Public Service Vehicle Hailing System for People with Disabilities: A Case in Kenya

Georgina Nyokabi Njoroge

119742

Mwanza Shem Nzamba

121425

Supervisor: Daniel Machanje

Submitted in partial fulfilment of the requirements of the Bachelor of Science in Informatics and Computer Science at Strathmore University

School of Computing and Engineering Science

Strathmore University

Nairobi, Kenya

September 2021

Declaration and Approval

We declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of our knowledge and belief, the research documentation contains no material previously published or written by another person except where due reference is made in the research documentation itself.

Student Name: Georgina Nyokabi Njoroge

Admission Number: 119742

Student Signature: ___________________________ Date:___________________________

Student Name: Mwanza Shem Nzamba

Admission Number: 121425

Student Signature: ___________________________ Date:___________________________

Supervisor Name: Daniel Machanje

Supervisor Signature: ___________________________ Date: 16/09/2021

Abstract

Boarding a public service vehicle for the majority Kenyans is a straightforward process. This, however, is not the case for people with disabilities. Despite the law requiring PSV operators to adapt to suit PWDs, close to none have adhered to it. Therefore, the operators are not sensitized to the plight of PWDs. However, few volunteer drivers carry them at no extra charge. This system lacks structure as there is no platform that links PWDs and the volunteer operators.

The developed system enables volunteer operators to register their vehicles. PWDs registered on the platform can hail a registered matatu at any given time. The system has been developed using the incremental model based on OOAD. The system meets the functional and non-functional requirements stated and this has been proven by carrying out of black and white box testing.

The mobile application is best suited for android devices with an API level 16 and above.
The administrator dashboard is best suited for personal computers as it is a web application. It is recommended that in future works, the application be improved to accommodate people with hearing and vision impairments as the current system is primarily developed for people with physical disabilities.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

API – Application Programming Interface

CPU – Central Processing Unit

CRUD - Create, Read, Update, Delete

dp - device-independent pixels

ERD – Entity Relationship Diagram

GB - Gigabyte

GPS – Global Positioning System

HTTP – Hypertext Transfer Protocol

NoSQL – Not only SQL

OOAD – Object-Oriented Analysis and Design

OTP – One-Time Password

PHP – Hypertext Preprocessor

PSV – Public Service Vehicle

PWD – People with Disabilities

RAM – Random Access Memory

SMS – Short Message Service

SQL – Structured Query Language

UML – Unified Modeling Language

UNHCR - United Nations High Commissioner for Refugee

Wi-Fi – Wireless Fidelity

Chapter 1: Introduction

1.1 Background Information

Public transportation has been the most common form of transport in Kenya. Public transport vehicles in Kenya range from taxis to minibuses to buses. 90% of households have matatus or buses available within their vicinity in urban Kenya (Salon & Gulyani, 2019). “Matatu”, as Kenyans call it, was derived from the English number “three” as people used to pay three coins to use it. It is the preferred form of transport for Kenyans as they commute in the cities to meet their daily needs because they are affordable (Tripadvisor, 2021).

In the country, bus stops have been put in specific places to accommodate boarding and alighting of passengers in a matatu. Matatus have specific routes to various destinations with several stops along the way. During transit, the conductor collects fare from the passengers. Fare charged on passengers varies depending on conditions such as distance, capacity, and fuel price (Wambugi, 2017).

Passengers are a key factor in public transport. One of the users of public transport are persons living with disabilities. According to UNHCR, these are people having long-term physical, mental, intellectual, or sensory impairments which in interaction with various barriers hinders their full and effective participation in society on an equal basis with other members of society (UNHCR, 2021).

According to the 2019 census, 918270 Kenyans are living with some form of disability. 42% of people living with disabilities, 0.4 million Kenyans, are reported to have mobility issues (Owino, 2020). These people use walking sticks, frame guides, wheelchairs, or crutches to aid in their movement (National Council for Persons with Disabilities, 2021). This often proves difficult when boarding and alighting matatus. Public service vehicle operators are required to adapt to suit persons with disabilities (Kenya Law Reports, 2010). They may do so by including low floors, automated wheelchair ramps, rail compartments, wheelchair space and wide aisles to their vehicles (The Kenya Institute for Public Policy Research and Analysis, 2020).

Despite these regulations provided by the law, there are no wheelchair accessible buses and taxis in the entire Nairobi city (Mwangi, 2016). PWDs are therefore forced to make do with the available public service vehicles which poses various challenges to them. Some find alternative methods to commute such as using tricycles which are difficult to use on unpaved streets with dirt and potholes (The Kenya Institute for Public Policy Research and Analysis, 2020). They are also impractical for long distances. Some travel organizations such as Uber have provided a feature that supports them known as 'UberAssist' (Uber Blog, 2019). However, this is an expensive alternative that most people with disabilities cannot afford, as approximately 67% of persons with disabilities in Kenya are destitute (Kabare, 2018).

These people have the right to use public transport but are often overlooked hence they are not able access the same rights as other members of society.

Following this, a system that offers easier and inclusive transport options for people with disabilities is essential. A system that will connect people with disabilities to public service operators that are willing to assist. This will change the norm that people with disabilities face as it will offer convenience and stability by enabling them to plan and schedule their trips ahead of time.

1.2 Problem Statement

Due to the lack of inclusivity in the public transportation sector, people with disabilities find it difficult to commute. Boarding and alighting of public service vehicles is time consuming for people with mobility challenges. Due to this many public service vehicle drivers will not take disabled passengers and when they do, they charge extra . In an interview by BBC News Africa (Mwangi, 2016), a matatu driver in Kenya caters for disabled passengers at no extra cost. Time invested in helping these passengers in boarding and alighting causes him to make fewer trips. This in turn reduces his profit margin.

Volunteer drivers have become an essential option for people with disabilities. This system, however, is unstructured as there are only a few volunteer drivers that cater for their own routes and at their own availability. There lacks a platform that provides structure to volunteer drivers and their beneficiaries.

1.3 Objectives

1.3.1 General Objective

To develop a mobile application that aids people with disabilities in commuting by enabling them to book a seat in matatus and buses registered on the system.

1.3.2 Specific Objectives

i. To investigate how people with disabilities have commuted in the past.

ii. To investigate the challenges in the current systems that have aided in commuting of people with disabilities.

iii. To design a mobile based public service vehicle hailing application for people with disabilities.

iv. To develop a mobile based public service vehicle hailing application for people with disabilities.

v. To test the developed mobile based public service vehicle hailing application for people with disabilities.

1.3.3 Research Questions

i. How have people with disabilities commuted in the past?

ii. What are the challenges in the current systems that have aided in commuting of people with disabilities?

iii. How will a mobile based public service vehicle hailing application for people with disabilities be designed?

iv. How will a mobile based public service vehicle hailing application for people with disabilities be developed?

v. How will the developed mobile based public service vehicle hailing application for people with disabilities be tested?

1.4 Justification

People with disabilities may end up not finding a matatu that is willing to let them board. Our platform enables them to have access to drivers that will assure them of a seat when they want to commute making it easier and efficient to use. This is because they will be picked at a specific time and not have to wait for hours as they are being shunned by matatu operators (National Gender and Equality Commission Communications, 2019). The platform offers standard rates making it cheaper to use as normally they are demanded to pay twice the standard fare (National Gender and Equality Commission Communications, 2019).

The platform provides structure to volunteer drivers and their beneficiaries. Volunteer drivers on the platform can state their availability and the routes they operate on. Therefore, people with disabilities using the platform are availed options that are relevant to the routes and time of their commute.

1.5 Scope and Limitations

The system allows volunteer operators to register their vehicles. Registered persons with disabilities on the system can hail matatus and buses available on their routes.

The system is available for android devices. It requires internet connectivity and access to the device's location

.

Chapter 2: Literature Review

2.1 Introduction

This chapter analyzes how people with disabilities have commuted in the past. It also discusses how current solutions have aided in commuting of people with disabilities and the gaps in these solutions.

2.2 Current State of Matatu Operation in Kenya

The leading mode of public transportation in Kenya is the matatu industry. The industry is a major employer with close to 350,000 workers. These workers include drivers, conductors, and office staff. Matatus are run by either Sacco arrangements or registered companies. These matatus come in different sizes and brandings (International Labour Organization, 2021).

Matatus have come up with several ways to appeal to their riders. These include Wi-Fi installations, setting up of music systems, plastering of artwork on the interiors and exteriors and fitting of large screen monitors in the vehicles (Wambugi, 2017).

Matatus have different carrying capacities. Some can carry only 14 passengers while others carry over 30 passengers. At the terminals, matatus wait for passengers until they fill up before they depart. Due to the onset of the COVID-19 pandemic, matatus must adhere to the regulations set by the Kenyan authorities. One of these regulations being that matatus can only carry 60% of their total capacity (Bastmeijer, 2020).

Matatus have specific routes to various destinations with several stops along the way. In the country, bus stops have been put in specific places to accommodate boarding and alighting of passengers in a matatu. During transit, the conductor collects fare from the passengers. Fare charged on passengers varies depending on conditions such as distance, capacity, and fuel price (Wambugi, 2017).

2.3 Past Commuting Methods for People with Disabilities

People with disabilities have in the past used various methods in commuting. Some of these methods include use of tricycles, personal vehicles, and public service vehicles.

2.3.1 Use of Tricycles

One of the assistive devices that people with disabilities use is tricycles. As seen on Figure 2.1 the tricycle requires the user to pedal themselves using their hands. This is however posed with a lot of difficulties from unpaved streets with dirt and potholes to heavy traffic and reckless road users (The Kenya Institute for Public Policy Research and Analysis, 2020).

Figure 2.1: Tricycle for PWDs (Association for the Physically Disabled of Kenya, 2021)

2.3.2 Use of Personal Vehicles

People with disabilities use personal vehicles to commute. These vehicles are modified to enable people with physical disabilities to commute as shown in Figure 2.2. They are mostly imported, and the Kenya Revenue Authority exempts persons with disabilities from paying duty for importation (Omulo, 2017).

Figure 2.2: PWD Friendly Vehicle (Integrity Exports, 2021)

2.3.3 Use of Public Service Vehicles

People with disabilities can board the public service vehicles available at bus stops (Mwangi, 2016).

2.4 Related Works

There are a few systems in place that have tried to solve this problem either within Kenya or in other countries. This section gives a brief explanation on how they operate.

2.4.1 ASSISTIVEtravel

ASSISTIVEtravel is an application for visual, hearing and mobility impaired riders (INIT, 2021). The app provides barrier free mobility for riders. For example, persons with mobility impairments can alert a driver that they are in a wheelchair before the bus arrives. In turn, the driver can respond that there is available wheelchair space and help them board when necessary (Pennecke, 2020).

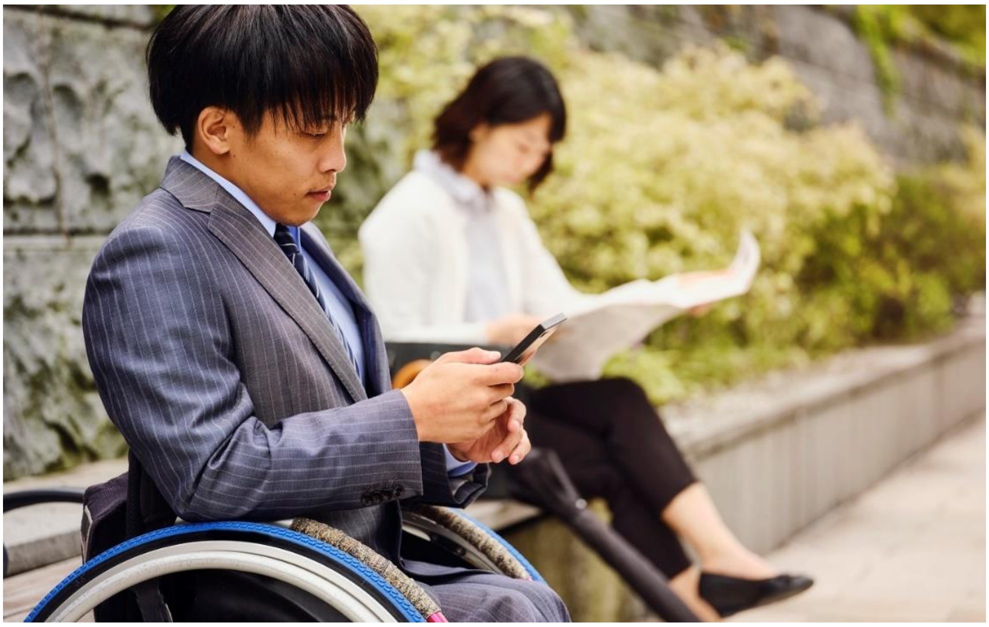


Figure 2.3: ASSISTIVEtravel User (INIT, 2021)

2.4.2 Taxi Hailing Apps – Uber

Uber is an American technology company that offers an assortment of services. These services include ride-hailing, package and food delivery, couriers etc. For the ride-hailing service, they offer a provision for the disabled and senior communities that require assistance. This feature is known as UberAssist as seen in Figure 2.4. Trained drivers help riders when getting into their vehicle and can accommodate folding wheelchairs and walkers in their vehicle (Uber Blog, 2019).

Figure 2.4: UberAssist Feature (Uber, 2021)

2.4.3 Volunteer Public Service Operators

Some public service operators are willing to carry the people with disabilities. In an interview by NTV Kenya, one such driver, Anthony, explains his daily evening trips to the Association for the Physically Disabled of Kenya to carry people with disabilities working there to their homes (Gikonyo, 2021).

2.5 Gaps in Related Works

Approximately 67% of persons with disabilities in Kenya are destitute (Kabare, 2018). For any trip made on Uber, the minimum amount of fare one expects to pay is one hundred and fifty shillings (Maina, 2019). This is costly for one to pay on a daily basis when commuting to and from work. Therefore, UberAssist is an expensive option that most people with disabilities cannot afford to use on a daily basis.

Some systems work for a few that have access to them. For example, in the case of Anthony (Gikonyo, 2021), only people with disabilities that live in Kinoo and know him personally can benefit from his service. Therefore, people with disabilities that have no way of accessing these systems are at a disadvantage.

In addition, some of the available systems lack structure, in the terms of a central source of communication between PSV operators and PWDs. This lack of structure causes inconvenience to the people with disabilities. In the case of Anthony, (Gikonyo, 2021), the people with disabilities contact him via call. In the case that they are unable to reach him, their transit plans are disrupted.

2.6 Technologies Used

The developed system incorporates specific technologies that offer seamless use of the system. These technologies include Android and GPS.

2.6.1 Android

Android is an open-source operating system based on Linux. It is created for a variety of devices and comprises of several components such as System Apps and Java API Framework (Android Developers, 2021). Android has released various versions over the years. The latest, Android 11, was released on September 8, 2020, (Summerson & Duino, 2020).

The developed system is available for Android devices running on API level 16 and above following the discontinuation of updates for API levels 14 and 15 by Google Play services (Spencer, 2018). Once complete the platform will be available on Google Play Store.

In Kenya, there is widespread use of Android devices. As of June 2021, 89.01% of the mobile operating system market in Kenya was accounted for by Android (O'Dea, 2021). Therefore, the Android platform is suitable as it will reach many of the targeted users.

2.6.2 Global Positioning System

GPS is a global navigation satellite system that provides location, velocity, and time synchronization. GPS is made up of three elements which include, satellites, ground control and user equipment. Satellites transmit signals on geographical position and time of day to users. Ground control comprises of monitoring stations that keep track of satellites in space and their transmissions. Finally, user equipment such as smartphones and watches act as GPS receivers and transmitters (Geotab Team, 2020).

User devices near or on the earth's surface read signals from at least 4 satellites to calculate location. This is achieved through a technique known as trilateration. A single satellite cannot give accurate information about a location as a GPS device only gives data about distance from satellites. The three satellites create spheres that intersect at two points. The intersection closest to earth is then picked as the actual location. The fourth satellite validates the information (Geotab Team, 2020).

GPS offers several features that have been incorporated in the developed system. It has been used to determine pickup point locations which will be visible to both the drivers and people with disabilities. It has also aided in navigation from one point to another by giving directions.

In addition, the driver's location is tracked while in transit. Finally, by use of GPS, people with disabilities can get time estimates on when their booked ride will arrive.

2.7 Conceptual Framework

Volunteer public service vehicle operators and people with disabilities both access the system via their mobile devices, on a mobile application. The administrator accesses the system via a personal computer, on a web application.

Volunteer public service vehicle operators register their vehicles on the platform. They specify the routes they operate on and their availability. They also specify the number of seats available for people with disabilities. This data is stored on a remote database.

People with disabilities register themselves on the platform. Once registered, they can view the available vehicle and the routes they operate on. They are also able to see the availability of those vehicles. This data is retrieved from a remote database.

Administrators register themselves on the platform. Once registered, they can view system entity details and perform basic CRUD functionality on these entities. The conceptual framework is illustrated in Figure 2.5.

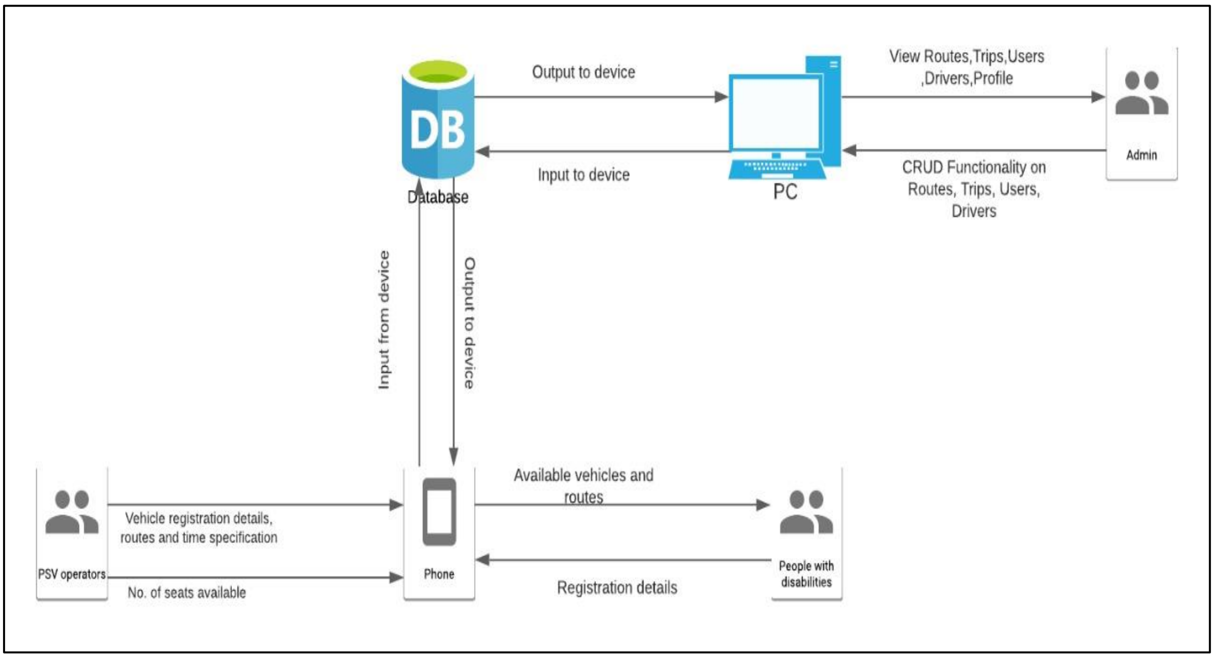


Figure 2.5: Conceptual Framework

Chapter 3: Methodology

3.1 Introduction

This chapter describes the Software Development Methodology that have been applied in the developed project. It will also discuss the software development approach that has been used and the system analysis, design, and its deliverables.

3.1.1 Object-Oriented Analysis and Design

This is a technical approach used in analysis and design of a system. It describes information systems by identifying objects which can represent people, events, or places. Objects can include data and processes that affect data. It uses UML to develop object models to visualize and document a system (Rosenblatt & Shelly, 2012).

This methodology is suitable for the developed system as it provides principles of encapsulation and abstraction. This allows for modularization that reduces problem complexity.

3.2 Software Development Approach to be Used

The applied development approach to be used is incremental development model. This model involves producing and delivering of the system in small increments. It focuses on essential features first with additional functionality being added when and if necessary (van Vliet, 2007).

This development model is suitable for the developed system as it is based on OOAD. It also allows for quick development within the minimal allocated time. In addition, it is easier to make changes during development thus easier to incorporate new requirements when they arise.

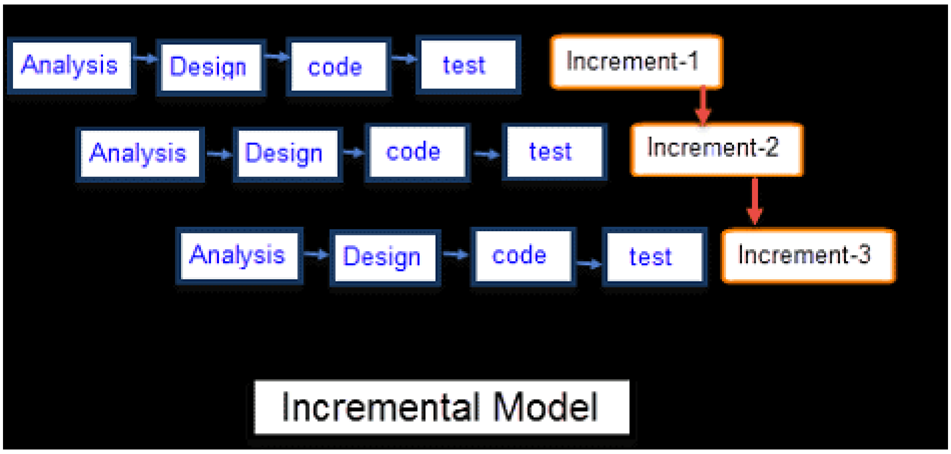


Figure 3.1: Steps in Incremental Model (Salman, 2021)

3.2.1 Requirement Analysis

This step involves identifying system requirements. For the developed system, functional and non-functional requirements for both the public service vehicle operators and the persons with disabilities are identified. This step also identifies the unique modules that need to be developed in their order of priority.

3.2.2 System Design

This step involves drafting the design of a system. In the developed system, the design has been drafted to meet the requirements identified in the requirement phase.

3.2.3 Implementation

The developed system has been coded ensuring constraints defined in the design are met. All the features specified for each specific module for example the public service operator module have been implemented. It has been coded in Java programming language for Android devices.

3.2.4 Testing

This step involves checking the performance of all functions. The modules of the developed system have been tested at a time to ensure functionality meets requirements. After each increment was completed, black box testing was done to ensure that it works seamlessly. For sensitive modules, such as the authentication module, white box testing was done.

3.3 System Analysis

This section involves analysis of the requirements for the system. This section discusses some of the modeling tools and techniques such as use case diagram, sequence diagram and system sequence diagram that illustrate the requirements of the developed system and user interaction with the system.

3.3.1 Use Case Diagram

A use case diagram is a visual representation of various related use cases . It illustrates the tasks that actors of a system perform (Rosenblatt & Shelly, 2012). This has been implemented in the developed system to illustrate how the actors, administrators, public service operators and people with disabilities, interact with the system.

3.3.2 Sequence Diagram

This is an interaction diagram that describes how a group of objects work together in specified period. It visually represents use case by showing the classes, messages, and timing in a system

(Rosenblatt & Shelly, 2012). It has been used in the developed system to show the interaction between the public service vehicle operators and people with disabilities at a particular time.

3.3.3 System Sequence Diagram

This is a sequence diagram that demonstrates when and how tasks relating to a use case are accomplished (Lucidchart Software Inc., 2021). For the developed system, a system sequence diagram has been used to illustrate the various use cases. For example, when persons with disabilities hail matatus and how the system handles the process.

3.3.4 Entity Relationship Diagram

This is a model that demonstrates the logical relationships among system entities stored in a database and their interactions (Rosenblatt & Shelly, 2012). For the developed system, an ERD has demonstrated the relationship of the entities in the system. For example, the relationship between public service vehicle and trips will be one to many. This means that one public service vehicle can make many trips in a day.

3.3.5 Class Diagram

Class Diagram is a diagram that gives deeper details of a use case by showing operations of classes and their relationship (Rosenblatt & Shelly, 2012). A class diagram has shown the orientation of the different classes in the system such as routes, trips and people with disabilities.

3.3.6 Activity Diagram

This is a flowchart that illustrates the activities involved in a system and their flow from one to another (Rosenblatt & Shelly, 2012). This in the developed system, has shown the sequence of activities involved. For example, sequence of activities from person with disabilities logging in, to hailing a matatu.

3.4 System Design

This phase focuses on providing models such as user interfaces that satisfy all the documented requirements for the system and demonstrate the outputs, inputs, and processes. These models are illustrated using wireframes, database schema, and system architecture.

3.4.1 Database Schema

This is a schema that describes the logical constraints that apply to the data stored. It defines views, integrity constraints and tables (Lucid Software Inc., 2021). This has described the logical constraints for the data in the developed system. For example, data on people with disabilities and public service vehicles registered on the system.

3.4.2 Wireframes

This is a blueprint that assists in visualizing the functionality and structure of an application. In the developed system, wireframes have been used to map out the various screens in the system and their functionality.

3.4.3 System Architecture

This is an illustration of the physical structure including hardware, software, and processing methods of a system (Rosenblatt & Shelly, 2012). This has been used in the developed system to conceptualize the structure. It captures the details of the user interaction with the system and how the system prepares the data requested by the user.

3.5 System Deliverables

This section describes the various deliverables for the developed system that satisfy the system requirements.

3.5.1 Authentication Module

This includes registration and login. Registration allows for new users of a system to register on the platform. Login allows registered users to access the system.

3.5.2 Public Service Vehicle Operator Module

This module allows matatu operators to specify details of their vehicles, routes, trips, and availability.

3.5.3 Person with Disability Module

This module allows persons with disabilities to hail matatus and view routes.

3.5.4 Geolocation Module

This module allows the matatu operator to view the live location of persons with disabilities who have booked seats at their pickup points. It also allows persons with disabilities to view live location of the matatu they booked.

3.5.5 Administrator Module

This module enables the administrator to manage the system entities. The administrator can view entity details such as trips, routes, drivers and users. The user can edit these details and add new entities. The administrator can also enable or disable users and drivers.

Chapter 4: System Analysis and Design

4.1 Introduction

This chapter will discuss the various components of the system identifying both the functional requirements of the system. It will also discuss the methodologies used in the development of the system. These methodologies will be represented in the form of diagrams, system analysis and system design diagrams.

4.2 System Requirements

The functionalities required in the system to meet the user requirements are stated below and grouped under functional and non-functional requirements.

4.2.1 Functional Requirements

Some of the services that the system has to offer are described below.

i. Authentication

This requirement is mandatory for the users and administrators in the system. It enables them to get access to the system. The system has few inputs required for the authentication module. For instance, a mobile number, the user is expected to key in their mobile number in the text field provided. The system collects the phone number provided by the user and approves if it is a valid phone number then sends a one-time password.

The one-time password is sent through SMS, the user is expected to key in the OTP key they have received in the text field provided. The system matches the one-time password sent to the user to the one entered by the user to approve and give access to the system.

For the administrator, an email and password. The administrator is expected to key in their email and password if they are not logged in. The system collects the email and password provided by the administrator and compares with the one stored under the specific child in the database to grant access to the system by redirecting to the landing page.

ii. Driver Account Management Functionality

This requirement is specifically for the drivers in the system. It enables the drivers to manage their account and update their details. Some of the inputs required from the driver include their driver's license, matatu number plate and number of seats they are willing to set aside. The system captures the information input by the driver and adds or updates in the specific driver child in the database. Lastly, the driver can switch his availability from available to not available. If the status indicates that the driver is available, then PWDs can hail or book the driver’s bus.

iii. View Pending Trips Functionality

This functionality is availed to the drivers on the platform. It enables them to view the trips that are yet to be completed. This data, for each specific driver, is obtained from the database. The driver can view the source and destination details of each trip on the map. They can also choose to either start or cancel the trip. The driver can also call the rider.

iv. Hailing

This feature is available for the passengers in the system. It enables them to book a seat in a bus or hail a nearby bus. The PWD keys in their location or specific stop and destination in the provided input field and the system captures the source and destination input and records in the database then checks for available drivers. The system then redirects the PWD to key in a message for the driver to be informed. For example, I am in a wheelchair. The matatu is then hailed and the PWD can view the driver’s live location. The PWD can also call the driver or choose to cancel a trip.

v. GPS Functionality

This functionality is available for all users in the system except the administrator. The GPS provides the source and destination views obtained from hailing module on the map by measuring the time it takes for a signal to arrive to the location from the four satellites. This displays the source and destination for the user on the map

vi. System Management Functionality

This functionality is only available for the administrator. It enables the administrator to perform basic CRUD functionalities on all users, routes and trips in the system.

Once the administrator is signed in, the administrator can view all the users in the system. The administrator can retrieve all routes data available from the database as well as retrieve all trips data. Furthermore, the administrator can enable or disable any user. The administrator can also add new users, routes and trips in the system.

vii. Profile Management Functionality

This functionality is available to all actors in the system, the administrator, driver and PWD. It enables them to manage their personal accounts. They provide inputs such as their name, profile picture, contact and email. The system then captures this information and adds or updates in the database.

viii. View Trip History Reports Functionality

This functionality is available to both the driver and PWD. The data on the trips related to each logged in driver or PWD is read from the database and presented to them in summary. They can view the details of the pending, completed, started and completed trips.

4.2.2 Non-Functional Requirements

Some of the system attributes are described below.

i. System Security

This requirement ensures that user data stored on the system is secure from unauthorized access and malware attacks. The system uses phone verification as a form of authentication. This is a two-factor authentication process where the system first ensures that the phone number entered is valid. The user then receives a one-time password that is only valid for a short period of time. The user enters this password, and the system confirms whether the characters match the one in the database. This process enables the system to associate each user account to a unique phone number therefore preventing creation of fake accounts.

ii. System Performance

This requirement ensures that the system responds fast to any user actions on the system. This has been achieved by use of a real time database that can work offline by allowing caching of data in the user's device memory and synchronizing data once it reconnects to the internet. This allows for fast and real time access of data. In turn, this allows for the data driven actions carried out by users on the system to be fast.

iii. System Usability

This requirement ensures that the system is easy to use. It specifies how learnable and memorable the system is. The system has been developed with features that are like other hailing applications in the market. This ensures familiarity of the system hence easy for users to learn how to use the system. Navigation in the system is linear thus guiding the user throughout the action they wish to perform. This eliminates confusion. In addition, the system is interactive as it gives the user feedback on any action to be carried out on the system. Sensitive tasks such as deletion and cancellation seek for confirmation from the user before they are carried out by the system.

iv. System Availability

This requirement ensures that the system is available for use by a user at a given time. The system allows for users to remain logged onto it until they themselves log out of the system. This is achieved by checking whether there is a current user when the application is being launched. When a current user is found, the user is directed to the main activity of the application.

v. System Portability

This requirement specifies how the system can be launched in different environments. The system's minimum API level is 16. Therefore, the system is available on Android version 4.1 to all the newest Android platform versions. This is possible due to the full backward compatibility feature of all new versions of Android.

vi. System Scalability

This requirement ensures that the system will manage to handle the workload as it grows. This has been achieved by use of a No-SQL database that allows for easy horizontal scaling. With an increase in workload, there will be no need to add more resources such as processing power. Scaling will be achieved by adding servers to the database.

vii. System Reliability

This requirement ensures that the system will run without failure for a predefined time and under specified conditions. The system will run without failure provided the usage does not exceed the current specified limit on the real time database. To optimize usage, the system utilizes indexed queries and listeners that only download data when an update occurs.

viii. Maintainability

This requirement specifies the amount of time it will take to fix components in the system, improve performance or adapt the system to a changing environment. The system will require minimum maintenance following the necessary measures taken during development. The system is well documented, built using simple rather than complex code and tested on various devices to check whether it works on various Android versions.

4.3 System Analysis Diagrams

The diagrams in this section describe what the system should do to meet requirements. These diagrams include use case diagram, sequence diagram, system sequence diagram, entity relationship diagram, class diagram and activity diagram.

4.3.1 Use Case Diagram

Figure 4.1 illustrates how the actors interact with different use cases in the system. The system has three actors that include a PWD, PSV Operator and an Administrator. Some use cases such as registration, login and logout are common for all actors in the system. The use cases associated with the administrator include basic CRUD functionality on all the system entities such as trips, routes, drivers and users. Shared use cases between the PWD and PSV operator include viewing trip history, viewing trip source and destination on map and cancelling trip. The PWD is able to hail matatus, call driver, view driver's live location. A PSV operator is able to create their driver account, enable and disable their availability, view pending trips, start trip, call rider and confirm payment.

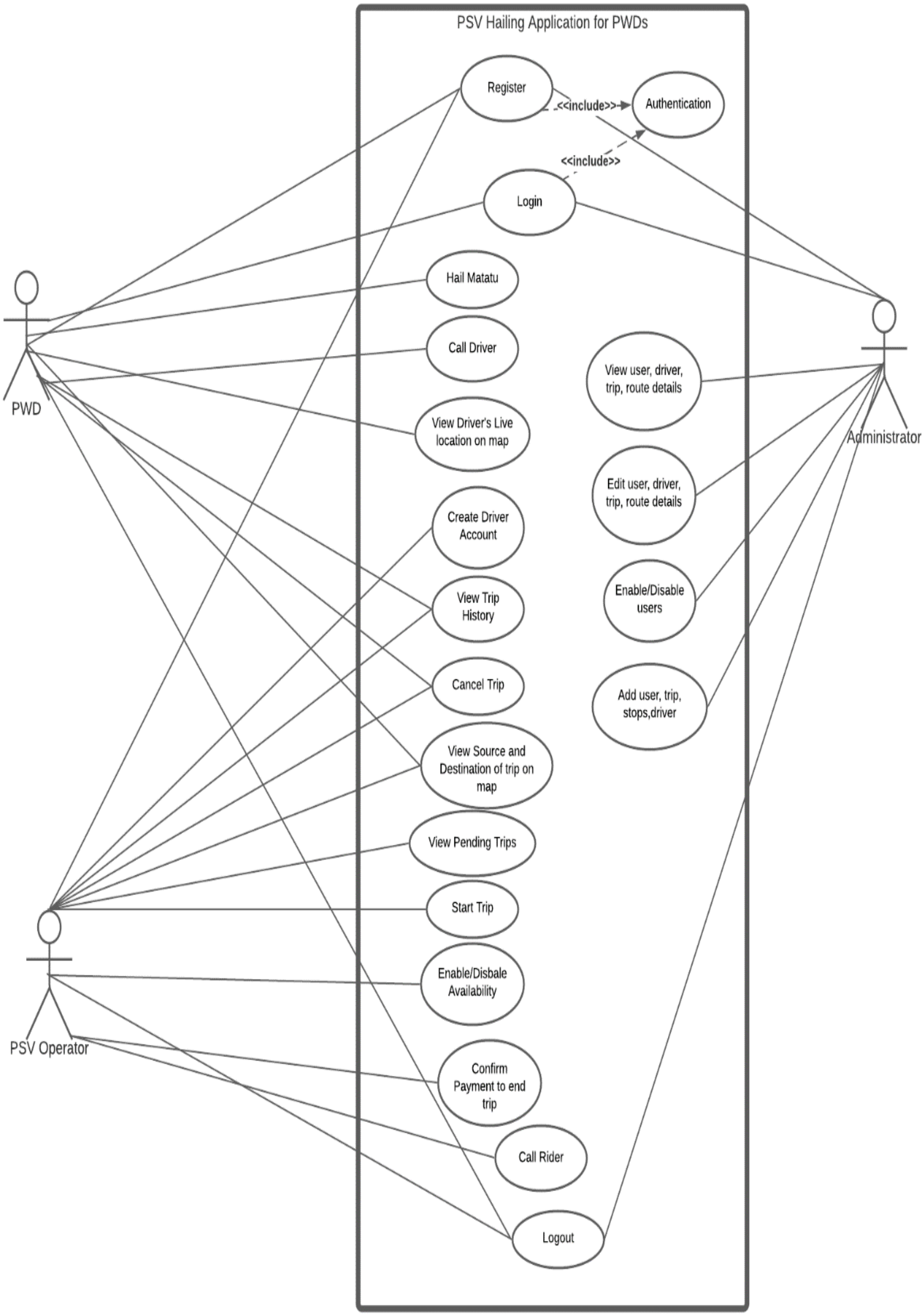


Figure 4.1: Use Case Diagram

4.3.2 Sequence Diagram

Figure 4.2 illustrates how the driver, PWD, system and the database work together in a specific period. For example, when a driver updates their routing details, the PWDs are shown the available routes. When either the PWD or driver wanted to sign in, the system verifies their sign in details. When the PWD is logged he/she can view the available routes. When the PWD hails a matatu, the driver is informed by the system and adds the details to the database.

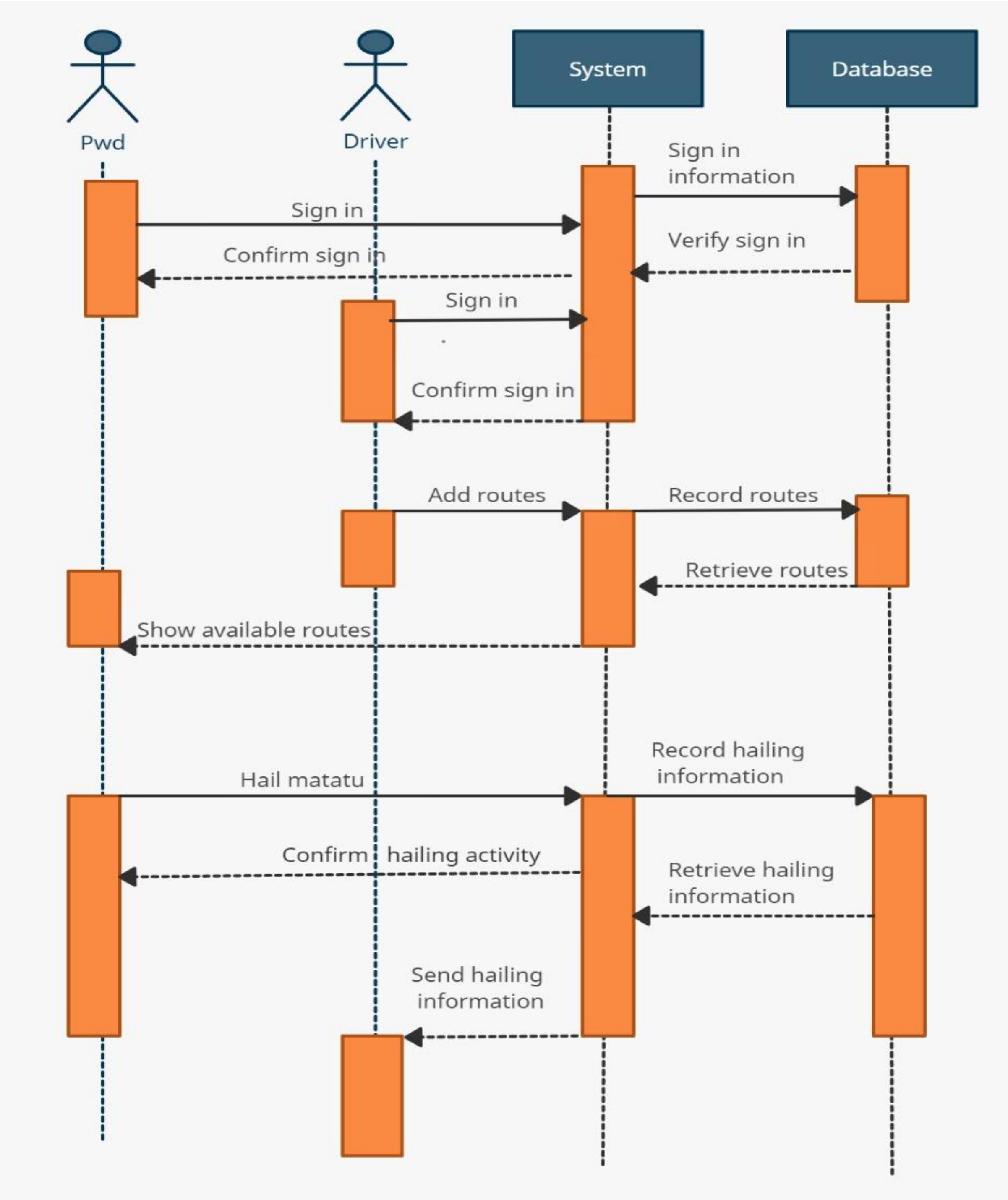


Figure 4.2: Sequence Diagram

4.3.3 System Sequence Diagram

Figure 4.3 illustrates how the tasks related to a use case are accomplished. For example, how the system handles the process when a user wants to access the system. The PWD and the driver both input their phone numbers and await verification by the system to access the system, once verified, they are redirected to their respective landing pages. The admin inputs their email and password to access the system, but the credentials provided are to be verified in the system to grant access.

The diagram also illustrates the hailing process. The PWD can hail a public service vehicle and the system records the details and confirms to the PWD. Once a PWD has hailed a PSV, the operator is informed. The history of the trips made or confirmed by the system are added to the system and the users can view a summary. The system ends the trip once the driver confirms that the PWD has paid.

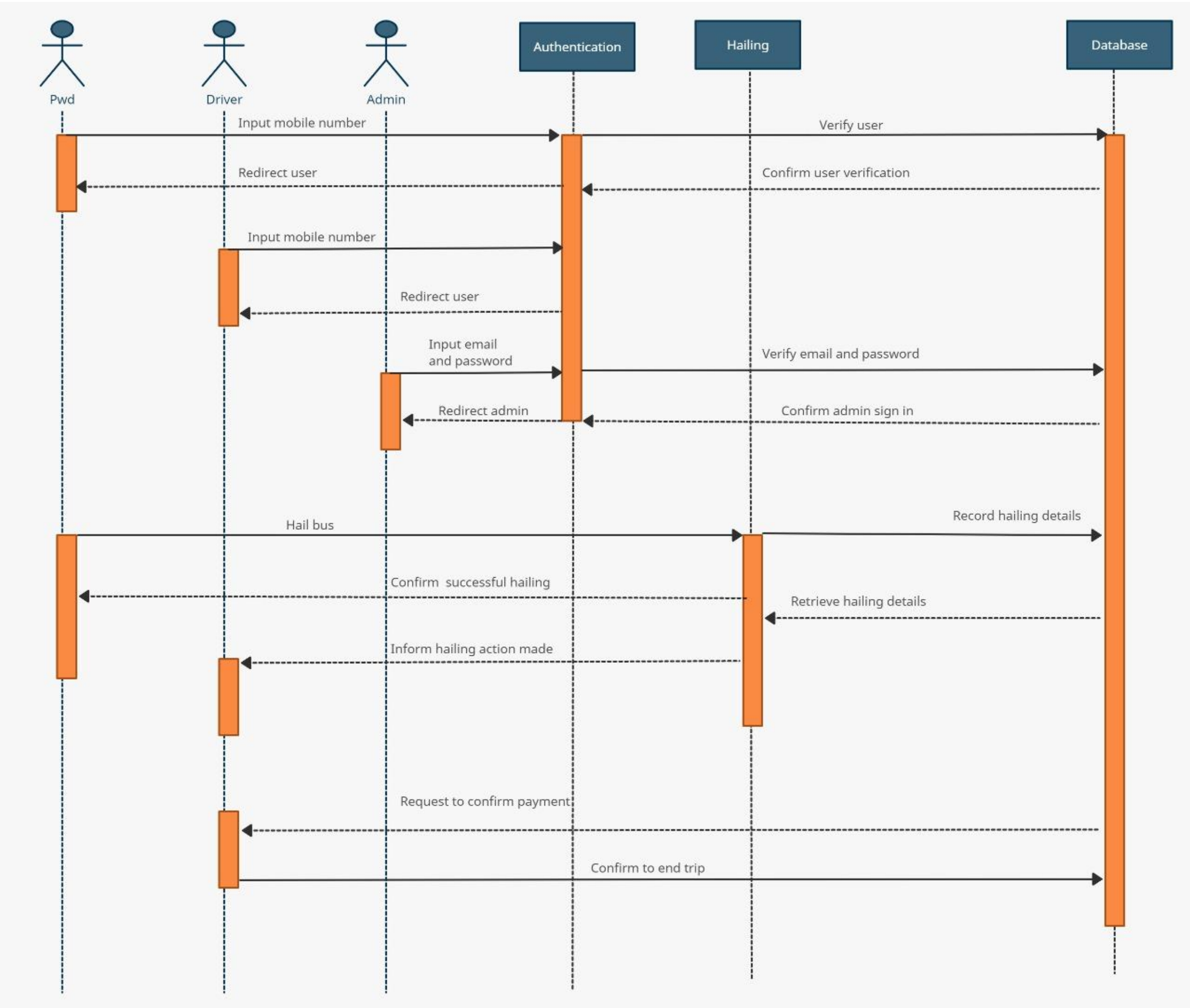


Figure 4.3: System Sequence Diagram

4.3.4 Entity Relationship Diagram

The system has a few entities that include PWDs, routes, driver, trips, and locations. Figure 4.4 illustrates the relationship among the entities. For example, the relationship between PWDs and trips was one to zero or many. This means that a PWD could make zero or many trips. A driver could make many trips, a driver operates on one route. A PWD could use one or more routes available.

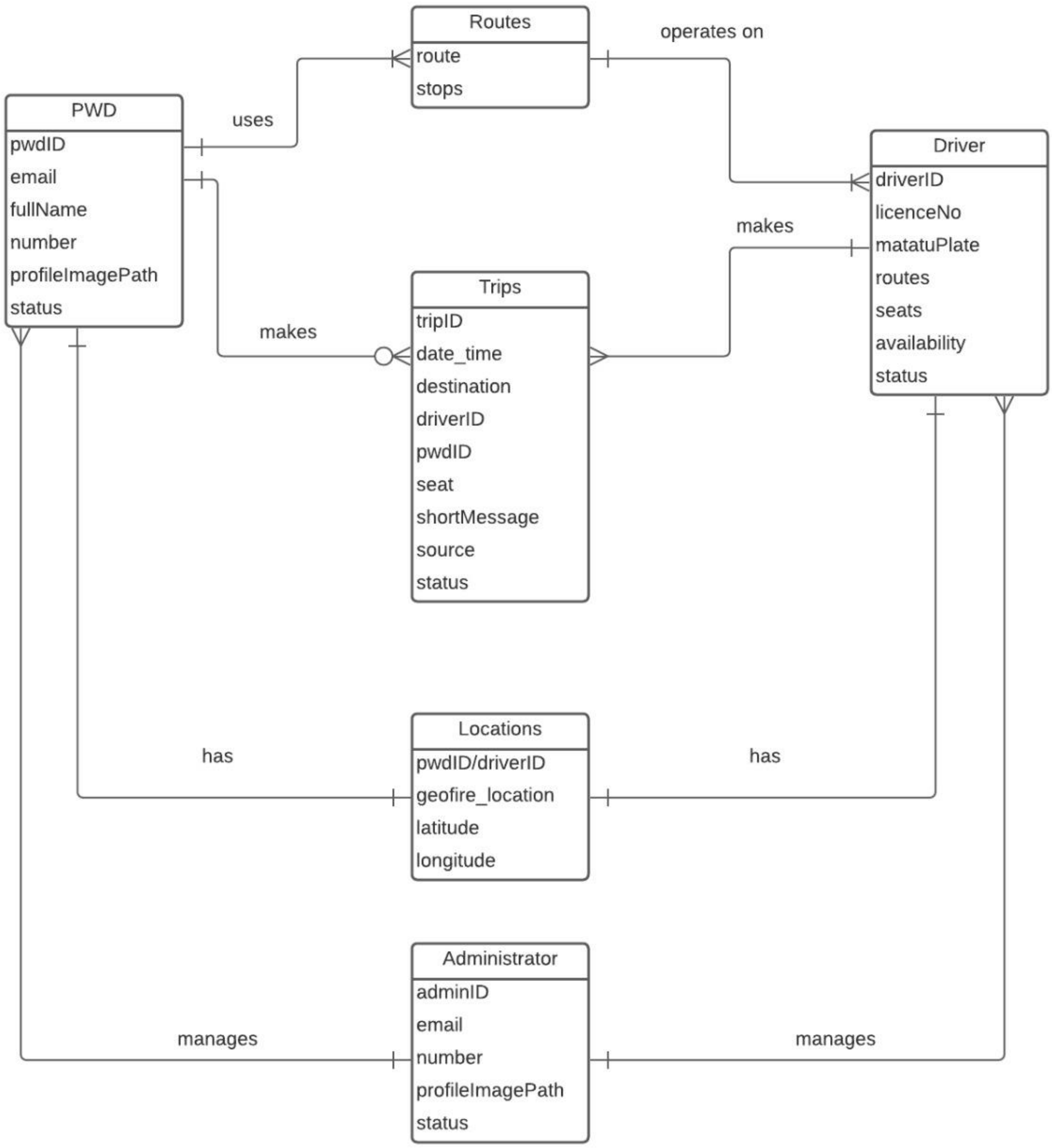


Figure 4.4: Entity Relationship Diagram

4.3.5 Class Diagram

This system has several classes that include the PWD, driver, and administrator classes. Figure 4.5 shows the attributes and methods of these classes and their relationships. The PWD class has the following attributes: an id, name, email, contact and status. Its methods include register, login, logout, view available routes, book seat and view driver's live location. The driver's class attributes include driver's license, route, matatu number plate, availability and number of seats. Its methods include view seat bookings, view trip details, change availability and confirm payment. Attributes in the administrator class include an id, email, and name. The methods in administrator class include view and disable or enable system users, drivers, routes, and trips. Other classes include the route class, location class and trip class. The attributes in route class include name and stops. The only method in route class is add route. The attributes in trip class include id, PWD id, driver id, pickup point, drop off point, date and time and status. The methods in the trip class include start, end and cancel trip. The location class has user id, latitude and longitude as attributes. The methods in location class are get latitude and get longitude.

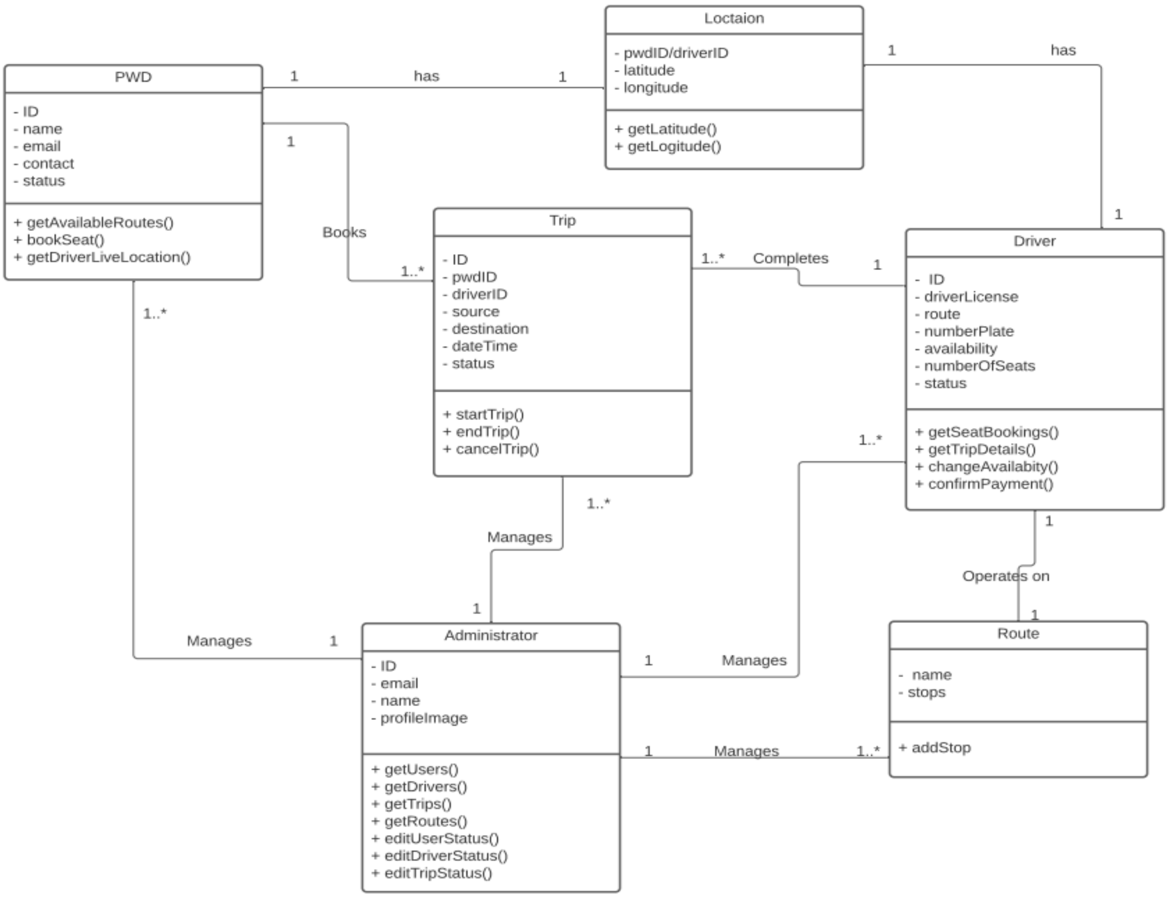


Figure 4.5: Class Diagram

4.3.6 Activity Diagram

Figure 4.6 illustrates the workflow of the system from start to end. The system has three distinct users which include the administrator, the PSV operator also referred to as the driver and the PWD. The system has a common start point for all users. They all have to register before using the system. After registration, the users log into the system. The administrator logs in using correct email and password details while the PWD and PSV operator log in using their phone number and the one-time password they receive. Once logged into the system, an administrator can perform basic CRUD functionality on all the system attributes which include users, drivers, trips and routes.

The PSV operator can view pending trips. For each pending trip the PSV operator can either cancel it or view source and destination details, call the rider and start the trip. After trip completion, the driver can confirm payment to end trip.

The PWD can hail a matatu. Once the trip is confirmed, they can either cancel the trip or view driver's live location, call driver then pay at the end of the trip.

Finally, all users log out of the system.

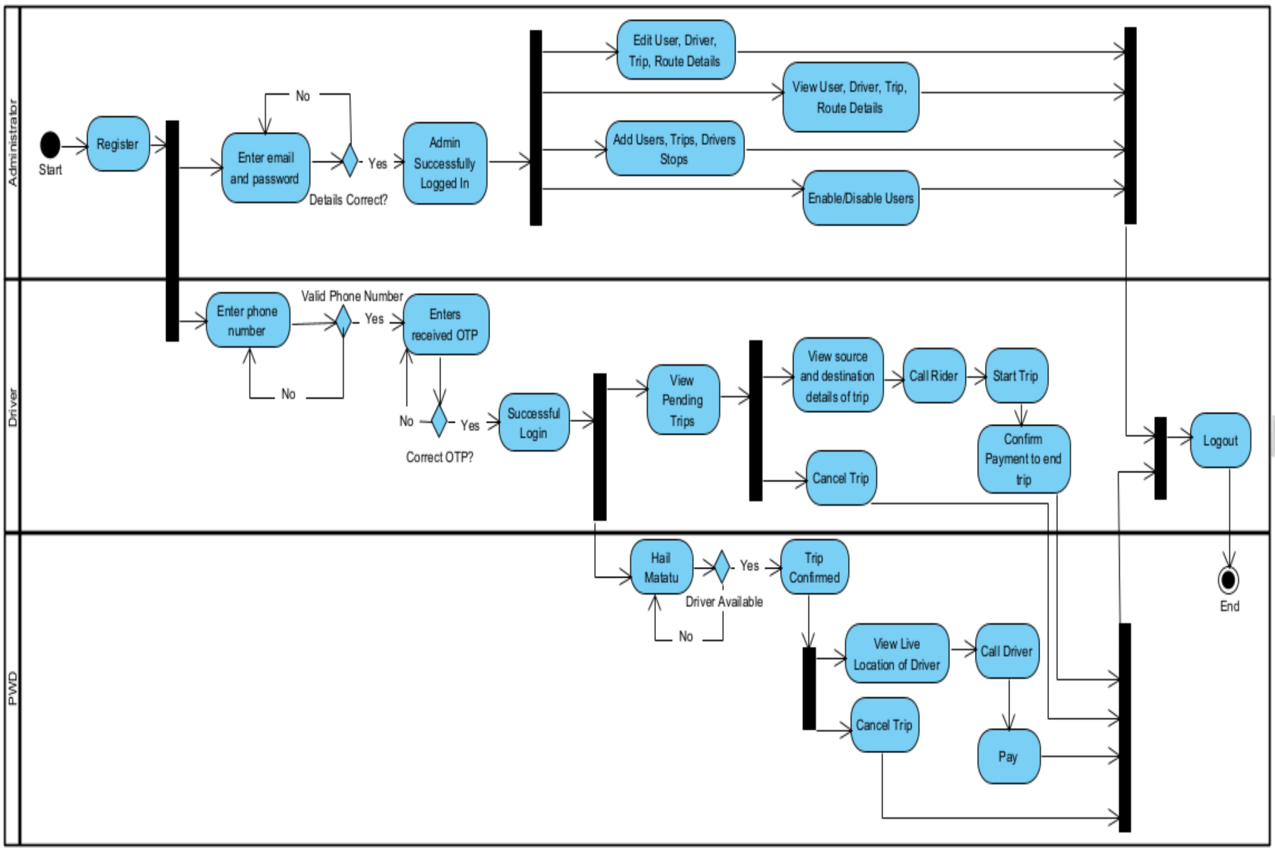


Figure 4.6: Activity Diagram

4.4 System Design Diagrams

The models such as user interfaces that satisfy all the documented requirements for the system and demonstrate the outputs, inputs, and processes are illustrated in this section. The models are illustrated using wireframes, database schema, and system architecture.

4.4.1 Database Schema

The developed system utilized Firebase, a NoSQL database, therefore, the data is unstructured. The schema modelling differs from that of a relational database. The mapping of the database is illustrated in Figure 4.7.

PWD	**Drivers**	**Admins**

ObjectID
{
"email": String,
"fullName": String,
"number": String,
"profileImagePath": String,
"status": String
}
	ObjectID
	{
	"availability": String,
	"licenceNo": String,
	"matatuPlate": String,
	"routes": String,
	"seats": int,
	"status": String
	}
		ObjectID
		{
		"email": String,
		"fullName": String,
		"number": String,
		"profileImagePath": String,
		"status": String
		}

Trips	**Routes**	**Locations**

ObjectID
{
"date_time": String,
"destination": String,
"driverID": String,
"pwdID": String,
"seat": int,
"shortMessage": String,
"source": String,
"status": String,
}
	{
	"Route": [
	{
	"Stop": boolean,
	}
	]
	}
		ObjectID
		{
		"g": String,
		"l":[
		{
		"0": double
		"1": double
		}
		]
		}

Figure 4.7: NoSQL Mapping

4.4.2 Wireframes

i. Universal Login and Registration Pages

Both the PWD and PSV operators have a uniform login user interface. They enter their phone number which is verified. The user receives an OTP once the phone number is verified, which they use to login. An already registered user is redirected to the landing page. An unregistered user is redirected to the account setup page. These pages are illustrated in Figure 4.8.

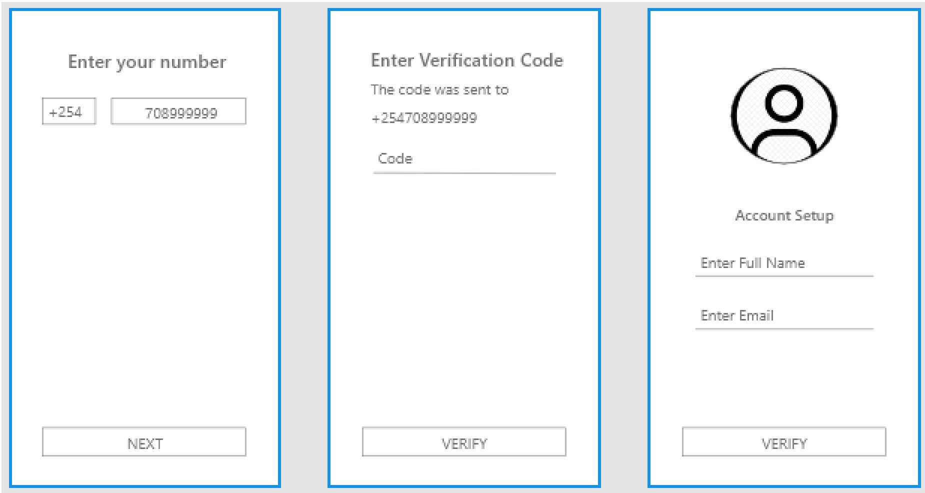


Figure 4.8: Universal Login and Registration Wireframes

ii. User Landing Page

Once the user is logged in, they are directed to this page. They can view their current location on this page. The navigation drawer provides various options on steps to take such as signing up as a driver, viewing trip history and logging out. This page is illustrated in Figure 4.9.

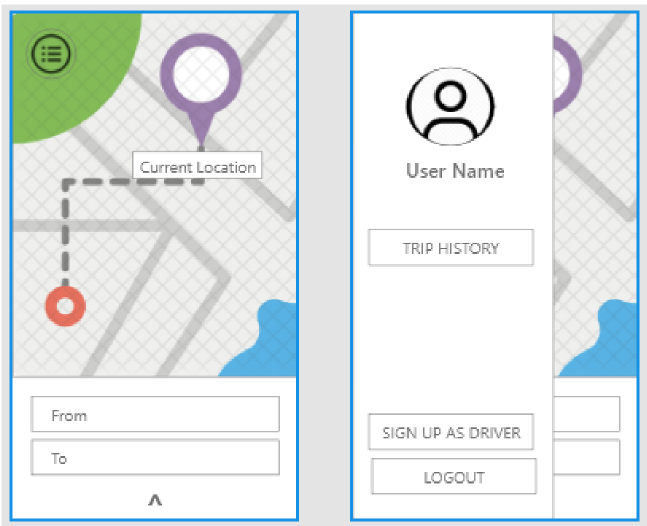


Figure 4.9: User Landing Wireframes

iii. Matatu Hailing Pages

These pages allow the user to hail a matatu. The bottom sheet view on the landing page allows user to choose from the available routes on the system. They are then redirected to the select pick up point page and drop off pages where they specify their source and destination. Alternatively, the user can search for their source and destination in the from and to entries on the bottom sheet. The user is then redirected to the final hailing page where they select the number of seats they wish to book. They also add a short message to give the driver information of what they require for example extra wheelchair space. This is illustrated in Figure 4.10.

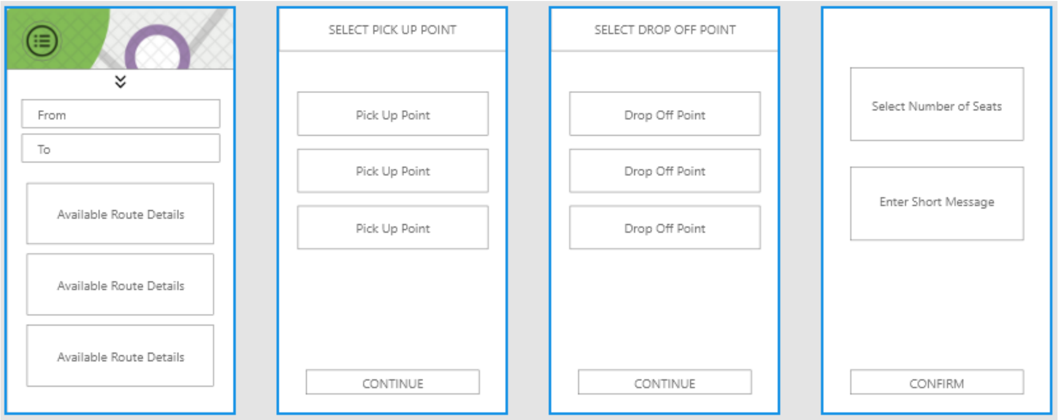


Figure 4.10: Matatu Hailing Wireframes

iv. Driver's Live Location View Page

Once the user confirms the trip, they can view the driver's live location as they wait for their driver to arrive. They can also call the driver or cancel the trip if they wish to. This is illustrated in Figure 4.11.

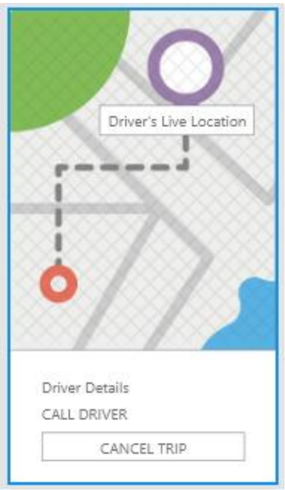


Figure 4.11: Driver's Live Location Wireframe

v. Driver's Account Setup Page

Drivers set up their accounts on this page. They enter their details which include driver's license, Matatu number plate, route and the seats they are willing to set aside. This is illustrated in Figure 4.12.

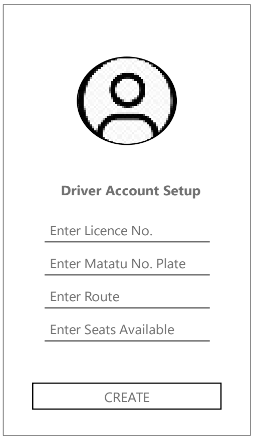


Figure 4.12: Driver Account Setup Wireframe

vi. Driver's Landing Page

Once a user is registered as a driver, this is their landing page. The navigation drawer allows the driver to switch between various fragments. They can view their account details, driver account and trip history. They can also logout from the application. The bottom sheet has the pending trips. Each trip has the option to cancel or start trip. Once a driver clicks on the trip, the trip source and destination are displayed on the map, with a polyline showing a route between the two points. Once a trip is started, the confirm payment button comes to view to allow the driver to end trip when they reach the destination and they are paid. This is illustrated in Figure 4.13.

Figure 4.13: Driver Landing Wireframe

vii. Trip History Page

This page is available for both the driver and the PWD. They can see their previous trips in this report display. This is illustrated in Figure 4.14.

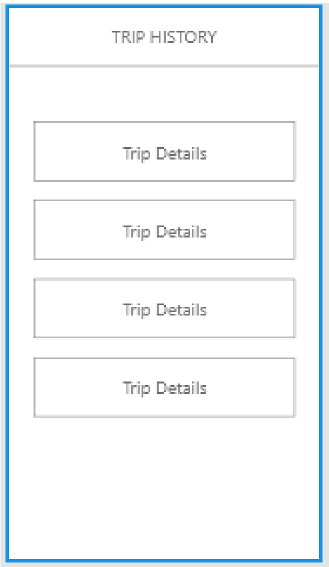


Figure 4.14: Trip History Wireframe

viii. Administrator Dashboard

An administrator can perform basic CRUD functionality on all the system attributes which include users, drivers, trips and routes on the dashboard. They can also view application usage reports. This is illustrated in Figure 4.15.

Figure 4.15: Administrator Dashboard Wireframe

4.4.3 System Architecture

Figure 4.16 illustrates the physical structure, hardware, and processing methods of the system. It shows data preparation process of requests by the user.

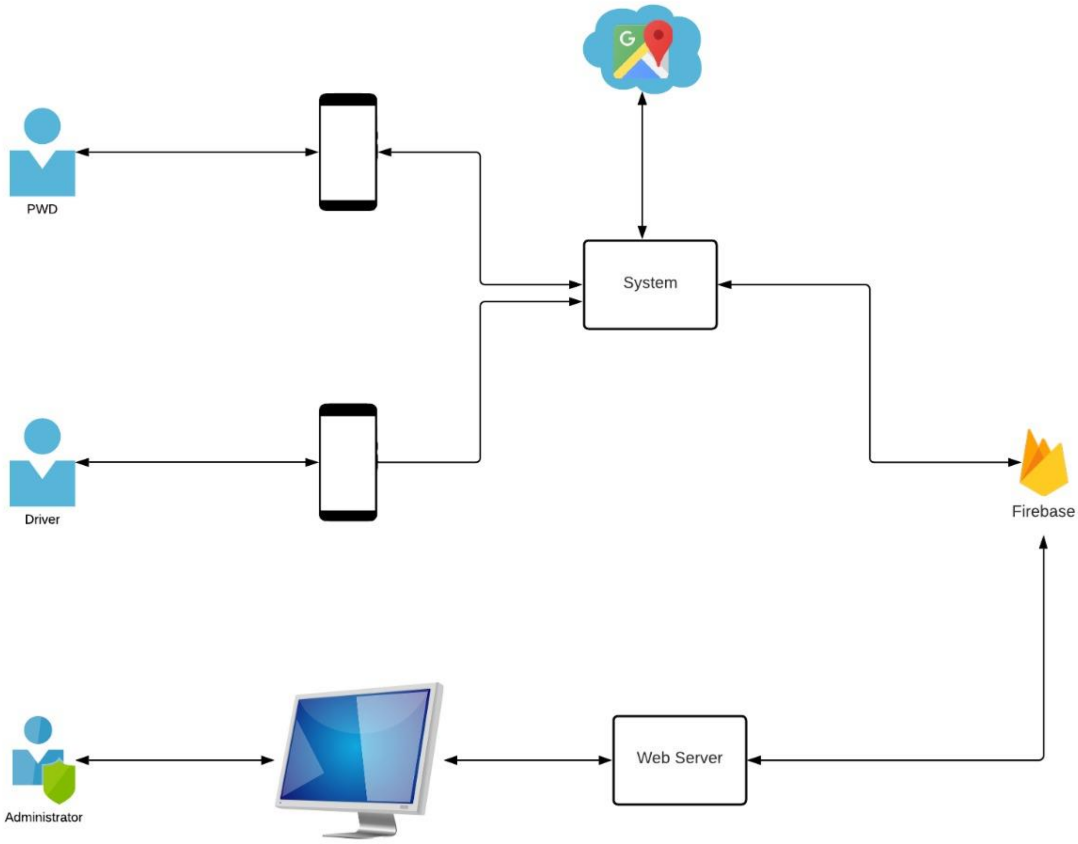


Figure 4.16: System Architecture Diagram

Chapter 5: System Implementation and Testing

5.1 Introduction

This chapter describes the system implementation and the testing that was conducted for the system modules to verify the system. It covers the software and hardware specifications. It also describes the testing, the testing paradigm and outlines the testing results.

5.2 Description of the Implementation Environment

This section covers the hardware and software specifications required to complete the system's implementation and get it up and running.

5.2.1 System Implementation

Some of the implemented system interfaces are displayed below.

i. **Administrator Registration Page**

The administrator registers onto the platform on Figure 5.1.

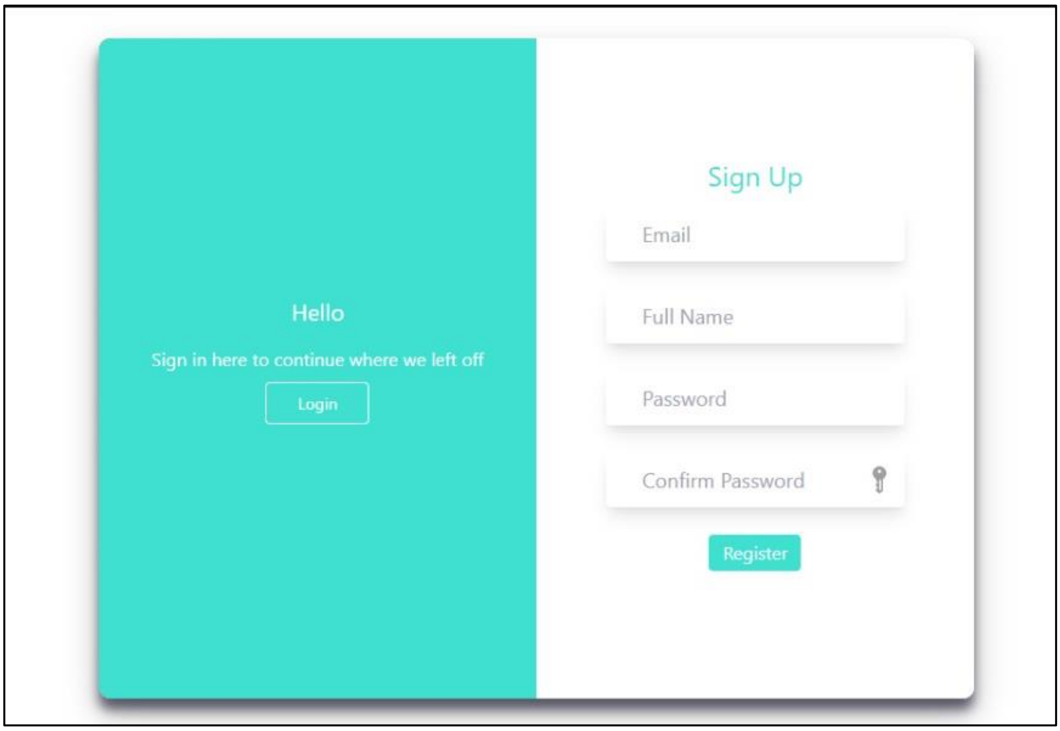


Figure 5.1: Administrator Registration Page

ii. **Administrator Login Page**

The administrator logs into the system using Figure 5.2.

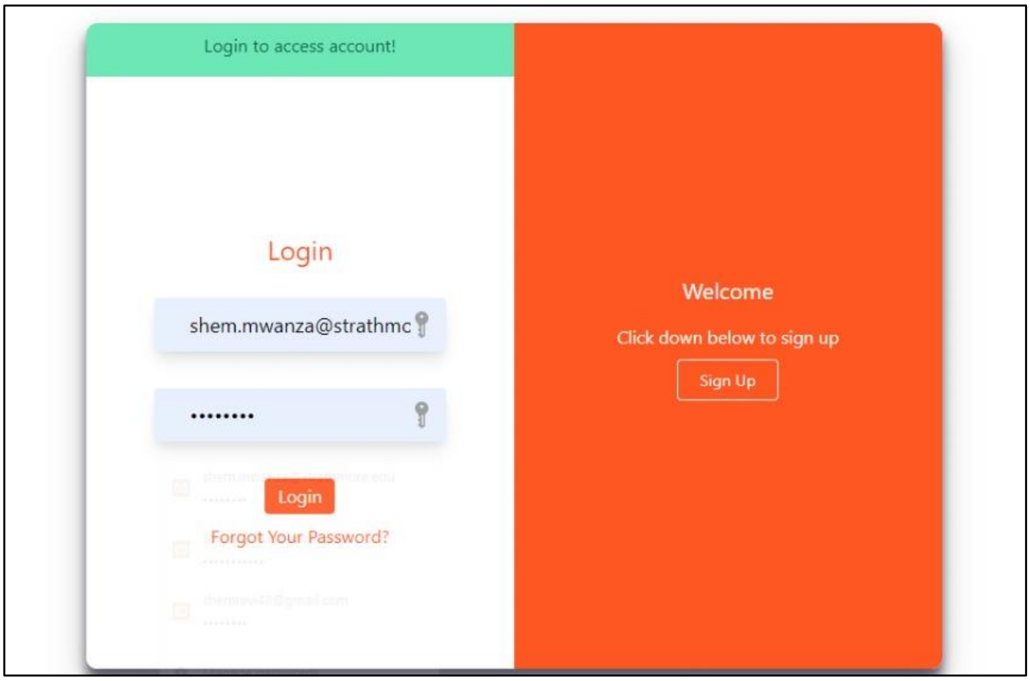


Figure 5.2: Administrator Login Page

iii. Administrator Dashboard

The administrator views reports on application usage on Figure 5.3.

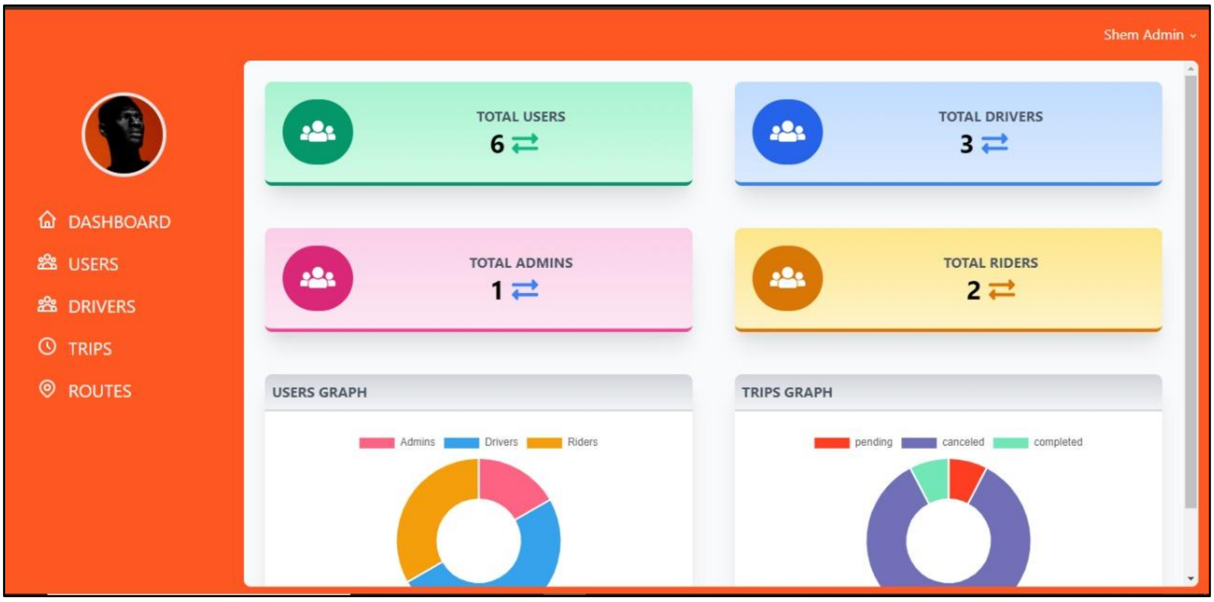


Figure 5.3: Administrator Dashboard

iv. Administrator Profile Page

The administrator can change their personal account details on Figure 5.4.

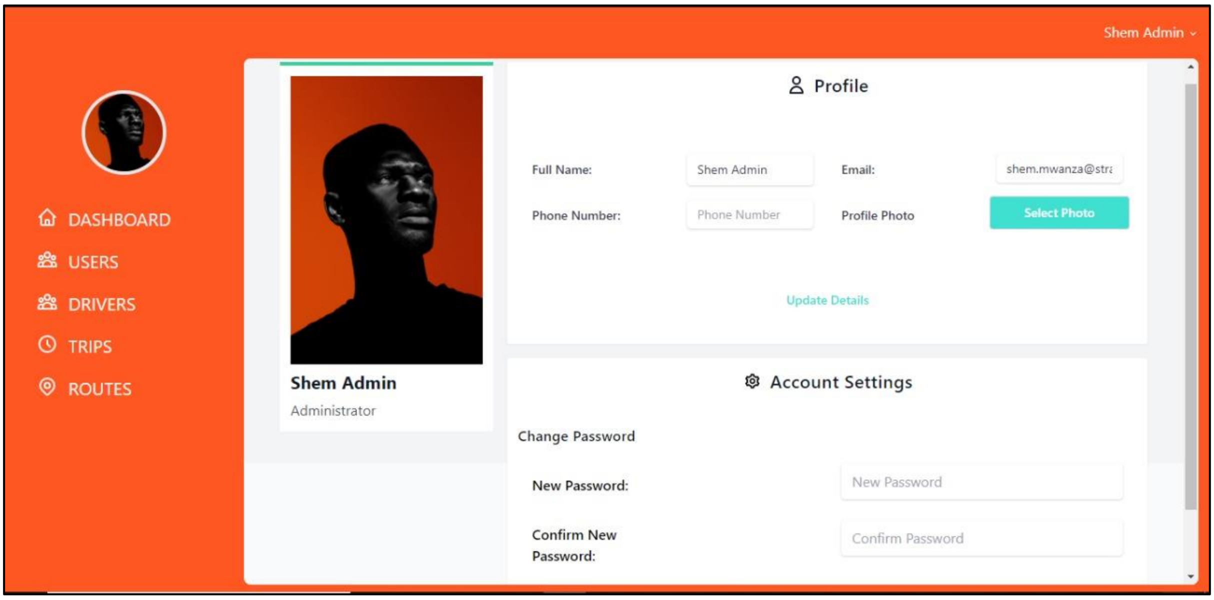


Figure 5.4: Administrator Profile Page

v. **PWD and Driver Login Pages**

Both the PWD and driver use the same pages to login by entering their phone number for verification and then the OTP they receive after verification.

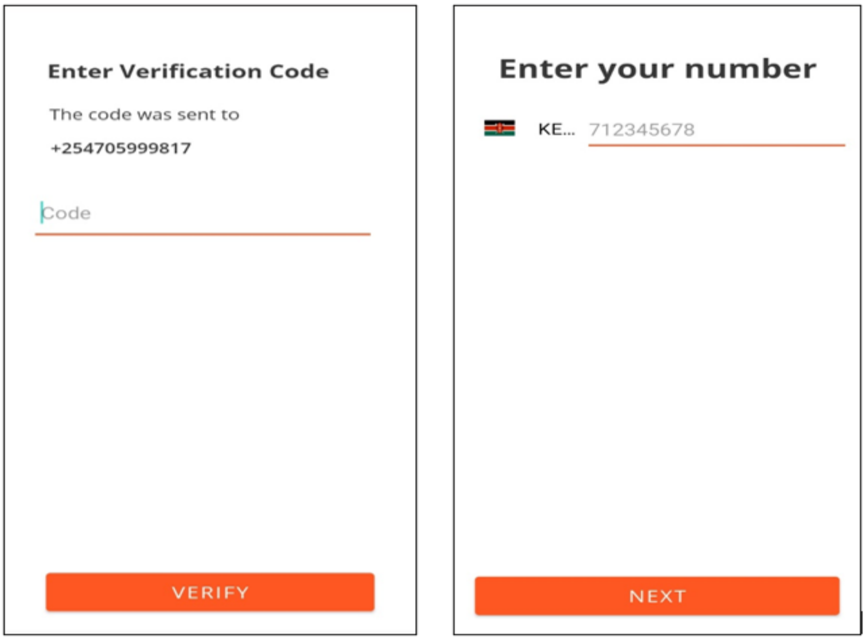


Figure 5.5: PWD and Driver Login Pages

vi. **PWD Landing Page**

Once logged in, the user is redirected to Figure 5.6 that has the map showing their current location, a navigation drawer with various options and a list of available routes.

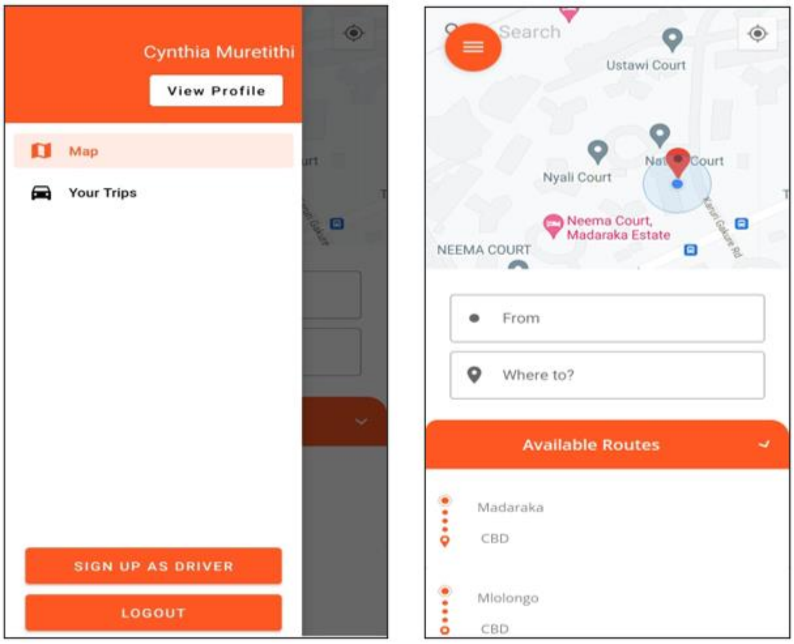


Figure 5.6: PWD Landing Page

vii. PWD Hailing Pages

Figure 5.7 enable the PWD to hail a matatu by selecting pick up and drop of points, number of seats and adding extra information.

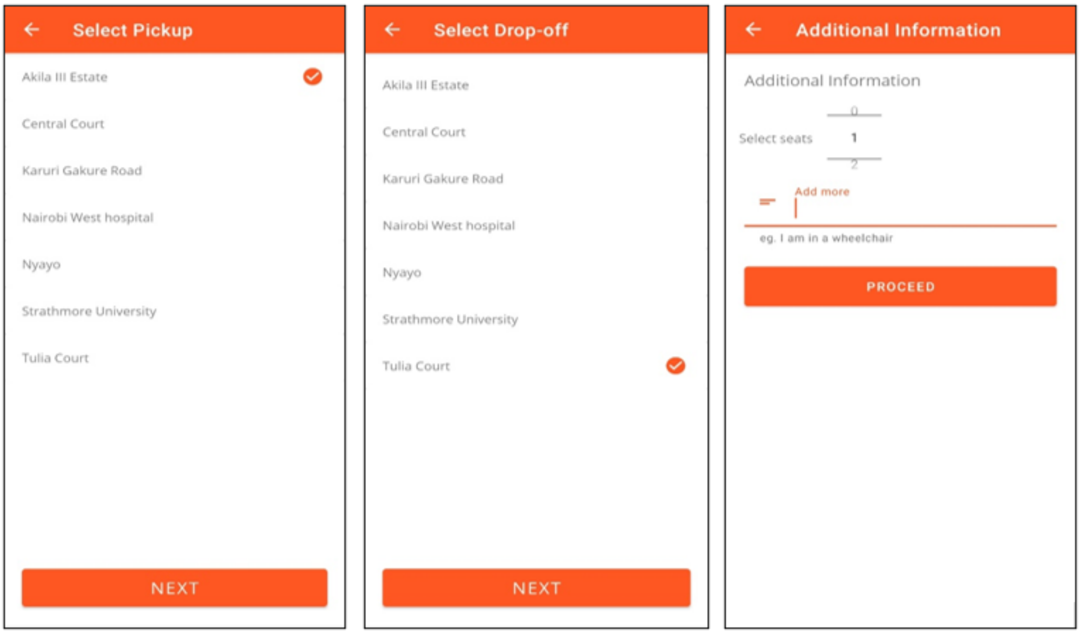


Figure 5.7: PWD Hailing Pages

viii. **Driver Landing Page**

Once a driver is successfully logged into the system, they are redirected to Figure 5.8. They have a navigation drawer that offers various options, they can view their current location on the map and they can also view active trip details on the bottom sheet. On clicking an active trip, they can view the pickup and drop off stops of that current trip.

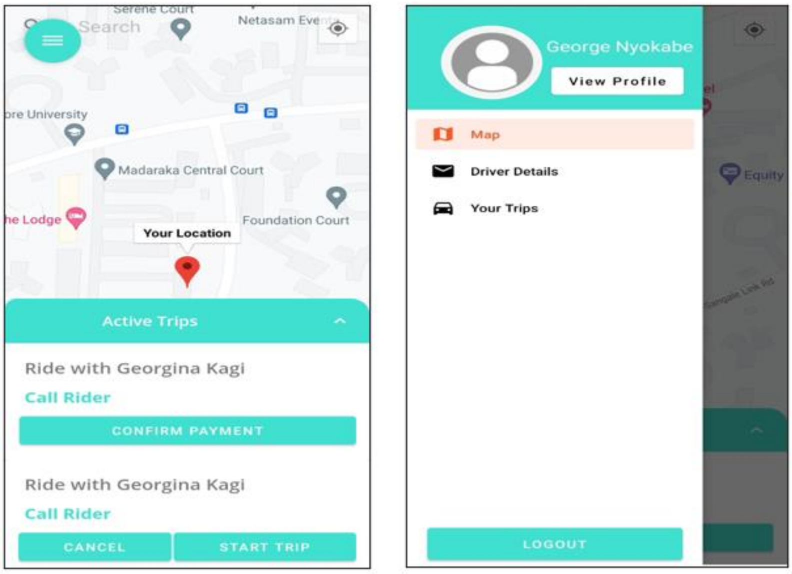


Figure 5.8: Driver Landing Page

ix. **PWD and Driver Personal Account Details Page**

Both the PWD and driver can edit their personal account details on Figure 5.9.

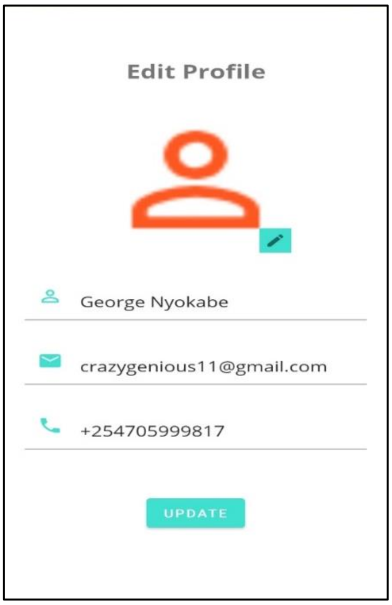


Figure 5.9: PWD and Driver Personal Account Details Page

x. **Driver Account Details Page**

The driver can view and edit their driver account details on Figure 5.10.

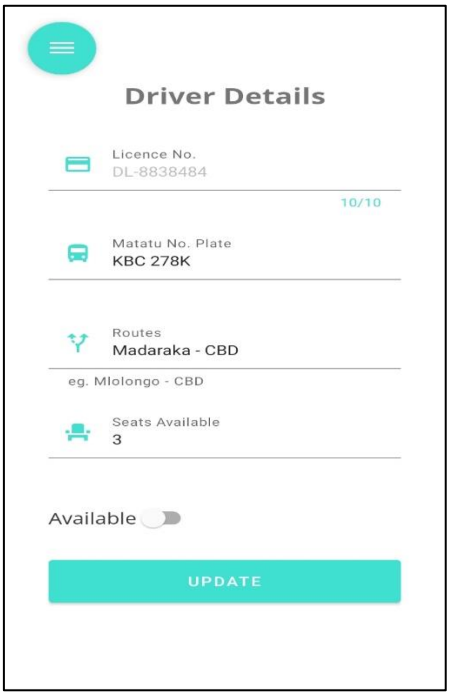


Figure 5.10: Driver Account Details Page

xi. **PWD Active Trip Page**

Once a trip is confirmed, a PWD can view the driver's live location on the map on Figure 5.11.

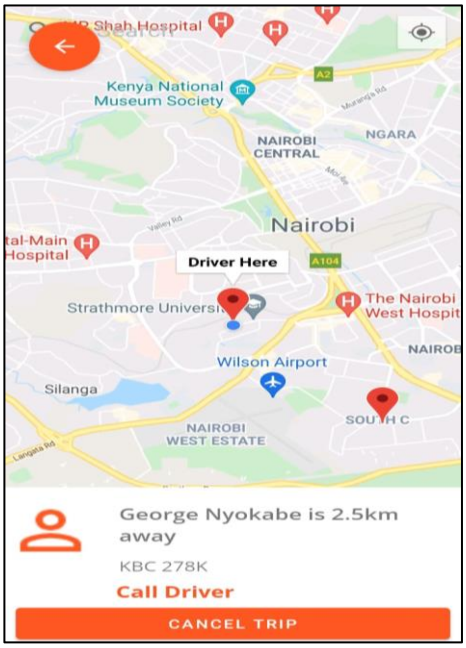


Figure 5.11: PWD Active Trip Page

xii. **Trip History Page**

Trip history reports are available to both the PWD and driver and can be viewed on Figure 5.12.

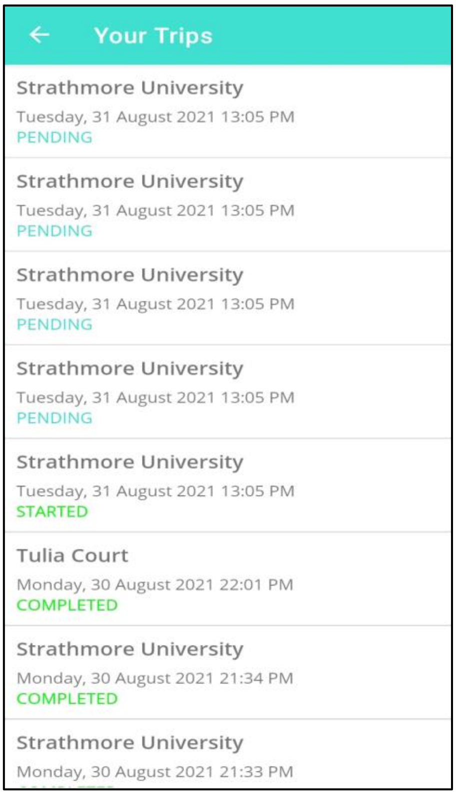


Figure 5.12: Trip History Page

5.2.2 Hardware Specifications

These are the hardware's technical minimum requirements and configurations for the system. Table 5.1 summarizes the important system's hardware requirements for implementation and execution and administrator module.

Table 5.1 Web Application Hardware Specifications

Hardware	**Specifications**
RAM	8 GB minimum
Screen Resolution	1280 x 800
Disk Storage	8 GB of available disk space
CPU architecture	x86_64
Processor	2nd generation Intel Core or newer

Table 5.2 summarizes the important system's hardware requirements for execution on the mobile phone.

Table 5.2 Mobile Application Hardware Specifications

Hardware	**Specifications**
RAM	2 GB minimum
Screen Width	320dp minimum
Disk Storage	50 MB available storage space

5.2.3 Software Specifications

These are the software's technical minimum requirements and configurations for the system. The system was developed using PHP and JavaScript for the admin module and Java Language for the mobile application. The environment used to develop the mobile application was Android Studio.

5.2.3.1 Operating System

The system is developed on Windows 10 operating system. The hailing application is intended to run on devices with Android Operating System with a minimum API level 16.

5.2.3.2 Web Server

The system has an administrator module which requires Apache HTTP Server which is an open-source HTTP Server that offers HTTP services that are compliant with current HTTP standards (Foundation, The Apache Software, 2021).

5.2.3.3 Database

The system is designed to use Firebase Realtime Database which is a NoSQL cloud database that syncs data across clients in real-time is accessible even when the mobile app is offline (Firebase, 2021).

5.3 Description of Testing

System testing is the process of validating the functionality of the different modules in the system and ensuring that they conform to the specified functional and non-functional requirements. Testing for the developed system was done by providing the correct input and checking whether the system behaved as expected. Incorrect input was also provided to the system to check whether the system had correct error handling and would not crash. This was done for all implemented modules in the system. All modules were also tested to confirm whether they met the requirements specified.

5.4 Testing Paradigms

This section will discuss the testing paradigms used for testing of the system. The testing paradigms discussed are white box texting and black box testing.

5.4.1 White Box Testing

White box testing involves evaluating the internal structure of an application. This testing paradigm requires in depth knowledge of the system and requires that each line of code in the system is evaluated. Due to its exhaustive nature, the testing was done for sensitive modules. The authentication module was tested using this paradigm to ensure that there were no mistakes in the code that could lead to compromise of users' accounts.

5.4.2 Black Box Testing

Black box testing involves examining the functionality of an application without prior knowledge of the internal structure. This testing was done for all the modules implemented in the system. Test data with predicted known output was used in testing. The expected output was compared with the systems actual output to understand system behavior and identify possible errors. Non-functional requirements were tested by providing incorrect input to see whether the system would still perform optimally as stated in the non-functional requirements.

5.5 Testing Results

Testing results for the previously outlined modules are provided below.

5.5.1 Authentication Module

Table 5.3 gives a summary of the tests and results obtained during the testing of the authentication module.

Table 5.3 Authentication Module Test Results

Test Case	Description	Test Data	Expected Outcome	Actual Results	Status (Pass/Fail)
1.	PWD and PSV registration with all fields provided	Full name – 'John Doe' Email – 'johndoe@gmail.com'	User details added to database and user is	As expected	Pass

		Phone number – ‘+254 705 999 817’	redirected to landing page		
2.	Admin registration with all fields provided	Full name – ‘Jake Doe’ Email – ‘jakedoe@gmail.com’ Password – ‘12345678’	User details added to database and user is redirected to login page	As expected	Pass
3.	Registration with some fields not provided	One of the fields missing data	Error message is displayed asking user to enter all fields	As expected	Pass
4.	PWD and PSV operator login with correct phone number and one-time-password	Phone number – ‘+254 705 999 817’ OTP – ‘123456’	Login is successful and user is redirected to landing page	As expected	Pass
5.	PWD and PSV operator login with incorrect phone number and one-time-password	Phone number – ‘+254 705 999 817’ OTP – ‘123356’	Error message is displayed indicating that the details entered are incorrect	As expected	Pass
6.	Administrator login with correct email and password	Email – ‘jakedoe@gmail.com’ Password – ‘12345678’	Login is successful and user is redirected to landing page	As expected	Pass

7.	Administrator login with incorrect email and password	Email – ‘jakeduck@gmail.com’ Password – ‘12345678’	Error message is displayed indicating that the details entered are incorrect	As expected	Pass
8.	Administrator reset password	Click on ‘Reset Password’ button	User receives password reset email and follows steps to reset password.	As expected	Pass
9.	Update personal account details	Full name – ‘King Mellow’	User details in the database change in the updated field	As expected	Pass

5.5.2 Public Service Vehicle Operator Module

Table 5.4 gives a summary of the tests and results obtained during the testing of the public service vehicle operator module.

Table 5.4 Public Service Operator Module Test Results

Test Case	Description	Test Data	Expected Outcome	Actual Results	Status (Pass/Fail)
10.	Start trip	Click on the ‘Start Trip’ button	Trip status on the database changes from ‘pending’ to ‘started’	As expected	Pass

11.	Cancel trip	Click on the 'Cancel Trip' button	Trip status on the database changes from 'pending' to 'cancelled - driver'	As expected	Pass
12.	Call rider	Click on the 'Call Rider' button	Driver redirected to dial pad with the rider's contact already filled	As expected	Pass
13.	Confirm payment	Click on the 'Confirm Payment' button	Trip status on the database changes from 'started to 'completed'	As expected	Pass

5.5.3 Person With Disability Module

Table 5.5 gives a summary of the tests and results obtained during the testing of the person with disability module.

Table 5.5 Person with Disabilities Module Test Results

Test Case	Description	Test Data	Expected Outcome	Actual Results	Status (Pass/Fail)
14.	Hail PSV by searching source and destination	Source – 'Strathmore University' Destination - 'Nyayo'	PWD is matched with closest available driver operating on that route	As expected	Pass
15.	Hail PSV by selecting from available routes	Route – 'Madaraka – Bus Station'	PWD is matched with closest available driver operating on that route	As expected	Pass

16.	Cancel trip	Click on the ‘Cancel Trip’ button	Trip status on the database changes from ‘pending’ to ‘cancelled – pwd’	As expected	Pass
17.	Call driver	Click on the ‘Call Driver’ button	PWD redirected to dial pad with the driver’s contact already filled	As expected	Pass

5.5.4 Administrator Module

Table 5.6 gives a summary of the tests and results obtained during the testing of the administrator module.

Table 5.6 Administrator Module Test Results

Test Case	**Description**	**Test Data**	**Expected Outcome**	**Actual Results**	**Status (Pass/Fail)**
18.	View application usage reports	Trips, Users, Drivers, Administrators	The administrator can see a visual representation of the trips' data based on their status. The administrator can also see a data visualization of the system's	As expected	Pass

			total number of users, administrators, and drivers.		
19.	Add new users	Full name – ‘John Doe’ Email – ‘johndoe@gmail.com’ Phone number – ‘+254 705 999 817’	New users are added to the database and can login to access the PWD module.	As expected	Pass
20.	Add new drivers	Full name – ‘John Doe’ Email – ‘johndoe@gmail.com’ Phone number – ‘+254 705 999 817’ Driver’s License Number – ‘DL-1234567’ Vehicle Number Plate – ‘KBB 788B’ Routes – ‘Madaraka – CBD’ Seats – ‘2’	New drivers are added to the database and can login to access the PSV operator module.	As expected	Pass
21.	Edit user details	Full name – ‘John Donald’ Email – ‘johndoe12@gmail.com’	User details are updated in the database and reflect on the user’s profile.	As expected	Pass
22.	Edit driver details	Vehicle Number Plate – ‘KBB 789B’ Routes – ‘Mlolongo – CBD’ Seats – ‘1’	Driver details are updated in the database and reflect on	As expected	Pass

			the driver's profile.		
23.	Disable users	Click on the 'Disable' button	The user is logged out of the system and is denied access upon trying to login again.	As expected	Pass
24.	Enable users	Click on the 'Enable' button	The user is whitelisted thus can access the system by logging in again.	As expected	Pass
25.	Disable drivers	Click on the 'Disable' button	The driver is redirected from the PSV operator module to the PWD module and is denied access upon trying to sign up as driver again.	As expected	Pass
26.	Enable drivers	Click on the 'Enable' button	The driver is redirected back to the PSV operator module.	As expected	Pass

27.	Add trips	Date and Time - 'Sunday, 29 August 2021 14:18 PM' Source – 'Strathmore University' Destination - 'Nyayo' Rider's Name – 'John Doe' PSV Operator's Name – 'Jane Doe' Short Message – 'In a wheelchair' Seats – '1'	The rider and driver are informed of the trip, which is entered into the database.	As expected	Pass
28.	Edit pending trips	Date and Time - 'Sunday, 29 August 2021 14:30 PM' Source – 'Strathmore University' Destination - 'Nyayo' Status – 'cancelled'	The trip data is updated, and changes are made with respect to the status of the trip.	As expected	Pass
29.	Add stops	Stop – 'Mlolongo'	A new stop is added to the database and can be viewed in the PWD module.	As expected	Pass

5.5.5 Geolocation Module

Table 5.7 gives a summary of the tests and results obtained during the testing of the geolocation module.

Table 5.7 Geolocation Module Test Results

Test Case	Description	Test Data	Expected Outcome	Actual Results	Status (Pass/Fail)
30.	Both PSV operator and PWD view route from source to destination	Source – ‘Strathmore University’ Destination - ‘Nyayo’	A polyline is displayed showing the route from source to destination	Not as expected	Fail
31.	Driver views PWD location for current active trip	PWD Location – ‘Madaraka’	Marker with label ‘Rider Location’ appears on map view	As expected	Pass
32.	PWD views driver location for current active trip	Driver Location – ‘Nyayo’	Marker with label ‘Driver Location’ appears on map view	As expected	Pass

Chapter 6: Conclusion, Recommendations and Future Works

6.1 Conclusions

Since PWDs have had challenges using public transportation due to failure to sensitize to their plight, the PSV hailing app was developed as a solution for them to get easier access to public transportation.. The project's goal was to bridge the gap between volunteer PSV operators and people with disabilities in the transportation industry. This was done to allow PWDs to contact PSV operators who would accommodate their needs in their matatus while charging them the same fare as other passengers.

PWDs can contact volunteer PSV operators through the PSV Hailing Application. As a result, the PWD can specify the number of seats they want and provide the driver with further information about their needs. As an outcome, if more space is needed, the driver can accommodate for them and assist them with boarding.

Due to the inflexibility of PSVs, it was difficult to implement the system in such a way that the PWD could board an available PSV within a short period of time after they hailed. Therefore, the PWD must wait an unspecified amount of time for the PSV to arrive at the stop.

6.2 Recommendations

The PSV Hailing App was designed primarily for passengers with physical disabilities. It is recommended that the application be improved to accommodate all people with disabilities, including those with hearing and vision impairments incorporating features such as voice command and haptic response.

6.3 Future Works

PWDs should be able to make payments cheaply and inexpensively through the app, with the funds being sent to the appropriate drivers. A payment mechanism, which will handle transactions and issue receipts to both the PWD and PSV operator, would be an ideal solution.

There is a need to provide a proper method for drivers in the system to be verified. When they register, their information can be recorded and sent to the appropriate authorities for approval. This will improve the system's efficiency and provide more security for PWDs.

References

Android Developers. (2021, March 11). Platform Architecture. Retrieved from Android Developers: https://developer.android.com/guide/platform

Association for the Physically Disabled of Kenya. (2021). Assistive Devices. Retrieved from Association for the Physically Disabled of Kenya: https://www.apdk.org/product/standard-tricycle-with-carrier-s0101/

Bastmeijer, J. (2020, March 26). Aljazeera. Retrieved from In Pictures: Riding Kenya's matatus amid new coronavirus measures: https://www.aljazeera.com/gallery/2020/3/26/in-pictures-riding-kenyas-matatus-amid-new-coronavirus-measures

Firebase. (2021). Firebase Realtime Database. Retrieved from Firebase: https://firebase.google.com/docs/database

Foundation, The Apache Software. (2021). Apache HTTP Server Project. Retrieved from Apache HTTP Server: https: //httpd.apache.org/

Geotab Team. (2020, May 22). What is GPS. Retrieved from Geotab: https://www.geotab.com/blog/what-is-gps/

Gikonyo, A. (2021, June 6). Kinoo matatu crew's extraordinary service to disabled people. (N. Kenya, Interviewer)

INIT. (2021). ASSISTIVEtravel. Retrieved from INIT: https://www.initse.com/enus/news-resources/knowledge-database/articles/2019/assistivetravel/

Integrity Exports. (2021). Vehicles for Disabled People. Retrieved from Integrity Exports: https://integrityexports.com/japan-car-auction-academy/buying-specialist-cars-from-japan/vehicles-for-disabled-people/

International Labour Organization. (2021). OPERATIONS/HUMAN RESOURCES MANUAL FOR MATATU SACCOS/COMPANIES. Retrieved from International Labour Organization: https://www.ilo.org/wcmsp5/groups/public/---africa/---ro-abidjan/---ilo-dar_es_salaam/documents/publication/wcms_493748.pdf

Kabare, K. (2018, October). Social Protection and Disability in Kenya. Retrieved from Development Pathways: https://www.developmentpathways.co.uk/wp-content/uploads/2018/10/Disability-Report-Kenya.pdf

Kenya Law Reports. (2010). Persons with Disabilities Act No. 14 of 2003. Laws of Kenya. Kenya: National Council for Law Reporting. Retrieved from United Nations: https://www.un.org/development/desa/disabilities/wp-content/uploads/sites/15/2019/11/Kenya_Persons-with-Disability-Act.pdf

Lucid Software Inc. (2021). What is a Database Schema. Retrieved from Lucidchart: https://www.lucidchart.com/pages/database-diagram/database-schema

Lucidchart Software Inc. (2021). System Sequence Diagrams in UML. Retrieved from Lucidchart: https://www.lucidchart.com/pages/uml-system-sequence-diagram

Maina, S. (2019, August 23). Here's Why Your Next Uber Ride in Kenya Will Cost More. Retrieved from Gadgets Africa: https://gadgets-africa.com/2019/08/23/heres-why-your-next-uber-kenya-ride-will-cost-more/

Mwangi, J. (2016, August 10). Kenyan bus driver who helps disabled people get to work. (B. N. Africa, Interviewer)

National Council for Persons with Disabilities. (2021). Assistive Devices. Retrieved from National Council for Persons with Disabilities: https://ncpwd.go.ke/assistive-device/#:~:text=Assistive%20devices%20and%20services%20are,Service%20is%20Sign%20Language%20interpretation.

National Gender and Equality Commission Communications. (2019, May 20). PWDS to Enjoy Inclusive Public Transport. Retrieved from National Gender and Equality Commission: https://www.ngeckenya.org/news/8231/pwds-to-enjoy-inclusive-public-transport#

O'Dea, S. (2021, June 29). Market share of mobile operating systems in Kenya from January 2018 to June 2021. Retrieved from statista: https://www.statista.com/statistics/1063958/market-share-held-by-mobile-operating-systems-in-kenya/

Omulo, C. (2017, December 1). People with disability unaware of their tax saving position: KRA. Retrieved from Business Daily: https://www.businessdailyafrica.com/bd/news/people-with-disability-unaware-of-their-tax-saving-position-kra-2179876

Owino, E. (2020, May 6). Status of disability in Kenya: Statistics from the 2019 census. Retrieved from Development Initiatives: https://devinit.org/resources/status-disability-kenya-statistics-2019-census/

Pennecke, S. J. (2020, February 11). App Makes Public Transit Easier for Riders with Disabilities. Retrieved from Government Technology: https://www.govtech.com/transportation/app-makes-public-transit-easier-for-riders-with-disabilities.html

Rosenblatt, H. J., & Shelly, G. B. (2012). Systems Analysis and Design, Ninth Edition. Boston: Course Technology, Cengage Learning.

Salman. (2021, June 24). Incremental Model in SDLC: Use, Advantage & Disadvantage. Retrieved from worldofitech: https://www.worldofitech.com/incremental-model-in-sdlc/

Salon, D., & Gulyani, S. (2019, July 12). Retrieved from https://www.mdpi.com/2071-1050/11/14/3823/pdf

Spencer, S. (2018, December 6). Google Play services discontinuing updates for API levels 14 and 15. Retrieved from Android Developers Blog: https://android-developers.googleblog.com/2018/12/google-play-services-discontinuing.html

Summerson, C., & Duino, J. (2020, October 23). What's the Latest Version of Android? Retrieved from How to Geek: https://www.howtogeek.com/345250/whats-the-latest-version-of-android/

The Kenya Institute for Public Policy Research and Analysis. (2020, July 28). Enhancing Accessibility in Transport Infrastructure by PWDs. Retrieved from The Kenya Institute for Public Policy Research and Analysis: https://kippra.or.ke/enhancing-accessibility-in-transport-infrastructure-by-pwds/

Tripadvisor. (2021). Kenya: Forms of Transport. Retrieved from Tripadvisor: https://www.tripadvisor.com/Travel-g294206-c3331/Kenya:Forms.Of.Transport.html

Uber. (2021). Uber Assist. Retrieved from Uber: https://www.uber.com/au/en/ride/assist/

Uber Blog. (2019, January 3). UberASSIST: making Nairobi more accessible. Retrieved from Uber: https://www.uber.com/en-KE/blog/uberassist-making-nairobi-more-accessible/#:~:text=UberASSIST%20has%20been%20designed%20to,accommodate%20folding%20wheelchairs%20and%20walkers

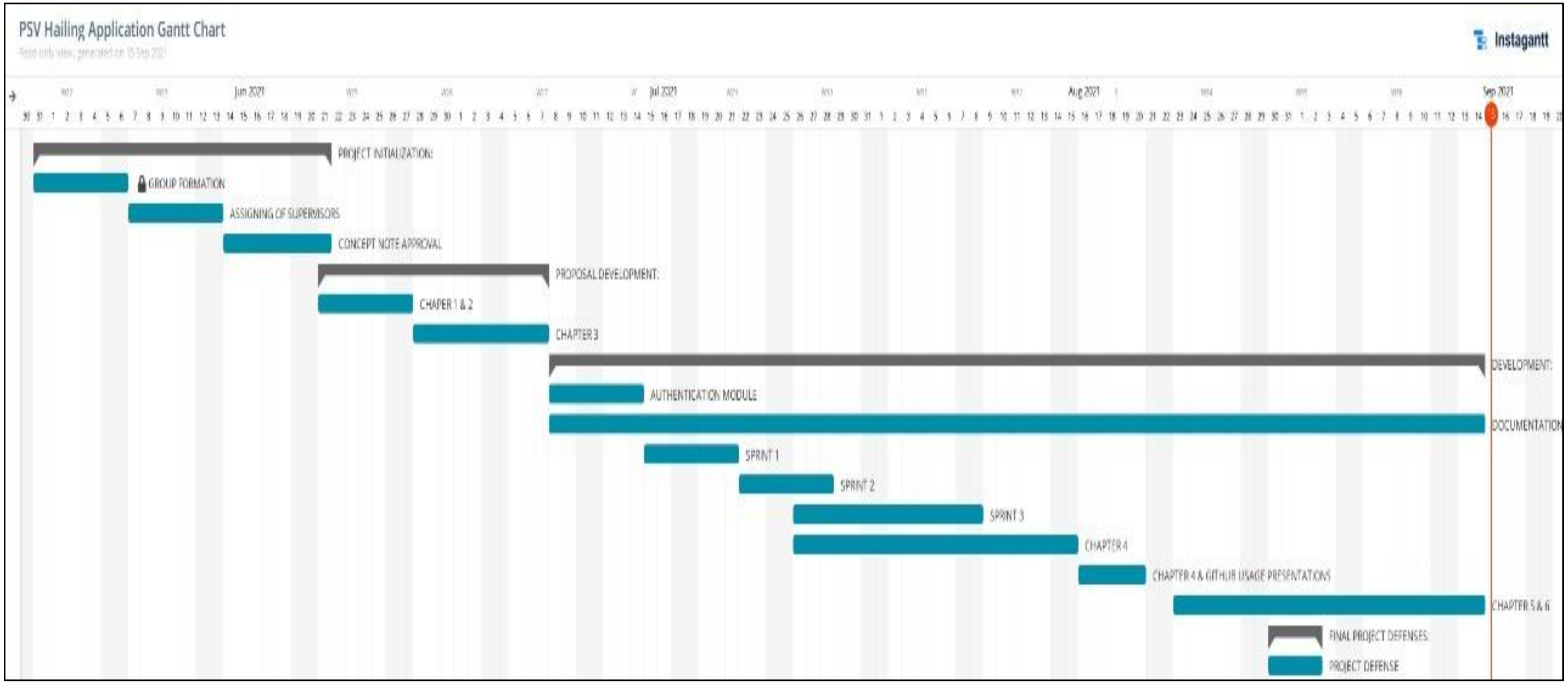
UNHCR. (2021). Persons with Disabilities. Retrieved from UNHCR Emergency Handbook: https://emergency.unhcr.org/entry/43586/persons-with-disabilities

van Vliet, H. (2007). Software Engineering: Principles. New Jersey: Wiley.

Wambugi, J. (2017, June 14). An Introduction to Nairobi's Matatu Culture. Retrieved from Culture Trip: https://theculturetrip.com/africa/kenya/articles/an-introduction-to-nairobis-matatu-culture/

Appendix

Appendix 1: Gantt Chart



Appendix 1: Gantt Chart