND PROFESSIONAL ISSUES

This section delves into the legal aspects relevant to the project, highlighting key issues that must be addressed to ensure the web application provides a satisfactory experience for Eco-waste Company. For more detailed information on specific legal, social, ethical, and professional considerations, please refer to **Appendix G(proposal).**

1. Legal

Compliance with the General Data Protection Regulation (GDPR) and Environmental Protection Agency (EPA) regulations is crucial. The system adheres to strict data privacy laws, obtains explicit consent from users, restricts access to authorized personnel, encrypts sensitive information, and adheres to waste management operational timelines.

2. Social

The system aims to inform users about collection schedules, recycling initiatives and the environmental impact of the company. It prioritizes user privacy, implements data protection measures and includes educational initiatives to raise awareness about waste management practices.

3. Ethical

Clear communication about the system's functionalities, data usage, and privacy policies is essential. It avoids deceptive practices, obtains user consent before collecting personal information and securely encrypts sensitive data. Adherence to GDPR regulations ensures ethical handling of personal data.

4. Professional

The project emphasizes the ethical and efficient allocation of waste management resources, aiming to maximize effectiveness while minimizing environmental impact.

8. PRODUCT TESTING/TEST DATA

This chapter, delves into the critical phase of testing, essential for ensuring the reliability, functionality and accessibility of the developed solution. Employing the LSEPi framework, it aligns the testing approach with project objectives and user requirements. This chapter outlines the strategies for both white and black box testing, including the execution of accessibility tests. Additionally, it also provides insights into our test schedules and preliminary results, laying the groundwork for a comprehensive evaluation of the system's performance.

8.1. LSEPi Framework Integration

The testing methodology integrates seamlessly with the LSEPi framework, ensuring that testing efforts remain focused on addressing the specific needs of Eco Waste Solutions Company. The framework serves as a guide to prioritizing testing activities according to the project's objectives and user expectations.

8.2. Black Box Testing

This approach of software testing examines the code structure of the program being tested (for context the waste management system). The tester doesn't know about it; instead, they concentrate

on the inputs and outputs of the program, assessing its behaviour and functioning without taking into account its internal implementation (Khan, 2021).

8.3. White Box Testing

Also referred to as clear box testing, is a method of software testing that assesses the logic and internal structure of the program's code. When doing this, the tester has complete access to the source code and is familiar with how it functions internally. (Muhammad Miftakhul Syaikhuddin, 2018). Its main objective is to make sure that every code path is run and extensively tested.

8.4. Accessibility Testing

Accessibility testing is a crucial aspect of software testing that emphasizes on ensuring that digital products, such as the Waste management system, are usable by individuals with disabilities. This type of testing evaluates whether the product can be accessed and used effectively by people with various impairments, including visual, auditory, motor, cognitive and neurological disabilities. Accessibility testing involves assessing the product against accessibility standards like the Web Content Accessibility Guidelines (WCAG), to determine and remove any obstacles that would keep people with disabilities from using or accessing the system (brajnik, 2006).

8.5. Level of Testing

This refers to the different phases at which software is tested. Every level focuses on a different area of the program and ensures quality is built throughout the development lifecycle. Here is a breakdown of the used level of testing;

8.5.1. **Unity Testing –** it examines the smallest component of the software, typically individual functions, methods or classes. Developers typically write unit tests to ensure their code works as expected in isolation. (Umar, 2019).

8.5.2. Integration Testing- shows how different software units (modules) work together after they are integrated. This ensures data flows smoothly between different components and functionalities work as intended when combined (Umar, 2019).

8.5.3. System Testing – it evaluates the entire software system to ensure it satisfies the specified requirements and functionalities. Tests non-functional aspects like performance, usability, security, and compatibility. Often involves user acceptance testing (UAT) where potential users or customers provide feedback (Umar, 2019).

8.5.4. **Acceptance testing -** This testing is conducted to determine if the software satisfies the user's acceptance criteria. It can involve various types of acceptance testing, such as alpha/beta testing. The goal is to make sure the program is ready for deployment (Umar, 2019).

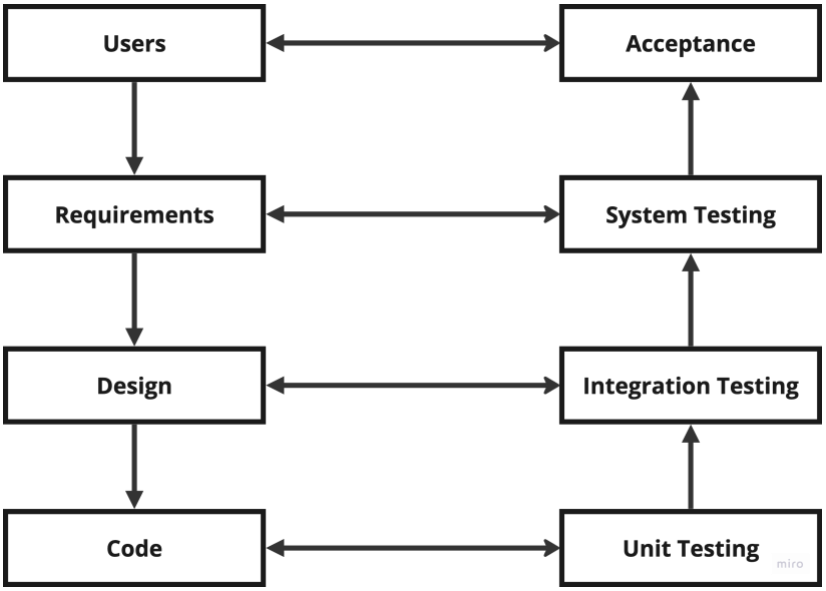


*Figure 40 . – **Show the Testing Levels conducted on the Waste Management System***

8.6. Test Schedules and Results

All the tests performed are available in **Appendix F**

It takes into account all the mentioned test methods to satisfy the system requirements.

9. Evaluation

This chapter delves into the approach to evaluating the project, encompassing various aspects such as functionality and usability. It reflects on both the product and the project process. Additionally, it considers potential pathways for the project's future development.

9.1. Functionality Evaluation

To begin with, it is important to confirm that, all the requirements collected in the Analysis chapter of this project have been met. The waste management system can be considered a fully functional application.

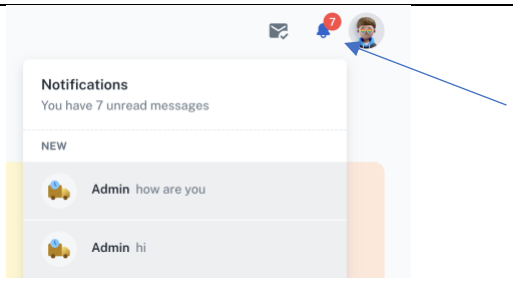
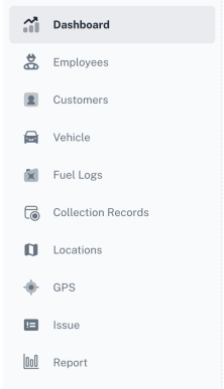
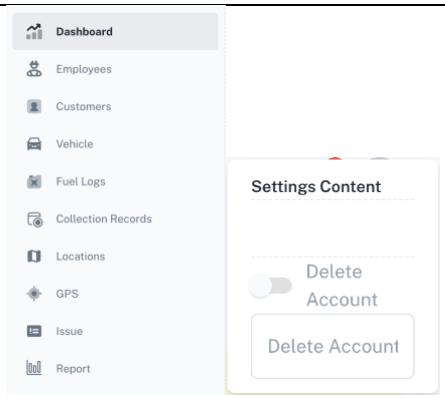
- **Firstly, Administrators** are capable of managing users, vehicles and waste collection points with ease, streamlining operational workflows and ensuring efficient resource allocation.
- **Secondly**, **Garbage collectors** benefit from seamless access to collection points, empowering them to record vital waste collection data in real time and report incidents promptly, thereby facilitating proactive problem-solving and resource optimization
- **Lastly**, **Customers** enjoy a seamless experience as they navigate through the system, effortlessly creating and managing their accounts, staying informed through timely notifications and swiftly reporting any issues encountered

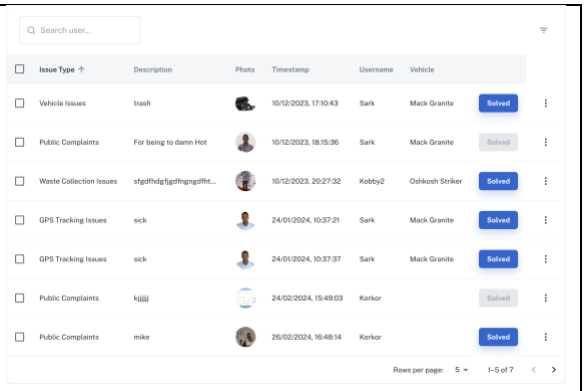
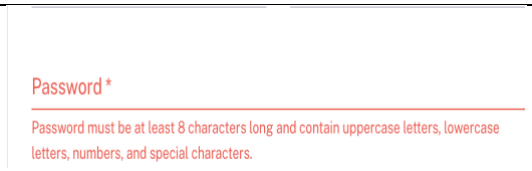
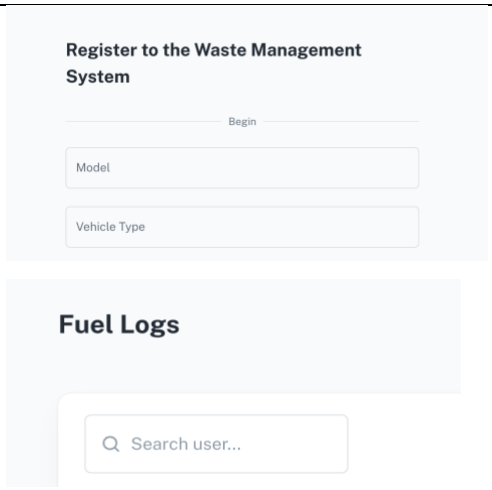
In essence, the system's rich functionality serves as a cornerstone for the smooth and effective operation of Eco Waste Solutions Company, aligning closely with its specific requirements and objectives.

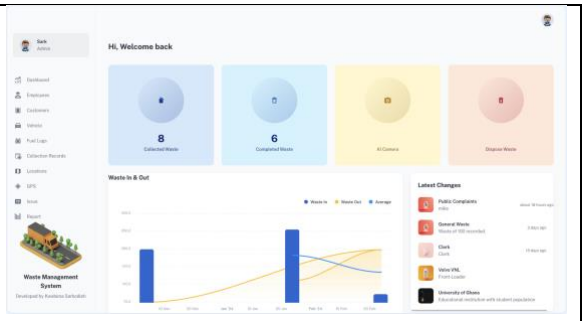
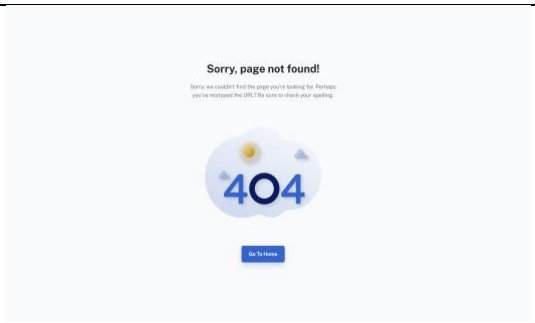
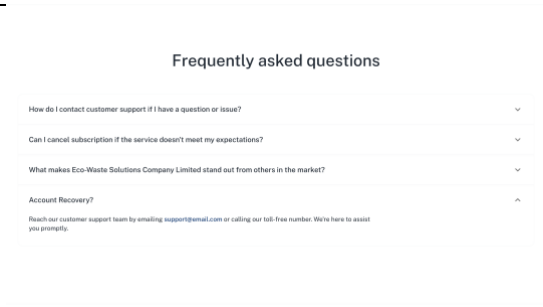
9.2. Usability Evaluation

During product research, Nielsen's Heuristics method was utilized to evaluate the products. Below is a table showing how successful the waste management system is at achieving all 10 principles.

Table 10

Nielsen Heuristics	Description	Proof
1. Visibility of system status	Provides clear indications of its current status, such as received notifications, ensuring users are aware of ongoing processes and actions	 *Figure 41*
2. Match between system and the real world	The system's terminologies, navigations and functionalities closely align with real-world waste management processes, minimizing cognitive load	 *Figure 42-* ***navigation icons***
3. User control and freedom	Users have free control over their interactions with the system, with options to navigate freely, even delete their accounts	 *Figure 43*

4. Consistency and standards	The system complies with industry standards and recognized design patterns, ensuring consistency in layout and behavior across different modules and screens.	 *Figure 44*
5. Error prevention	The system incorporates measures to prevent errors before they occur, such as validation checks and input methods that guide users.	 *Figure 45*
6. Recognition rather than recall	To adhere to this, the system labels all the form pages in large and bold text to reduce cognitive load	 *Figure 46*
7. Flexibility and efficiency of use	The system offers flexibility in user interactions, allowing both novice and experienced users to navigate and perform tasks efficiently. Advanced features are available for Admin	 *Figure 47-* ***example:***

8. Aesthetic and minimalist design	Its aesthetic features a clear and minimalist design, with clean layouts, intuitive navigation, and uncluttered interfaces that prioritize essential information and functions	 *Figure 48*
9. Help users recognize, diagnose, and recover from errors	In case of an error, the system provides clear and actionable error messages (Error 404), along with guidance on how to navigate back to the home page	 *Figure 49*
10. Help and documentation	Besides the FAQs on the landing page, users have the option to reach out for assistance or queries by reporting an issue or emailing the company.	 *Figure 50*

9.3. Accessibility Evaluation

Accessibility testing reveals that the waste management system adheres to accessibility standards and guidelines, ensuring usability for individuals with disabilities. The system supports assistive technologies such as screen readers (**description on all photos**) and keyboard navigation, enabling users with diverse needs to access and interact with the platform effectively. Accessibility features are integrated seamlessly into the user interface, promoting inclusivity and equal access for all users.

9.4. Compliance Evaluation

The waste management system demonstrates compliance with relevant regulations, standards and industry best practices. Data privacy and security measures are implemented to protect sensitive

user information, ensuring compliance with data protection regulations such as GDPR. The system's design follows established coding standards and practices, facilitating maintenance, scalability, and interoperability.

9.5. User Feedback

Feedback from users provided valuable perspectives on the system's performance and usability. Overall, users appreciate the system's intuitive interface, functionality and responsiveness. However, some users have highlighted areas for improvement, such as the need for additional features, enhanced reporting capabilities and optimization of certain processes.

9.6. Future Pathways

Looking ahead, the waste management system can benefit from continuous improvement and evolution. Future enhancements may include innovative technology, such as predictive analytics using artificial intelligence, machine learning for waste categorization and Internet of Things (IoT) to monitor waste bins in real-time. Additionally, expanding the system's scope to include features such as route optimization, demand forecasting and environmental impact assessment could further enhance its value proposition for Eco Waste Solutions Company and its stakeholders. But as the system is being used, new requirements for the system will emerge which will help make the system more capable.

9.7. Conclusion

In conclusion, the evaluation of the waste management system highlights its overall effectiveness, functionality, and usability in addressing the needs of Eco Waste Solutions Company. By incorporating user feedback, leveraging emerging technologies and staying abreast of regulatory developments, the waste management system can continue to evolve as a valuable tool for sustainable waste management practices.

10. Critical Appraisal

This chapter provides a comprehensive overview of the entire project, covering its inception, development process, and final product. It delves into the methodologies employed, challenges faced, and lessons learned throughout the journey. Furthermore, it evaluates the end product objectively and reflects on personal growth.

10.1. Project Inception

The project began towards the end of the first semester, November 2023. The idea for a waste management system stemmed from a personal interest in environmental sustainability. Recognized an inefficiency in the current procedure for collecting and transporting waste. Inspired by this, the goal of the project was to develop a comprehensive waste management system that streamlines waste collection and transportation to a disposal site. A proposal was written (Available in **Appendix F**)

10.2. Methodologies Employed

The project embraced an agile approach specifically SCRUM for development, leveraging its iterative nature and flexibility to adapt to evolving requirements and stakeholder feedback throughout the project lifecycle.

To begin, a literature review was conducted on topics such as **waste management history, Waste technologies and Waste regulations**, to fully comprehend the waste management industr .

After that, a thorough analysis of project requirements was conducted and divided into manageable tasks. These were then ranked according to importance and possible influence, allowing the development of the project to focus on high-value features first (**Must have and Should have**).

10.3. Development Process

The development process started in the Design chapter where iterative design sessions were conducted to visualize the user interface and system architecture, prioritizing principles like usability and accessibility while still ensuring all requirements are satisfied. The use of agile methodologies facilitated rapid prototyping (wireframes, ER diagram etc.) and user testing, enabling early validation of design concepts and functionality.

With the design finalized, development commenced following agile SCRUM principles. Tasks were divided into sprints (timeboxes), to implement features and functionalities. Regular code reviews and testing were conducted to maintain code quality and identify bugs early in the process.
Different testing techniques were employed to confirm functionality, performance and security. Following successful testing and validation, the solution was deployed. Deployment processes were carefully orchestrated to ensure a smooth transition from development to production.

10.4. Challenges Faced and Lessons Learned

One significant challenge faced was the unexpected delays in project timelines because of external factors such as changes in project requirements due to feedback from supervisors and users. Through proactive problem-solving and effective communication, I learnt the importance of effective communication and the significance of adaptability and perseverance in the face of difficulties. I successfully navigated these challenges, ultimately delivering a successful project outcome.

10.5. Objective Product Evaluation

The final product underwent a comprehensive evaluation to assess its functionality, usability, reliability and overall effectiveness. The product demonstrated strong performance across key metrics, meeting or exceeding expectations in most areas.

10.6. Personal Growth and Contributions

I honed my technical skills through hands-on experience with various tools, technologies and methodologies, gaining proficiency in areas such as web development, project management and quality assurance. Moreover, the experience fostered a growth mindset, encouraging me to embrace challenges.

11. Conclusion

In conclusion, the completion of this report marks a significant milestone in the journey towards addressing the pressing challenges in waste management. Through meticulous planning, diligent execution and unwavering dedication, I successfully developed a comprehensive waste management system that aligns with the needs of Eco Waste Solutions Company. The project's inception was fueled by the desire to revolutionize waste management practices, driven by the recognition of the urgent need for sustainable solutions in the face of environmental degradation. Despite encountering various challenges along the way, including technical complexities and unforeseen setbacks, the project leveraged innovative methodologies and collaborative efforts to overcome obstacles. The methodologies employed, including agile project management and iterative development, proved instrumental in navigating uncertainties and achieving project objectives efficiently. As a result, the final product stands as a testament to the efforts and commitment to excellence, offering a robust and user-friendly platform that streamlines waste management processes while promoting environmental sustainability. Looking ahead, I was inspired by the lessons learned and the invaluable experiences gained throughout this project, fueling my resolve to overcome all development-related issues and develop a proof-of-concept application.

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Appendix A – Literature Criteria

Table 11- Search Parameters Impact on Database Results

Search Parameter	Impact on Database Results
Sustainable waste	Increases relevance of articles focusing on sustainable waste management practices
Waste history	Identifies historical perspectives on waste management systems
Waste technologies	Accesses articles discussing technological advancements in waste management
Waste regulations	Includes articles exploring legal frameworks and regulations related to waste management
Smart waste	Identifies articles discussing smart technologies in waste management
Waste collection	Focuses on articles discussing waste collection methods and strategies
Urban Waste Management	Includes articles specifically addressing waste management in urban areas
Environmental Impact	Assesses articles discussing the environmental impact of waste management practices
Ghana waste management	Accesses articles discussing waste management practices in Ghana

Table 12 Inclusive/Exclusive Criteria

Criteria	Inclusion Criteria	Exclusion Criteria
Peer-reviewed Journals	Articles published in peer-reviewed journals to ensure reliability and credibility of information	Non-peer-reviewed sources such as blog posts or opinion pieces
Conference Proceedings	Inclusion of conference proceedings presenting recent research findings and innovative approaches	Conference proceedings not related to computing or lacking relevance to the research topic
Books	Relevant books providing comprehensive insights into computing topics	Books unrelated to computing or lacking relevance to the research topic
Keywords	Articles containing specified keywords to ensure relevance to the research topic	Articles not containing any of the specified keywords

Appendix B- Survey Questions

Stakeholder Requirements Questionnaire for Eco-Waste Solution Company

1. **What is your role in the waste management process?**

- [ ] Administrator
- [ ] Garbage Collector
- [ ] Customer
- [ ] Other (please specify)

2. **How would you rate the current waste management system's effectiveness in meeting your needs?**

- [ ] Very Effective
- [ ] Effective
- [ ] Neutral
- [ ] Ineffective
- [ ] Very Ineffective

3. **Which of the following features do you consider most important for the new waste management system? (Select all that apply)**

- [ ] Real-time access to waste collection data
- [ ] Optimization of collection routes with GPS
- [ ] Regulatory compliance enforcement tools
- [ ] Improved communication between workers and customers
- [ ] Other (please specify)

4. **On a scale of 1 to 5, how important is it for the new system to provide real-time access to waste collection data?**

- [ ] 1 - Not Important
- [ ] 2 - Somewhat Important
- [ ] 3 - Neutral
- [ ] 4 - Important
- [ ] 5 - Very Important

5. **What challenges do you currently face with the existing waste management system? (Select all that apply)**

- [ ] Lack of real-time access to data
- [ ] Inefficient collection routes
- [ ] Difficulty ensuring regulatory compliance
- [ ] Poor communication between workers and customers

- [ ] Other (please specify)

6. **How satisfied are you with the level of communication between workers and customers in the current system?**

- [ ] Very Satisfied
- [ ] Satisfied
- [ ] Neutral
- [ ] Dissatisfied
- [ ] Very Dissatisfied

7. **Would you prefer the new waste management system to prioritize:**

- [ ] Efficiency in waste collection
- [ ] Compliance with regulations
- [ ] Improved communication with customers
- [ ] All of the above
- [ ] Other (please specify)

8. **How frequently do you encounter issues with waste collection in the current system?**

- [ ] Rarely
- [ ] Occasionally
- [ ] Frequently
- [ ] Very Frequently
- [ ] Not Applicable

9. **Which aspect of waste management do you think needs the most improvement?**

- [ ] Collection efficiency
- [ ] Data accessibility
- [ ] Regulatory compliance
- [ ] Customer communication
- [ ] Other (please specify)

10. **On a scale of 1 to 5, how likely are you to adopt and use the new waste management system once it is implemented?**

- [ ] 1 - Very Unlikely
- [ ] 2 - Unlikely
- [ ] 3 - Neutral
- [ ] 4 - Likely
- [ ] 5 - Very Likely

Appendix C- Survey Questions Results

Eco -Waste Solutions Company Questionnaire

6 responses

Publish analytics

Stakeholder Requirements Questionnaire for Eco-Waste Solution Comapny

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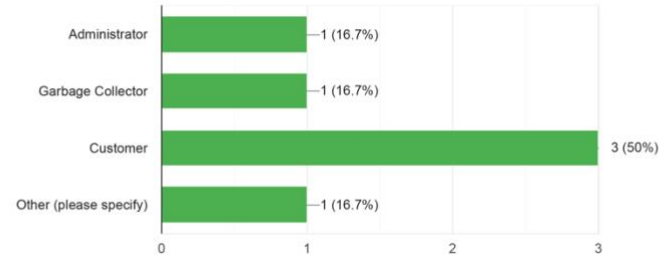
6 responses



How would you rate the current waste management system's effectiveness in meeting your needs?

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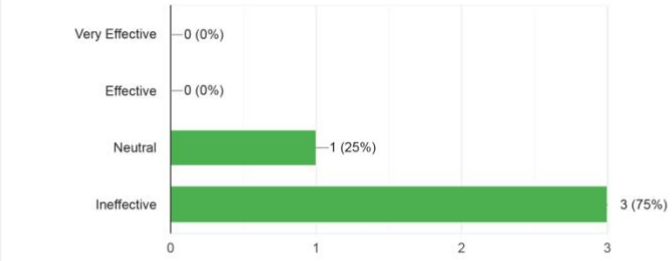

Which of the following features do you consider most important for the new waste management system? (Select all that apply)

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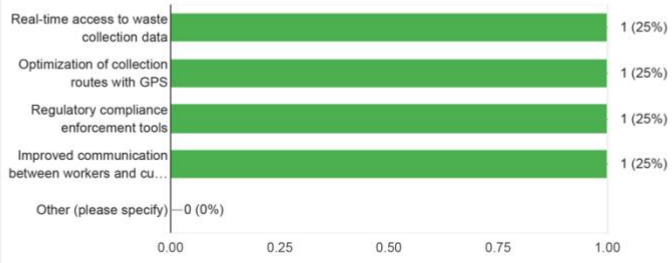

On a scale of 1 to 5, how important is it for the new system to provide real-time access to waste collection data?

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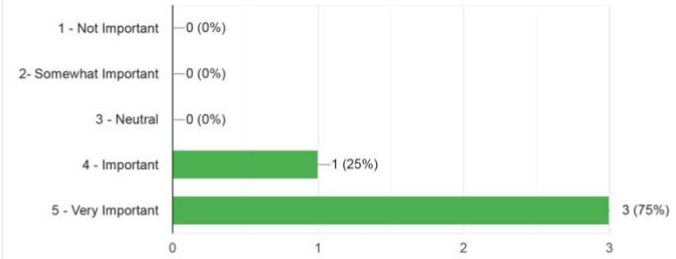

What challenges do you currently face with the existing waste management system? (Select all that apply)

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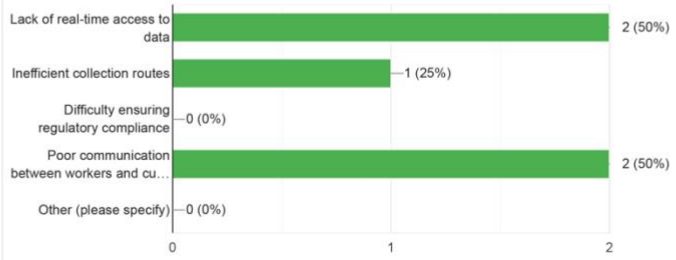

How satisfied are you with the level of communication between workers and customers in the current system?

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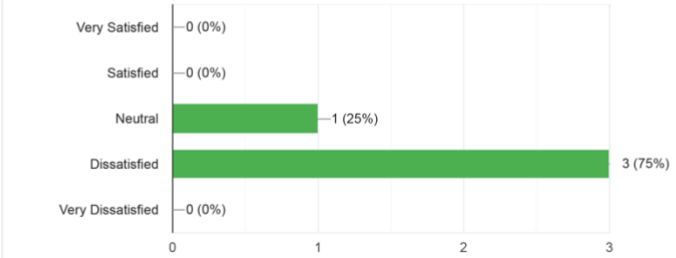

Would you prefer the new waste management system to prioritize:

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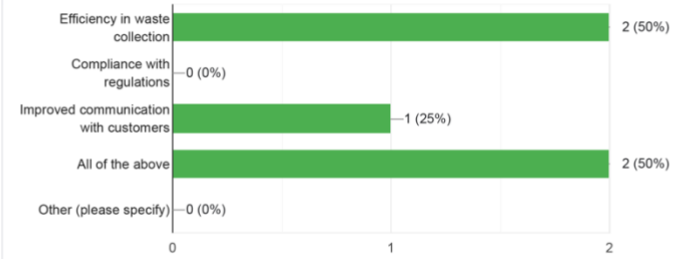

How frequently do you encounter issues with waste collection in the current system?

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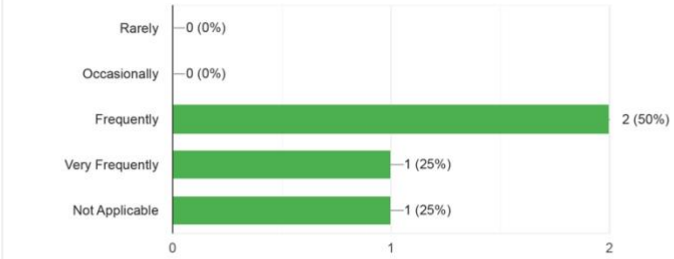

Which aspect of waste management do you think needs the most improvement?

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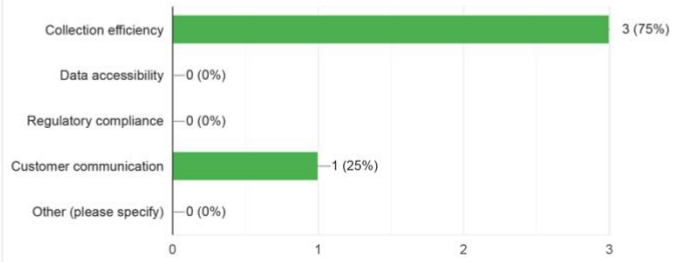

On a scale of 1 to 5, how likely are you to adopt and use the new waste management system once it is implemented?

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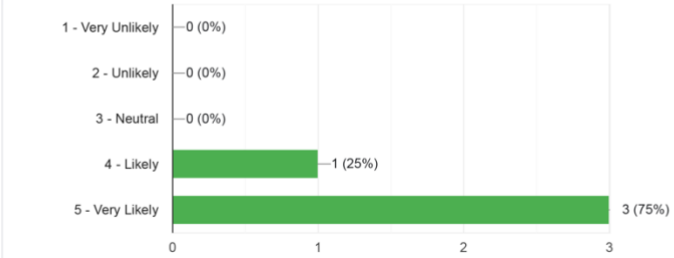

Appendix D – Wireframes and Prototype

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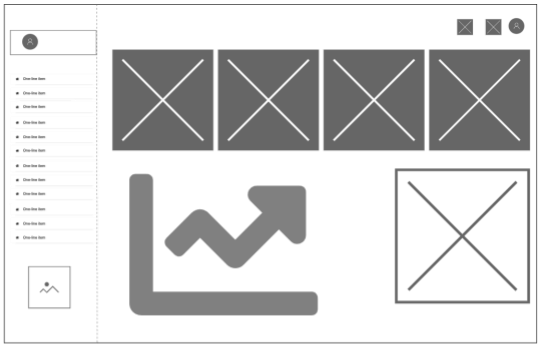

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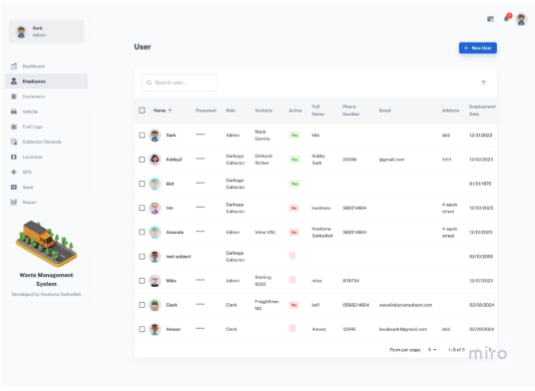

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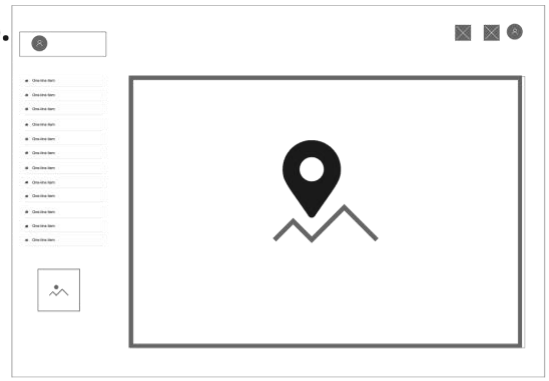

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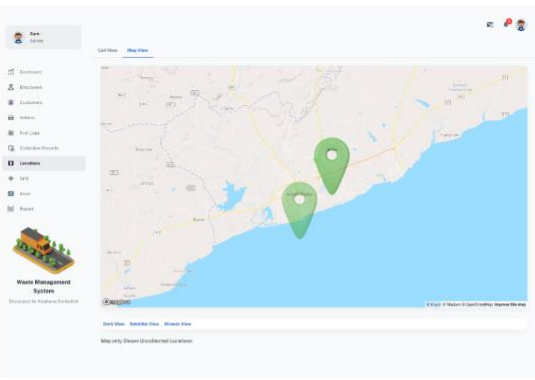

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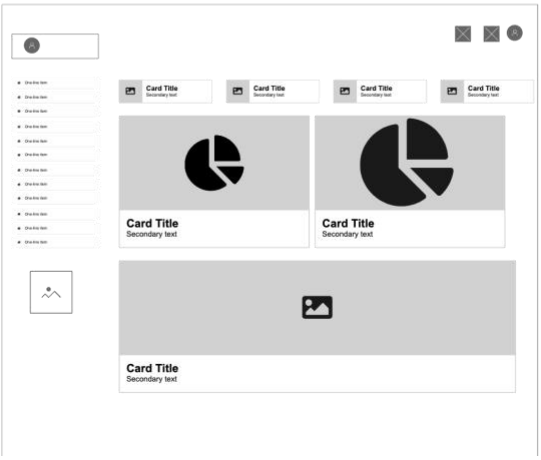

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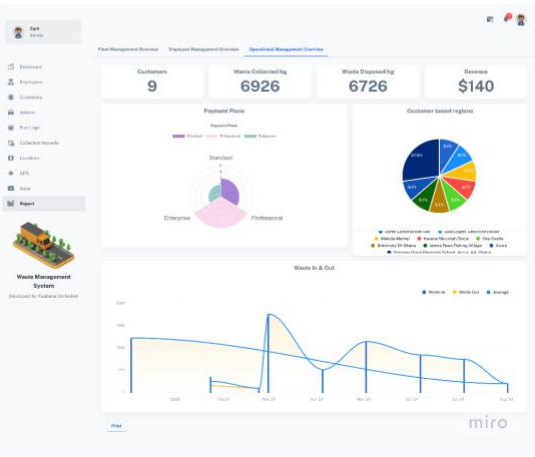
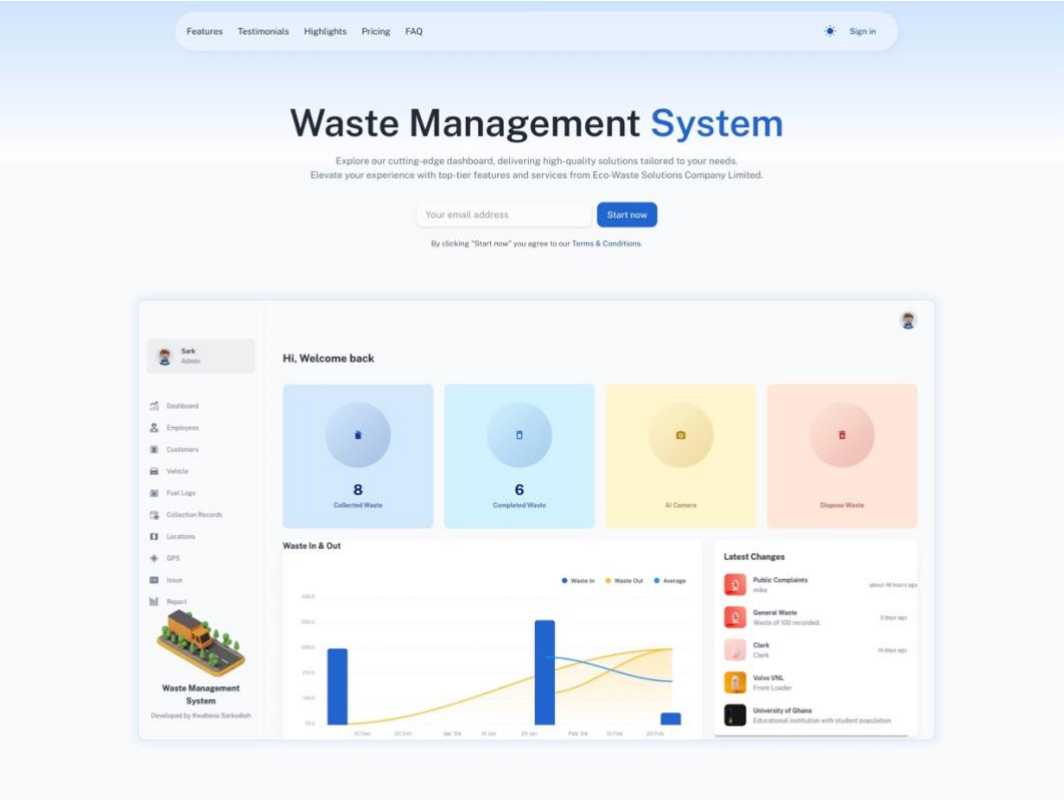
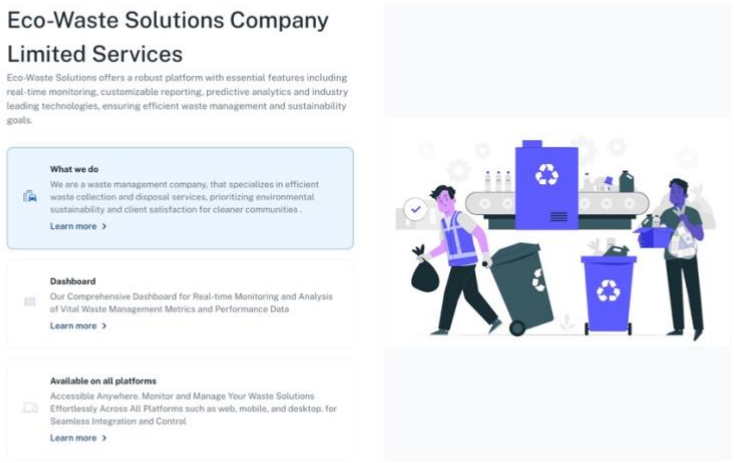
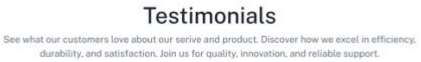


Appendix E- Overview of Waste Management System

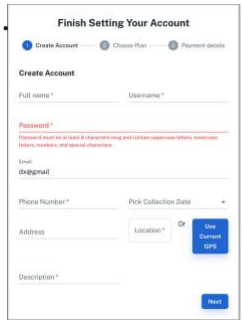
Landing / Home Page

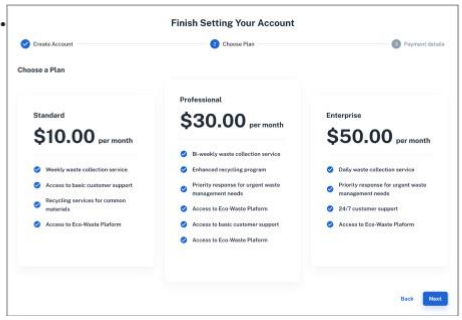


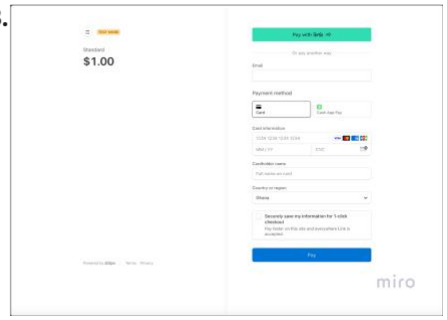




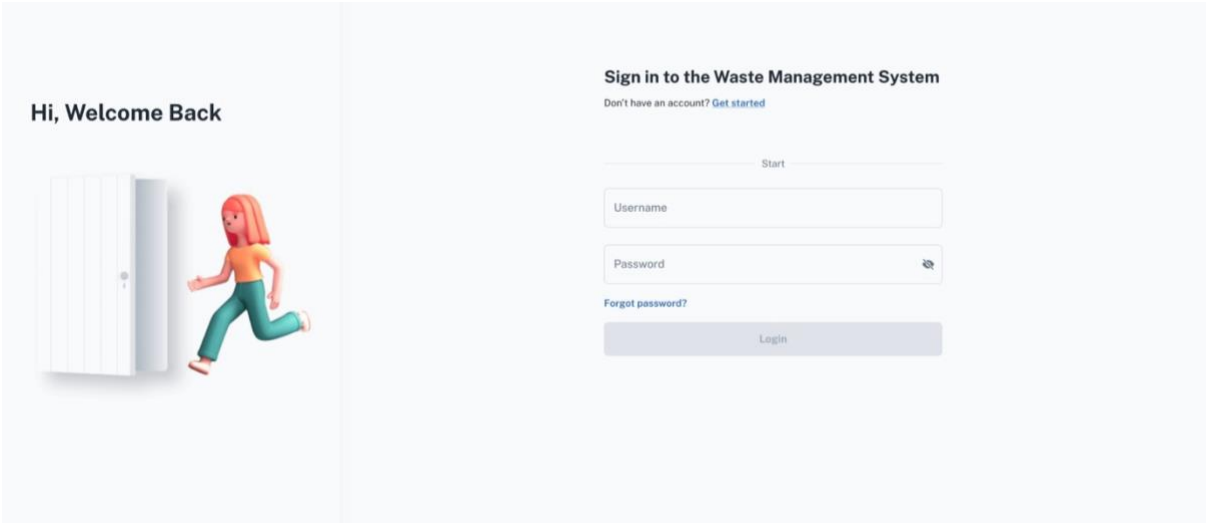
Registration

1. 

2. 

3. 

Login



Privacy Policy

Privacy Policy

Effective Date: 01/01/2024

Thank you for choosing Eco-Waste Solutions for your waste management needs. We are committed to protecting your privacy and ensuring that your personal information is handled securely. This Privacy Policy outlines how we collect, use, disclose, and safeguard your information when you use our waste management system, including our website and mobile applications. By accessing or using our services, you agree to the terms of this Privacy Policy.

1. Information We Collect

We may collect personal information from you when you interact with our waste management system. This may include:

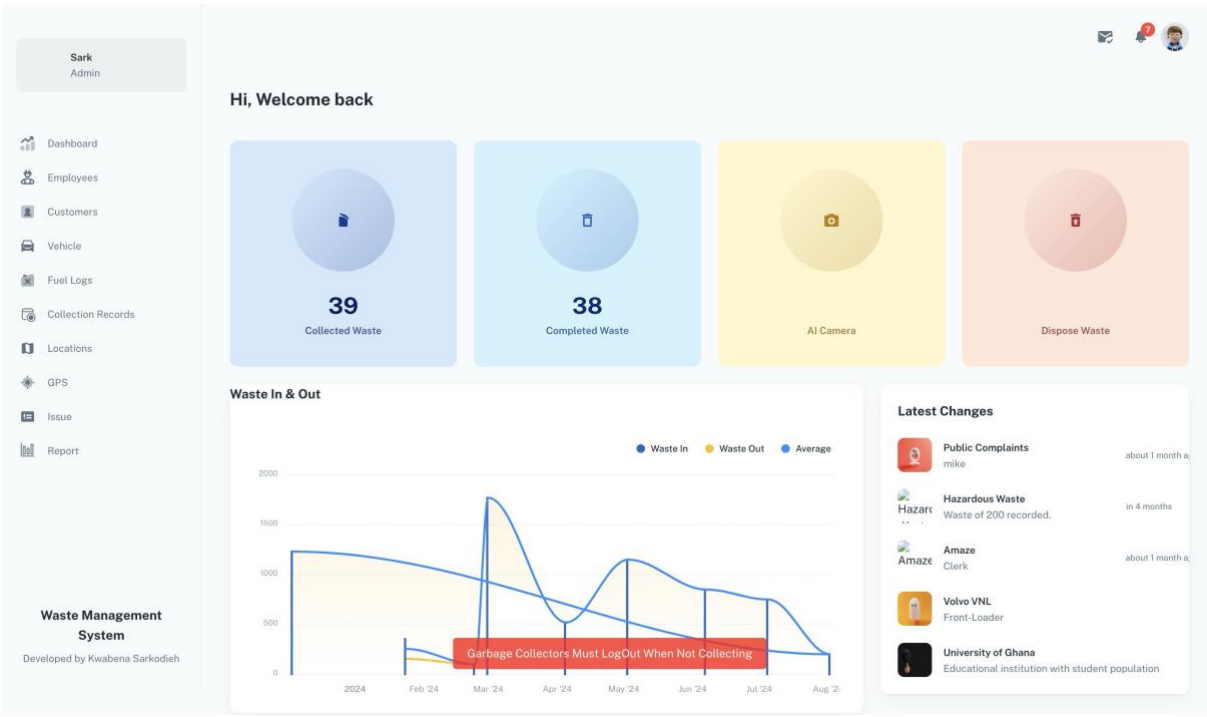
- Contact information such as name, address, email address, and phone number.
- Account credentials such as username and password.
- Payment information for billing purposes.
- Information about your waste management preferences and usage.
- Device information such as IP address, browser type, and operating system.

We collect this information to provide you with our services, process your transactions, improve our products and services, and communicate with you.

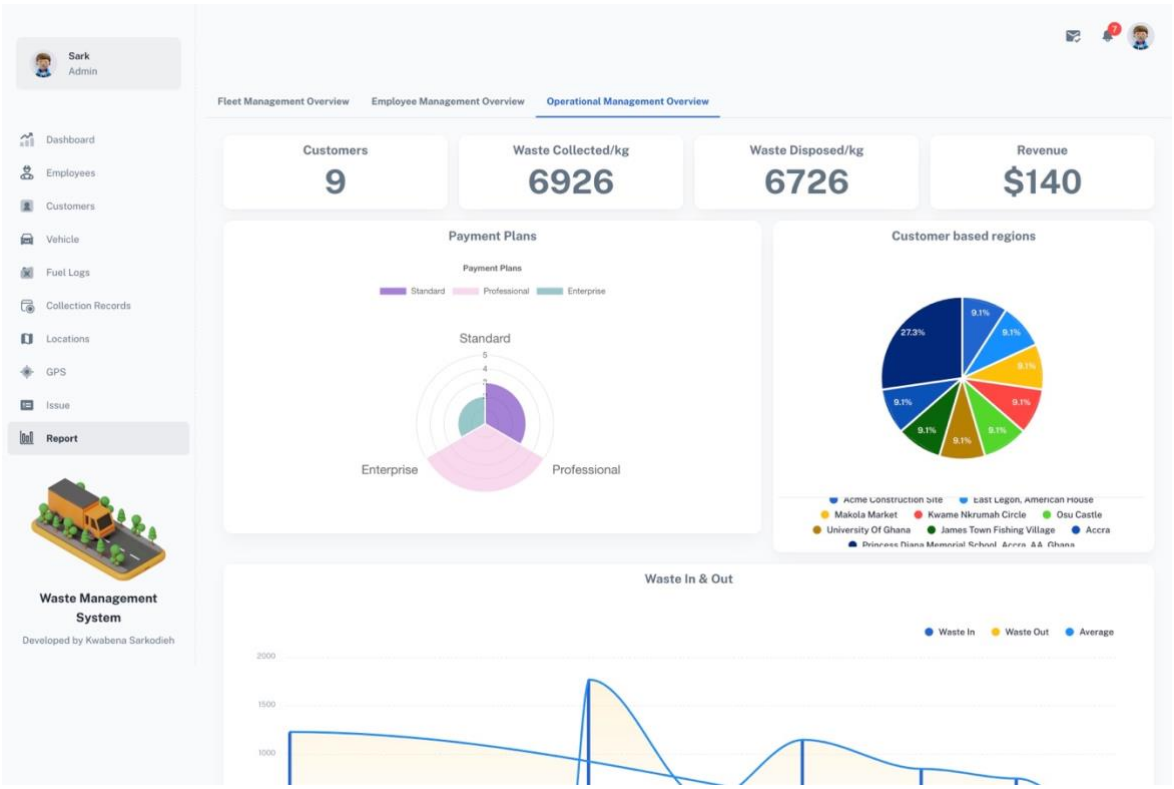
2. How We Use Your Information

We use your information for the following purposes:

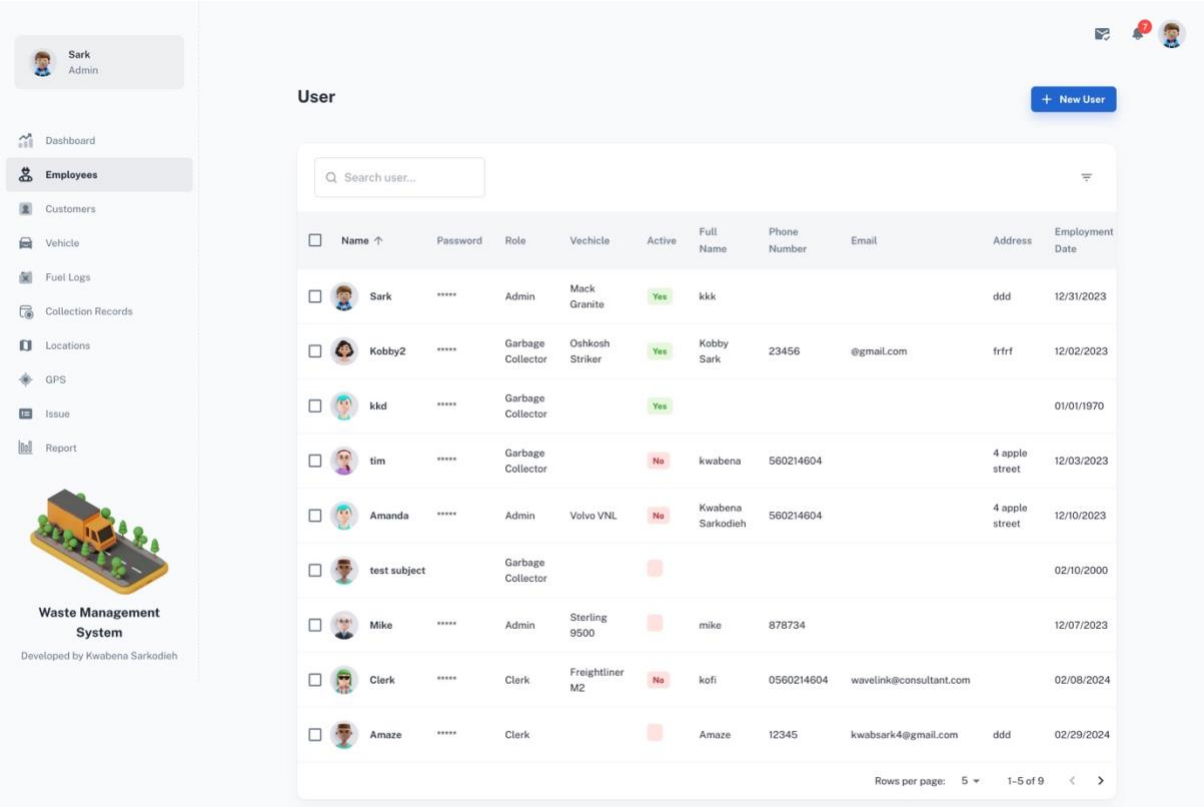
Dashboard



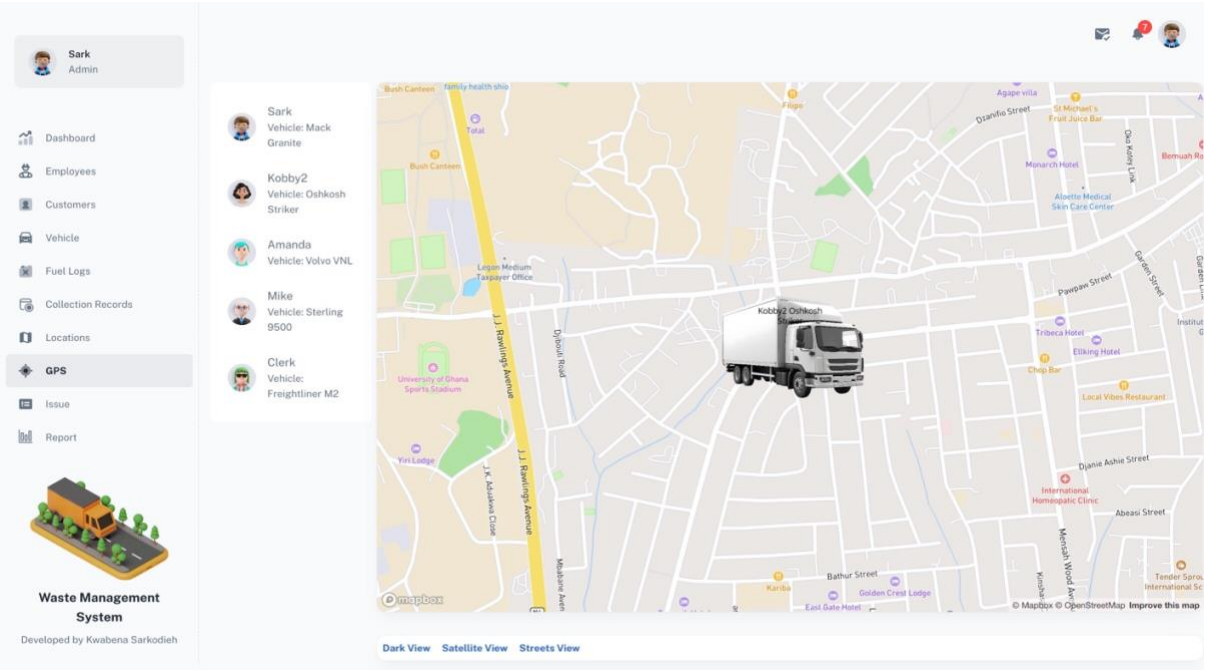
Report



Employees Page

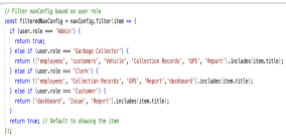


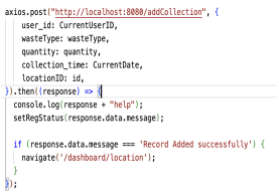
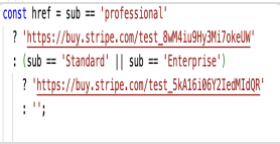
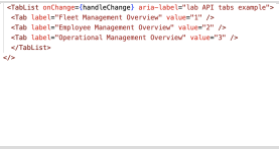
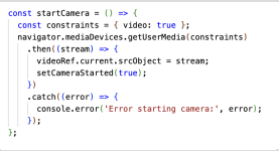
GPS Page



Appendix F – Product Testing

Table 13 – ***Test Plan & Results***

Test N.	Requirement	Result Obtained	Snippet of Code	Pass/ Fail	Testing Level
1	The system should have Databases for Users, Vehicles records, fuel logs, waste Collection records, and Locations	All databases successfully created and operational	`const db = mysql.createConnection({ host: "localhost", port: 3306, user: "root", password: "12345678", database: "test" });`	Pass	Black Box, White Box, Integration
2	Admin must be able to manage (add/edit/delete) Users, Vehicles, and Fusel Logs	Admin interface provides buttons to management of users/ vehicles, /fuel logs		Pass	Black Box, Acceptance Testing
3	Admin must Assign Vehicles to Garbage Collectors	The system ensures this is accomplished through a form		Pass	Black Box, Integration
4	Admin can Send notifications to all users while the clerk can send to only customers/collectors	Admin and clerk interfaces allow for sending notifications to respective user groups		Pass	Black Box, White Box,
5	Admin can Monitor GPS locations and vehicle issues logged by Garbage Collectors	The system ensures this with strict user roles		Pass	Black Box, Integration, White Box,
6	Admin Set waste collection time periods	Admin interface allows for setting waste collection time periods	`<TextField name="start_time" label="Start Time" value={updatesett.start_time} onChange={handleSetting} />   <TextField name="end_time" label="End Time" onChange={handleSetting} value={updatesett.end_time} />`	Pass	Black Box, White Box,
7	Garbage Collectors must be able to access collection points on the map (Route Planning)	Garbage collector interface provides access to collection points on the map for route planning	`<TableCell align="left">{user.Location_Name}</TableCell> <TableCell align="left">{user.Description}</TableCell> <TableCell align="left">{user.Customer_Name}</TableCell>`	Pass	Black Box, White Box,

8	Garbage Collectors must be able to record collected waste and waste disposed	Garbage collector interface includes functionality to record collected waste and waste disposal		Pass	Black Box
9	Garbage Collectors must record fuel logs with proof	Garbage collector interface allows for recording fuel logs with proof		Pass	Black Box
10	Customers must be able to manage their accounts	The system provides profile pages to Customers only		Pass	Black Box
11	Customers must be able to make payments via Credit/Debit cards	The system uses stripe for payments		Pass	Black Box, Integration
12	Users must be able to receive notifications	User interface enables receipt of notifications		Pass	Black Box
13	Users must be able to report issues	User interface includes functionality to report issues		Pass	Black Box
14	Clerk has restricted access to manage (edit/view) vehicles, Customer, Fuel Log, Reported issues, and locations	The system ensures this with strict user roles		Pass	Black Box
15	The system should generate reports	System generates reports as per specified requirements		Pass	Black Box
16	All users should be able to use the A.I Camera in the system	A.I camera functionality accessible to all users		Pass	Black Box
17	The system should adhere to accessibility standards	The system is accessible to users with disabilities, tested with screen readers and keyboard navigation		Pass	Accessibility Testing

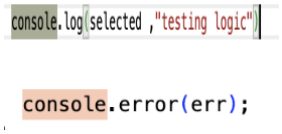
18	Internal code structure and logic should be tested	Internal code structure and logic verified through unit tests and code reviews		Pass	Unit Testing, System Testing

Table 14 – ***Performance Testing***

Task	Avg Response Time (Speed)	90% response Time (Quality)
Login	0.0029 sec	0.01 sec
Display Pages	0.000 sec	0.005 sec
Submit to Database	0.0014 sec	0.007 sec
Retrieve from Database	0.0029 sec	0.012 sec
Report Visualization	0.0067 sec	0.025 sec

This benchmark, conducted using various benchmarking tools, evaluated the trade-offs between performance and Quality in the latest version of Chrome on an M2 MacBook Pro.

'**Avg Response Time**' provides quick average response times to expedite tasks, while "**90% response Time**," ensures that the majority of responses meet a higher quality standard by aiming for lower response times for 90% of the interactions. This allows users to gauge the system's performance under different operational conditions and choose the appropriate mode based on their priorities

Performance may vary depending on the hardware.

Appendix G – Proposal

Undergraduate Final Year Project Proposal

An Analysis of Waste Management Systems to produce a web-based system to help in the collection, transportation and dumping of waste at a site. (Eco-Waste Solutions Company Limited case study).

Kwabena Sarkodieh

Final Year Report

COMP1682 Final Year Project

001353760

1. Introduction

1.1. Background

Waste management is a critical aspect of environmental sustainability and public health. Today, waste management is a growing concern due to an increase in population, urbanization and overall increase in waste. Waste management companies play an important role in efficiently collecting, transporting, and disposing of waste to reduce its negative impact on our environment.

However, waste management companies often face daily challenges when operating. The term “waste management” is often scrutinized by governments and individuals. This is because certain regulatory processes must be followed to dispose of waste properly. These processes are complex and ever-changing. Making waste management more efficient and reliable from collection to dumping, requires an innovative system that relies on real-time data to minimise cost and optimize labour force.

A management system is a software system that helps streamline operations within businesses. It is capable of capturing real-time information, providing data analysis, enforcing regulatory compliances and improving overall efficiency.

The project aims to develop a waste management system specifically designed to handle the collection, transportation and dumping of waste to a site. The data collected from these procedures will be visualized using a Analysis Dashboard interface which will provide insights into all the stages. Furthermore, such data will be visualised in different forms to gain a better understanding of the process. From this, they can make informed decisions to further improve their operations

Keywords: [Management System, Waste Management, Dashboard, Data Visualisation, Vehicle Management, GPS Tracking]

1.2. Existing Waste Management System Used by Eco-Waste Solutions Company Limited

Eco-Waste Solutions Company Limited currently employs a traditional waste management system that relies heavily on manual book records to track and manage its operations. The system is primarily paper-based, requiring employees to maintain physical records of vehicle details, fuel logs, garbage collector information, waste collection locations, and other critical data.

1.3. The Problem with the Current System

There are several problems with the manual system used by **Eco-Waste Solutions Company Limited.** Some of the more distich ones are:

1.3.1. **It is not scalable:** The current system is already struggling to meet the growing demand from its customers. Especially the paper-based system, which is holding Eco Waste Solutions back. They are not accessible since they are stored in one location, prone to damage or loss, and make it challenging to access or retrieve information quickly. This is hindering the company's growth potential, leading to delays in collection, transportation and overall service disruptions.

1.3.2. **Human errors:** Mistakes are prone to occur in areas such as data entry, organizing entries and miscommunication among workers. These errors compromise the accuracy of the company's operations, leading to issues such as missed collections, billing discrepancies and regulatory warnings from governing bodies. Inability to keep correct records and submit reports on time, or adhere to environmental standards can result in fines, penalties, and legal liabilities for **Eco-Waste Solutions Company Limited.**

1.3.3. **Too many Inefficiencies:** The current system fails to make the best of time and resources. Collectors often get lost, which slows down operations. Limited communication between Clerks and collectors leads to confusion about collection schedules or missed pickups, while inefficient routes with excessive backtracking or unnecessary stops, waste fuel and increase work times. These challenges hinder the accuracy and reliability of waste management operations, resulting in customer dissatisfaction and environmental impacts.

1.3.4. **There is no mechanism for efficient data collection and analysis:**

The manual system, cannot automate some of the data collection process. As a result of this, the company struggles to gather accurate data in minute areas that are beneficial. Having a digital platform for storing and analyzing data will help Eco Waste Solutions make informed decisions, identify areas for improvements and optimize resource allocations.

2. Aims

The project takes a new approach based on the historical insights and challenges of Eco Waste Solutions Limited to produce a web-based application. The goal of the application is to be a centralized hub that will be responsible for streamlining the waste collection process as shown in **Figure 1**

Unlike the current system, this is how the project will tackle the 4 problems listed above:

2.1.1. **Digitalize all recorded data**: as a result of this it will provide real-time data on the waste collection process and make the stored data more accessible and secure. Plus, also automating some of the data collection process will reduce human errors.

2.1.2. **Use GPS tracking and navigation systems** to optimize route planning, and minimize travel time and fuel consumption.

2.1.3. **Enforce regulatory Compliance:** by having built-in features that will assist in adhering to regulations and minimizing the risk of non-compliance issues

2.1.4. **Enhance Communication** amongst workers which will improve the coordination and efficiency

2.1.5. **Improve customer convenience** as it will keep them informed on their collection schedule, handle payments and improve overall transparency and trust.

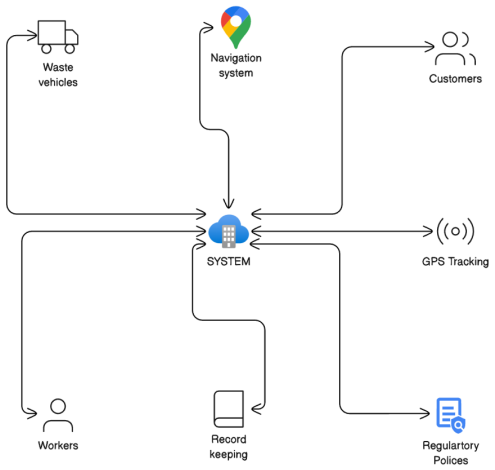


Figure 1 – A centralised hub as the proposed waste management system

2.1. The Proposed System

Below is a brief outline of the technologies that will be used to develop the proposed system as shown in **Figure 2**:

2.1.1. **Front-End**: This will be the part users directly interact it. The user will be provided with a feature based on their role and permissions access. This component will be built using **React JS** since it is one of the best frameworks for building web applications because of its dynamic elements (Roldan, , 2018.).

2.1.2. **Back-End**: This will be the engine, that powers the entire application. It will be responsible for all crucial functionalities that happen within the system. It will be made up of two components, that is, the server-side logic and the database management.

1. ***Server-side Logic*** - this will be built using Node JS. Why Node JS? This is because it is a JavaScript runtime environment that allows servers to handle requests and responses efficiently at a very fast rate (Kai, 2014).

2. ***Database Management*** – The chosen database is MySQL, a popular relational database management system, which is particularly useful for a waste management system where data needs to be structured and related in a meaningful way

2.1.3. **External Services**: For the system to deliver on its promises, it will also have to integrate with some third-party resources or functionalities through APIs (Application Programming Interfaces).

1. ***Mapbox API*** – This will be integrated into the system to help provide functionalities such as displaying waste routes and visualising pick-up locations

2. ***Position Stack API*** – This will allow for geocoding (converting addresses into geographic coordinates), and reverse geocoding (determining the address or place based on geographic coordinates). To get accurate data for GPS tracking.

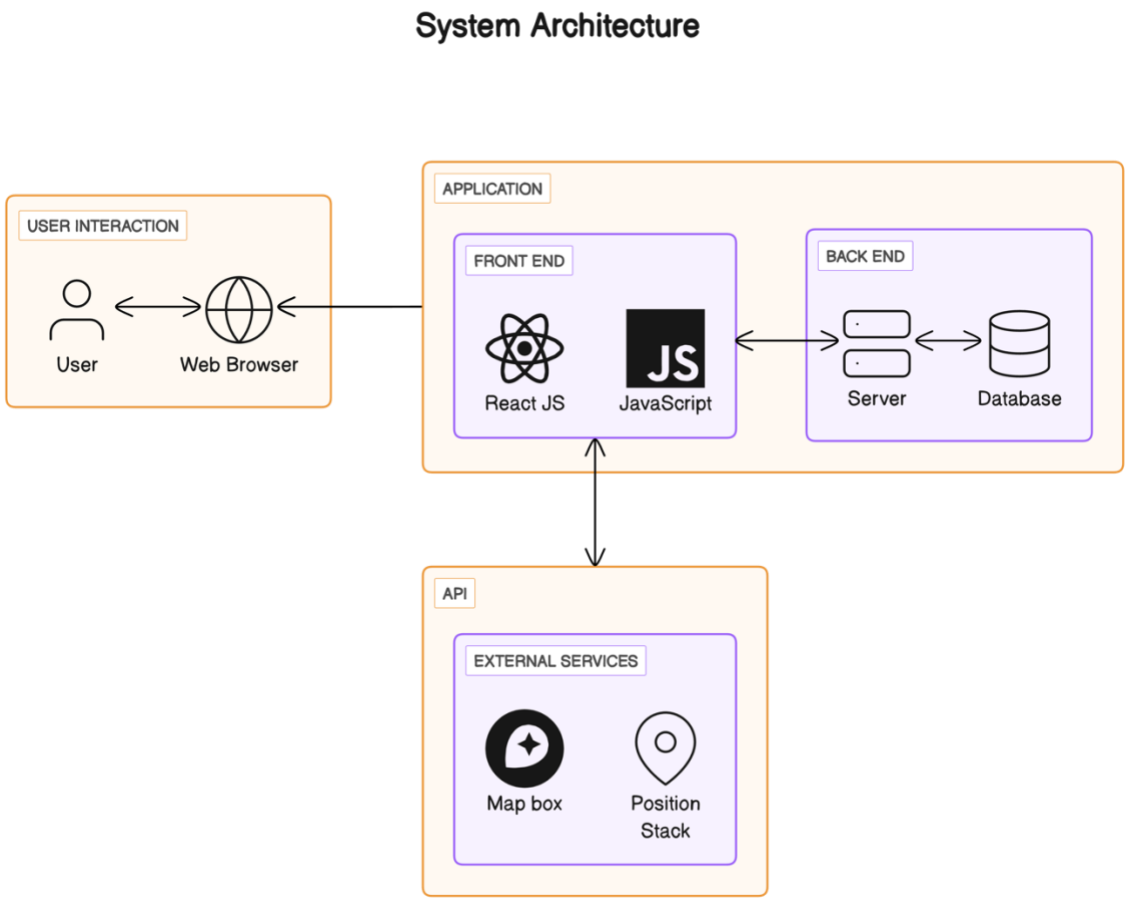


Figure 2 – System Architecture of the Proposed System

2.2. Functionalities Expected of the Proposed System

1. The system should allow administrators to add, edit, and remove vehicles, including details such as model, vehicle type, registration number, and maintenance history.
2. Administrators must be able to add, edit, and delete fuel logs, including dates, costs, and notes.
3. Administrators should have the capability to assign vehicles to drivers.
4. The system must facilitate the addition, editing, and removal of garbage collectors, incorporating details like driver's license information, contact details, and employment history.
5. Administrators should be able to create and manage waste collection locations.
6. The system must provide tools for monitoring vehicle issues.
7. Administrators must have the ability to track garbage collection progress.
8. The system should enable the tracking of the GPS location of vehicles and garbage collectors.
9. Garbage collectors should have access to waste collection locations, available in either list view or map view.
10. Garbage collectors must be able to record waste collection activities at each location.
11. There should be a feature for reporting safety incidents or issues, with the ability to attach photos or descriptions.
12. Garbage collectors should be able to record information such as waste type, quantity (in terms of bin type), locations, and timestamps.
13. Garbage collectors must record the time of disposal.
14. Garbage collectors should be able to log fuel usage.

2.3. Non-Functional Requirements Expected of the Proposed System

- **Performance –** The system should be able to handle large numbers of data which performance degradation.

- **Security –**The system should implement user authentication and authorization mechanisms to control access to different system functionalities.

- **Reliability-** The system should be available and reliable, with minimal downtime or failure.

- **Data Integrity -** Errors should be avoided and data integrity should be guaranteed by the system. Inconsistencies in data such as vehicle information, fuel logs, garbage collector details, and waste collection locations.

3. Objective

1. **Conduct a Systematic Research** [Week 1-2]

1.1. Research waste management systems to understand their benefits, problems and why it's important

1.2. Examine the unique challenges confronting waste management stakeholders' issues

1.3. Investigate recent developments in waste management technologies to discern emerging trends and potential innovations

1.4. Analyse case studies and empirical data to identify successful waste management strategies and best practices adopted by different regions or industries.

***Outcome**:* This chapter [2] aims to provide insights into current trends and needs in waste management processes, informing strategic decisions and actions to optimize waste management.

2. **Analysis** [Week 3-4]

2.1. Identify specific business needs and expectations of Eco Waste Solution Company through a stakeholder analysis (rich picture)

2.2. Utilize various techniques such as Questioning to gather insights into requirements

2.3. Translate the business requirements into functional specifications for the waste management system using Moscow.

2.4. Create diagrams to illustrate the product ideated.

***Outcome**:* chapter [3], This analysis will yield comprehensive system requirements tailored to the needs of Eco-Waste Solutions Company Limited.

3. ***Design*** [Week 5-6]

3.1. Create a high-level conceptual model outlining the structure, components and interactions of the system. (wireframes and fidelity Prototype)

3.2. Define the database schema to organize and store waste management data efficiently, ensuring scalability and performance.

3.3. Determine the relationships between different data entities and enforce constraints to maintain data integrity and consistency.

3.4. considerations for data privacy and security measures implemented within the database schema design

4. ***Implementation*** [Week 7-8]

4.1. Develop administrative and other users' functionalities to support user roles and permissions within the system

4.2. Implementing a robust login with encryption and log monitoring

4.3. specific security measures implemented to mitigate potential security threats and ensure data confidentiality and integrity

4.4. Integrate the MySQL database with the user interface components to enable seamless data interaction and presentation

Outcome*:* chapter [4] (***Design and Implementation***), This will result in a finalized system with user roles, integrated database, and user interface components.

5. ***Testing*** [Week 9-10]

5.1. Conduct database testing to ensure data integrity, reliability and performance

5.2. Test all functionality to verify accuracy, reliability, and compatibility with the system

5.3. Perform different testing standards to assess usability, accessibility, and responsiveness.

5.4. Iterate on testing results to identify and address any issues or discrepancies, refining the system for optimal performance

Outcome**:* chapter [4] (Testing***), This will yield a capable system that has been thoroughly tested and refined for optimal performance.

6. **Evaluation and Conclusion** [Week 10-11]

6.1. Provide a summary of the key findings and outcomes of the project, highlighting achievements and insights gained.

6.2. Offer recommendations for future improvements, enhancements, and extensions based on the project's findings and experiences.

6.3. Conclude the project by reflecting on the journey, lessons learned, and implications for the field of waste management.

***Outcome**:* chapter [6], This will result in a comprehensive evaluation of the project and offer potential future development paths for the system

4. Methodology used

The project will employ Agile methodology, offering flexibility throughout development. Utilizing techniques like Scrum to ensure on-time delivery of only essential features crucial for waste management. With an adaptable approach, it will accommodate any evolving requirements during the project. Following Agile Scrum principles will guarantee timely delivery without compromising quality. This iterative development and timeboxing strategy will result in a visual dashboard tool tailored to streamline waste management, along with key functions and features, all delivered on schedule (Rivera S., 2023).

While Agile Scrum has numerous advantages, it's important to note that tailoring the methodology to the project will help overcome potential challenges. By adopting this approach, we can produce a minimum viable system in just a few months, providing early benefits and insights into the system's potential (Sasmoko Indrianti, 2022).

4.1. Techniques and Practices

Using Agile methodology with a focus on Scrum, several techniques and practices will be employed to ensure the successful development of the waste management system. Here are some key techniques and practices:

1. **Creating Backlogs:**

   This ensures specific features and functionalities of the system are outlined to guide its development.

2. **Iterations:**

   This defines the development workflow, making sure goals for each iteration are set, Such as completing a feature at a set date.

3. **Sprint Planning:**

   Having each sprint (iteration) outlined, will help create a clear roadmap for the upcoming development cycle.

4. **Incremental Development:**

   This concept will allow for gradual and regular development of components for the system.

5. **Continuous Integrations**

   Integrate code regularly, even if it's just you working on it. This practice helps catch integration issues early and maintains code consistency.

6. **MVP Approach**

   Prioritizing the development of a Minimum Viable Product to get a functional version of your system sooner. This allows you to gather feedback and make improvements iteratively.

7. **Task Management Tools**

   The use of task management tools to visualize workflow, track tasks, and maintain transparency in your progress

8. **Test Driven Development (TDD)**

   Writing tests before implementing features can help ensure the reliability of the code. Hence the system.

(Raicevic, 2023)

5. Legal, Social, Ethical and Professional issues

5.1. Legal

When discussing the legal frameworks concerning a digital product, it is important to outline the General Data Protection Regulation Act (GDPR). This legislation, enacted by the European Union, governs the protection and processing of the personal data of individuals and has set a benchmark for data protection laws worldwide. It imposes strict guidelines on how websites collect, store and utilize user data, aiming to safeguard individuals' privacy rights and enhance data security measures. Compliance with GDPR is essential for any web-based application operating globally or handling data of its users, ensuring transparency, accountability and trustworthiness in data handling practices (European Commission, 2023).

For the waste management system to comply with this regulation;

1. The data collected from stakeholders to track procedures will adhere to stringent data privacy laws set by the GDPR.

2. Before collection and usage, explicit consent from users and stakeholders will be mandatory, ensuring alignment with data privacy regulations.

3. Access to this data will be restricted to authorized users only, enhancing security and transparency.

4. Additionally, sensitive information like passwords will undergo encryption measures to bolster data protection and prevent unauthorized access

In accordance to the Environmental Protection Agency (EPA) Regulation, which outlines the requirements for handling waste and involves operational timelines for waste management activities to ensure environmental protection and public health standards.

This includes scheduling waste collection activities during designated hours to comply with regulatory requirements. Additionally, the system will provide functionalities for monitoring and reporting on operational timelines to ensure accountability and regulatory compliance. By integrating these features, the system will facilitate adherence to waste management regulations regarding operational hours and contribute to maintaining environmental standards and community well-being (US Environmental Protection Agency., 2023).

5.2. Social

The primary focus of the project lies in addressing the social impact it will have on Eco Waste Company and its users.

1. The System will be able to inform users (Customers) about collection schedules, recycling initiatives, and the environmental impact of the Eco-Waste company

2. Respect user privacy by implementing robust data protection measures through regulations such as GDPR (General Data Protection Regulation). Users should have control over their personal information and be assured that their data is handled securely.

5.3. Ethical

This plays a crucial role in the development of the waste management system for Eco-Waste Solution Company.

1. This system will provide clear and honest communication of the system's functionalities, data usage and privacy policies

2. The system will avoid deceptive patterns such as forced continuity, hidden cost and scarcity tactics

3. The system will obtain user consent before collecting and storing personal information, such as names, addresses, and contact details. Additionally, sensitive data like credit card numbers and passwords will be securely encrypted and protected from unauthorized access or misuse.

4. The system will adhere to GDPR to ensure that the system handles personal data ethically and responsibly

5.4. Professional

Professional considerations encompass various aspects related to the conduct, standards, and responsibilities within the waste management industry.

1. The project will ensure the ethical and efficient allocation of waste management resources, emphasizing responsible utilization to maximize effectiveness and minimize environmental impact.

6. Planning

6.1. Plan

Objective Plan	Start Date	End Date	Duration
Research			
Conduct a Feasibility Study			
Investigate current trends and challenges in the waste management processes [0.3]	**1st January, 2024**	**5th January 2024**	**5 Days**
Examine the need for efficient waste collection, transportation and disposal at a site [0.3]	**6th January 2024**	**10th January 2024**	**5 Days**
Research Technologies and Tools			
Explore existing waste management systems and their functionalities	**11th January 2024**	**15th January 2024**	**5 Days**
Investigate the advantages and disadvantages of GPS tracking in waste management	**16th January 2024**	**20th January 2024**	**5 Days**

investigate legal and ethical of implementing waste management technologies	**21st January 2024**	**25th January 2024**	**5 Days**
Analysis			
Define System Requirements			
Produce Business requirements specific to ECO-WASTE SOLUTIONS COMPANY LIMITED waste management	**26th January 2024**	**31st January 2024**	**6 Days**
Produce Functional requirements	**1st February 2024**	**7th February 2024**	**7 Days**
Produce Non-Functional Requirements	**8th February 2024**	**11th February 2024**	**4 Days**
Design & Implementation			
Design Waste Management System Architecture			
Develop a conceptual framework for the waste management system	**12th February 2024**	**20th February 2024**	**9 Days**
Plan the integration of GPS tracking for the Driver side and other technologies	**21st February 2024**	**25th February 2024**	**5 Days**
Architecture of the MySQL Database			

Design the database schema for efficient storage and retrieval of waste management data	**26th February 2024**	**29th February 2024**	**4 Days**
Establish data relationships and constraints	**1st March 2024**	**5th March 2024**	**5 Days**
Create Final Implementations			
Implement Admin and Driver management features	**7th March 2024**	**14th March 2024**	**8 Days**
Integrate Database and UI components	**15th March 2024**	**22nd March 2024**	**8 Days**
Display different kind of data reports on the Dashboard	**23rd March 2024**	**25th March 2024**	**3 Days**
Testing			
Produce Testing Documentation			
Test MySQL Database for the waste management system	**26th March 2024**	**27th March 2024**	**2 Days**
Test GPS for the waste management system	**28th March 2024**	**30th March 2024**	**3 Days**

Test the interface for the waste management system	**31st march 2024**	**2nd April 2024**	**3 Days**
Make refinements	**3rd April 2024**	**4th April 2024**	**2 Days**
Evaluation and conclusion for Project			
Summarize the key findings from the project	**5rd April 2024**	**11th April 2024**	**7 Days**
Produce recommendations using the information gathered from the waste management system	**12th April 2024**	**17th April 2024**	**6 Days**
project conclusion	**18th April 2024**	**20th April 2024**	**3 Days**
Write about the future development of the system	**21st April 2024**	**22nd April 2024**	**2 Days**

6.2. Gantt Chart

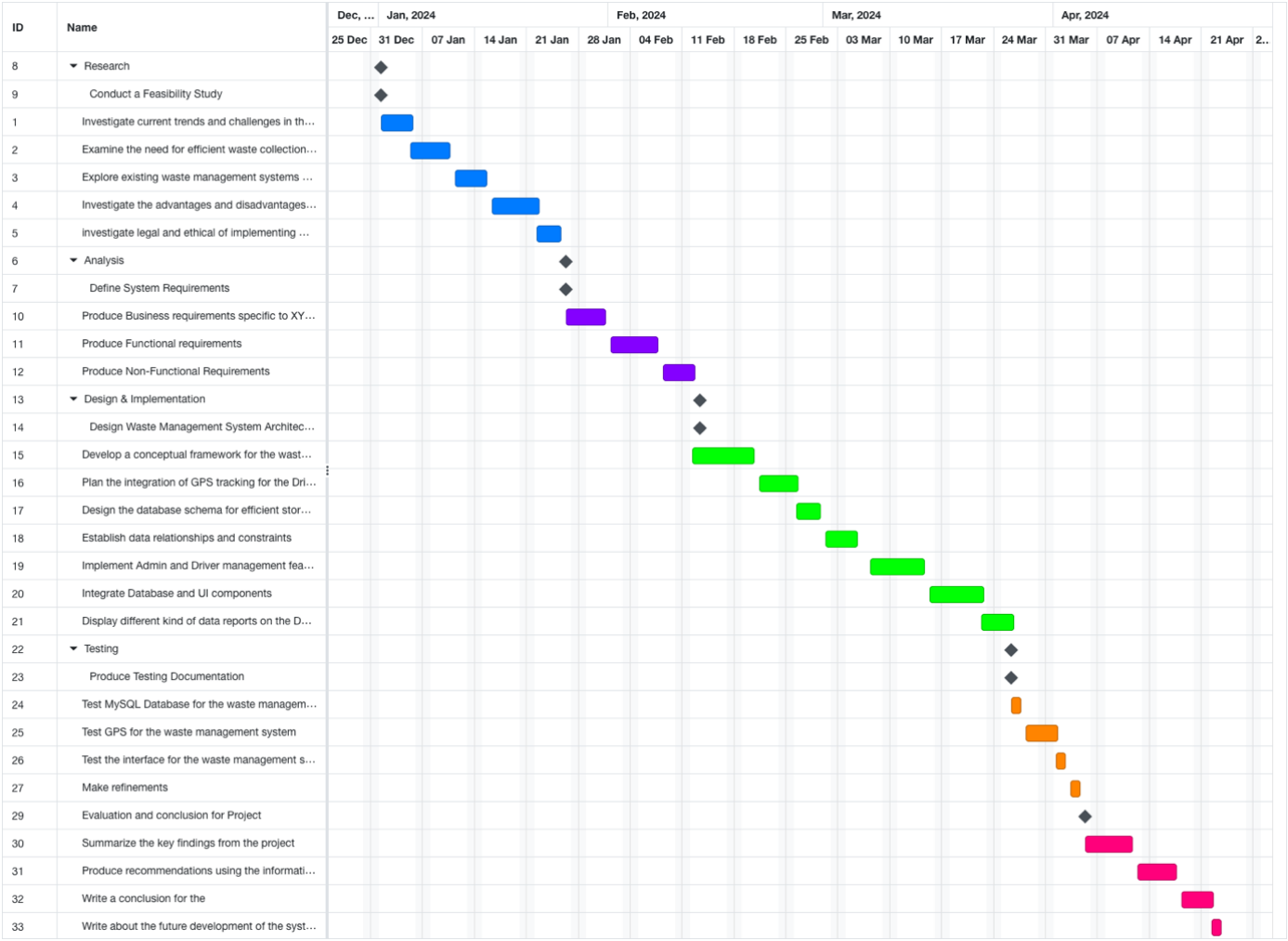


Figure 51

7. Conclusion

The proposed system will transition Eco-Waste Solutions Limited from manual record-keeping to a web-based system to streamline its operations with real-time tracking and enhanced reporting/communication.

After successful developments and implementations, Eco Waste Solution Limited will be able to overcome some of its challenges which will mark a significant step towards sustainable waste management.

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