Adventist University of Central Africa

IMAS: INTELLIGENTMOBILITY ASSISTANCE SYSTEM

CASE STUDY: TRANSPORT AU CONGO(TRANSCO)

A Research Project Presented in Partial Fulfillment of the Requirements for the Degree OF BACHELOR OF SCIENCE IN INFORMATION TECHNOLOGY

Major in

Software Engineering

By

Mubu Maseya Daniel

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ABSTRACT

Research project for the bachelor's degree in information technology

Emphasis in Software Engineering

Adventist University of Central Africa

TITLE: IMAS (INTELLIGENT MOBILITY ASSISTANCE SYSTEM)

Name of Researcher: Mubu Maseya Daniel

Name of Faculty Advisor: Ishimwe Prince

Date Completed: August 2025

The Intelligent Mobility Assistance System (IMAS) is a digital solution designed to improve Transport au Congo (TRANSCO), the main provider of urban and interurban transport in the Democratic Republic of Congo. TRANSCO currently faces challenges due to manual processes, including delays, revenue losses, lack of real-time fleet tracking, and poor passenger communication. These problems reduce service quality and passenger satisfaction.

IMAS offers a technology platform that integrates real-time vehicle tracking, digital ticketing, and automated communication. Smart route planning gives passengers accurate travel details, while digital ticketing reduces fraud and cash handling. Real-time fleet monitoring helps managers respond swiftly to delays or emergencies. Automated notifications keep passengers informed, improving transparency and trust.

By lowering manual work and operational costs, IMAS increases efficiency and enhances commuter experience. Passengers benefit from easier access to information, convenience, and reliable service. The project supports global smart city trends, helping TRANSCO modernize its transportation system and promote sustainable urban mobility.

Overall, IMAS aims to boost service reliability, passenger confidence, and contribute to developing the DRC's public transport infrastructure. It represents a key step toward a more efficient, accountable, and passenger-centered transit system.

DECLARATION

I, **Mubu Maseya Daniel**, bearing Registration Number **24913**, am a student at the Adventist University of Central Africa (AUCA), enrolled in the Faculty of Information Technology, Department of Software Engineering. I hereby affirm that, to the best of my knowledge, this research project is a true and original representation of my personal work and experience.

Signature: ………………………

Date: ………/………/…………

APPROVAL

I, **Ishimwe Mukotsi Prince** hereby certify that this project report has been done under my supervision and submitted with my approval.

Signature: **………………**

Date: **……/………/………**

DEDICATION

I dedicate this work first and foremost to God, whose grace, guidance, and strength have been my foundation.

To my family, for their endless love, support, and encouragement through every step of this journey.

To my supervisor, for their invaluable guidance, patience, and belief in my potential.

And to the pursuit of professional growth, which continues to inspire me to learn, improve, and serve with excellence.

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LIST OF SYMBOLS

AUCA	Adventist University of Central Africa
DRC	Democratic Republic of Congo
GPS	Global Positioning System
IMAS	Intelligent Mobility Assistance System
QR	Quick Response
SMS	Short Message Service
SDLC	Software Development Life Cycle
TRANSCO	Transport au Congo
UML	Unified Modeling Language
HTML	Hyper Text Markup Language
CSS	Cascading Styles Sheets
URL	Uniform Resource Locator
DBMS	Database Management System
MYSQL	Structure Query Language
UX	User experience
UI	User Interface
PHP	Hypertext Preprocessor
IDE	Integrated development Environment

ACKNOWLEDGEMENTS

I would like to begin by expressing my heartfelt appreciation to my friends, whose companionship, encouragement, and uplifting spirit have made this academic journey both memorable and meaningful. Your constant support has been a true source of strength and joy throughout every step of this process.

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To my beloved family, I offer my deepest appreciation for your unwavering love, sacrifice, and encouragement. Your constant belief in my potential and your tireless support have been the foundation of all my achievements.

Finally, I offer all glory and honor to God, whose grace has sustained me throughout this journey. His wisdom, protection, and endless blessings have made this accomplishment possible, and I am forever grateful.

Mubu Maseya Daniel

CHAPTER 1

GENERAL INTRODUCTION

Introduction

Urban mobility is a critical component of sustainable development in growing cities, especially in regions experiencing rapid urbanization such as Kinshasa, the capital of the Democratic Republic of Congo (DRC). With a population exceeding 17 778 500 million, Kinshasa faces significant challenges in its public transportation system, including inefficiency, congestion, lack of real-time information, and limited accessibility for passengers. These challenges hinder the city's economic productivity and negatively affect the quality of life for its residents.

To address these issues, innovative, data-driven solutions are required to modernize the way people move across the city. The Intelligent Mobility Assistance System (IMAS). proposes a comprehensive approach to enhance public transport operations through the integration of real-time tracking, electronic ticketing, and smart notifications. This project aims to support both commuters and transport service providers by leveraging modern technologies such as GPS, cloud computing, and mobile applications.

By introducing IMAS in Kinshasa, the goal is to optimize transportation logistics, reduce waiting times, improve route transparency, and foster better coordination among stakeholders such as transit agencies, drivers, and passengers. This initiative aligns with broader urban development goals in the DRC and positions Kinshasa as a forward-looking metropolis in the realm of intelligent transportation systems.

Background of the Study

Public transportation is a foundational element of urban development, facilitating mobility, economic productivity, and social inclusion. In the Democratic Republic of the Congo (DRC), particularly in Kinshasa, the capital city, public transport is critical to daily life for millions of residents. TRANSCO, the state-owned transport company established in 2013, plays a central role in meeting the city's mobility needs through its urban and interurban services.

Despite its importance, TRANSCO's operations remain largely manual and outdated, relying on paper-based ticketing systems, fixed-route scheduling, and limited passenger communication. These inefficiencies contribute to common challenges such as delays, reduced fleet availability, revenue leakage, and poor user satisfaction. As Kinshasa's urban population continues to grow rapidly, the demand for a more efficient, reliable, and responsive transportation system becomes increasingly urgent.

Meanwhile, cities around the world are embracing digital transformation in the transportation sector. Global examples—from London to Nairobi demonstrate how integrating technologies such as GPS tracking, e-ticketing, and real-time alerts can significantly enhance service delivery, reduce operational costs, and improve customer trust. However, the adoption of such intelligent systems in Sub-Saharan Africa remains limited, primarily due to infrastructural gaps, funding constraints, and the lack of context-specific technological solutions.

In Kinshasa, a major gap exists in the absence of an integrated platform that can simultaneously manage key aspects of public transportation-ticketing, fleet tracking, maintenance, and passenger communication. Current systems tend to address individual issues in isolation, missing the opportunity for comprehensive improvement. As identified by Bocquier (2005) and Dimitriou et al. (2011), urban transport systems in low-income regions must evolve using adaptable, scalable digital tools that suit the regional context.

To address these pressing challenges, the proposed **Intelligent Mobility Assistance System (IMAS)** offers a unified, digital solution designed specifically for TRANSCO's needs. IMAS will introduce real-time fleet monitoring, QR code ticketing, predictive maintenance scheduling, and real-time passenger notifications all within a centralized platform. By digitizing and streamlining key processes, IMAS aims to enhance operational efficiency, transparency, and service delivery, ultimately contributing to the modernization of public transport in Kinshasa and setting a precedent for smart mobility across the DRC.

Statement of the Problem

The public transportation system managed by TRANSCO in Kinshasa, DRC, continues to rely on outdated manual operations for ticketing, scheduling, and communication. This leads to frequent delays, inefficiencies, and poor delivery service, reducing commuter satisfaction and trust.

The absence of a digital platform for real-time fleet monitoring, automated ticketing, and timely passenger updates has resulted in operational inefficiencies, revenue leakages, and limited data for informed decision-making.

To meet the growing demands of urban mobility, there is an urgent need for a modern, integrated solution that can enhance transparency, reliability, and overall efficiency. The proposed **Intelligent Mobility Assistance System (IMAS)** addresses these challenges by digitizing core processes and transforming public transport into a smarter, more responsive system.

Choice and Motivation

The decision to focus this study on public transportation in Kinshasa, Democratic Republic of the Congo (DRC), stems from both personal experience and a deep-rooted desire to drive change in a system that affects millions daily. Born and raised in Kinshasa, I spent the first 18 years of my life navigating the city's congested and often unreliable transport network. This experience exposed me firsthand to the daily struggles faced by commuters long wait times, overcrowded buses, lack of clear schedules, and frequent delays, all of which contribute to a high level of frustration and inefficiency.

Throughout my youth, I witnessed how these challenges not only made everyday life more difficult for the city's residents but also hindered productivity, economic activity, and social mobility. The imbalance between the growing urban population and the limited availability of transport options has created persistent strain on the system, pushing many to rely on informal, and at times unsafe alternatives.

From a young age, I was driven by a dream to transform the way transportation works in Kinshasa. This project, the **Intelligent Mobility Assistance System (IMAS)** represents the realization of that dream. It is motivated by a commitment to leverage technology and innovation to improve public service delivery, ensure transparency, and enhance the overall commuter experience. By addressing the systemic inefficiencies in TRANSCO's operations, this study aims not only to modernize public transportation but also to contribute to a more dignified, efficient, and equitable mobility system for the people of Kinshasa.

Objectives of the Study

The **Intelligent Mobility Assistance System (IMAS)** project aims to transform the operational efficiency, transparency, and reliability of public transport services provided by **TRANSCO** in the Democratic Republic of the Congo (DRC). The initiative is guided by one overarching objective, supported by a set of specific, actionable goals that ensure measurable and sustainable outcomes.

General Objectives

To design, develop, and implement a real-time, digital Intelligent Mobility Assistance System (IMAS) that improves fleet tracking, automates ticketing, enhances passenger communication, and optimizes operational management for TRANSCO's urban and interurban transport services.

Specific Objectives

To ensure the successful implementation and measurable impact of the Intelligent Mobility Assistance System (IMAS) for TRANSCO in Kinshasa, the following specific objectives have been defined:

1. **Develop a real-time GPS-based bus tracking system**
   To enhance fleet visibility and enable live monitoring by both passengers and administrators, ultimately reducing average waiting times at bus stops and improving operational transparency.
2. **Implement a secure digital ticketing platform**
   To replace manual ticketing methods with a QR code-based validation system integrated with mobile payment options, eliminating revenue leakage and increasing transaction efficiency and traceability.
3. **Design a predictive maintenance system**
   To monitor vehicle health and schedule proactive maintenance tasks, reducing fleet downtime, minimizing unexpected breakdowns, and extending the operational life of vehicles.
4. **Create a real-time passenger notification module**
   To provide commuters with timely alerts on service disruptions, estimated bus arrival times, and route changes via mobile and web interfaces, enhancing the overall passenger experience.
5. **Enable advanced data analytics and administrative dashboards**
   To support data-driven decision-making by providing TRANSCO with tools for performance tracking, route optimization, and strategic resource allocation.

Scope of the Project

The scope of this study is to design and implement the **Intelligent Mobility Assistance System (IMAS)** a digital solution aimed at transforming the operational processes of **TRANSCO**, the state-owned public transportation provider in Kinshasa, Democratic Republic of Congo. This system will focus on enhancing the efficiency, transparency, and responsiveness of public transport services through the integration of modern digital technologies.

The project will involve the development of an integrated platform that includes real-time GPS-based bus tracking, secure QR code digital ticketing with mobile payment support, predictive maintenance features for vehicle health monitoring, a passenger communication module for service alerts, and a comprehensive dashboard for data analytics and administrative decision-making.

The implementation will be context-specific, taking into account the unique infrastructural and socio-economic realities of Kinshasa's urban mobility environment. The system will be designed for use by TRANSCO administrators, bus drivers, and the commuting public, ensuring a user-friendly interface across both mobile and web applications.

This study will be conducted within the urban public transportation context of Kinshasa, focusing exclusively on TRANSCO's fleet and operational structure. It will not cover informal transportation modes (e.g., taxis, motor taxis), nor will it extend to long-term urban transport infrastructure planning or construction.

To inform system requirements and ensure contextual alignment, the study will gather insights through field observations, user feedback, stakeholder consultations, and analysis of TRANSCO's existing workflows. Emphasis will be placed on scalable system design, with the potential for future expansion across other Congolese cities or transport operators.

By concentrating on these targeted aspects, the IMAS project aims to deliver a comprehensive, sustainable, and smart solution that addresses the most pressing challenges in Kinshasa's public transport system.

Methodology and Techniques

To design an effective and context-aware **Intelligent Mobility Assistance System (IMAS)** for TRANSCO in Kinshasa, the study employed a mixed-methods approach. This included qualitative and quantitative data collection through multiple research techniques. The following methodologies were used to ensure a comprehensive and practical system design:

Participatory Research

Community members, passengers, TRANSCO staff, and other stakeholders were actively engaged in the research process. Their direct involvement allowed the researchers to gather firsthand accounts of daily commuting experiences, challenges in using public transport, and expectations for digital transformation. This participatory approach ensured that the IMAS system would reflect the real needs of its users and enhance public acceptance.

Document Analysis

Document analysis is a qualitative research technique that involves the systematic evaluation of written, visual, or digital materials to extract meaningful insights. In the context of this study, document analysis was used to understand the existing operational landscape of TRANSCO and the broader public transport ecosystem in Kinshasa.

A detailed review of existing documents was conducted, including TRANSCO's operational policies, maintenance schedules, ticketing records, fleet logs, and government transport reports. These documents provided a clear picture of the internal processes, regulatory frameworks, and systemic challenges that hinder efficient service delivery.

The analysis helped identify several inefficiencies in current workflows such as manual ticketing systems, inconsistent maintenance planning, lack of real-time fleet tracking, and limited access to performance data. These findings highlighted critical areas where automation, digital integration, and data-driven systems like IMAS could significantly enhance accountability, reliability, and strategic planning.

By grounding the system design in real-world documentation, the project ensures that IMAS directly addresses the existing pain points within TRANSCO and aligns with national mobility goals in the Democratic Republic of Congo.

Observation

Observation is a direct data collection method that involves systematically watching and recording behaviors, events, and operational processes in their natural settings. It enables researchers to gain firsthand insights into how systems function in practice, beyond what is documented or reported.

In this study, the research team conducted field observations at several TRANSCO bus stations across Kinshasa. The focus was placed on key operational aspects such as passenger boarding times, schedule adherence, fare collection processes, staff coordination, and overall passenger behavior.

These real-time observations revealed a number of challenges, including frequent delays, inconsistent boarding procedures, overcrowding, and a lack of standardized communication between staff and commuters. Additionally, fare collection was observed to be highly manual and prone to leakage or errors, further underscoring the need for digital intervention.

By complementing other research methods with on-site observation, the study ensured that the design of the Intelligent Mobility Assistance System (IMAS) reflects the actual conditions and needs on the ground, thereby increasing the system's relevance and practical impact.

Interviews

Interviews are a qualitative research method that allows for in-depth exploration of individual experiences, perceptions, and insights. They are particularly effective in uncovering nuanced challenges and identifying user-specific needs in complex systems.

In this study, semi-structured interviews were conducted with a diverse group of stakeholders, including TRANSCO managers, bus drivers, ticket conductors, and regular commuters in Kinshasa. These interviews were guided by open-ended questions designed to prompt detailed responses, while still allowing flexibility to explore emerging themes.

The discussions highlighted several core operational issues within TRANSCO's transport system. Participants frequently cited the absence of real-time updates, unreliable schedules, ticketing inconsistencies, and poor vehicle maintenance as major pain points. Commuters, in particular, expressed frustration over long waiting times and a general lack of transparency in service delivery.

Insights gathered from these interviews directly informed the design of the Intelligent Mobility Assistance System (IMAS), ensuring that the proposed solution addresses not only technical inefficiencies but also user-centric concerns and expectations.

Surveys

Quantitative data was collected through structured questionnaires distributed to passengers in various parts of Kinshasa. The surveys focused on average wait times, satisfaction levels, frequency of transit use, pain points, and openness to using digital systems. The results provided statistical support for the project's direction and feature prioritization.

Expected Results

The Intelligent Mobility Assistance System (IMAS) is expected to deliver the following outcomes:

➢ The system will provide real-time GPS tracking of buses, enabling passengers and administrators to monitor fleet locations and reduce waiting times at bus stops.

➢ The system will eliminate manual ticketing by introducing a secure digital ticketing platform using QR code validation and mobile payments, improving revenue tracking and minimizing fraud.

➢ The system will support predictive maintenance by continuously monitoring vehicle health and scheduling preventive repairs, thereby reducing unexpected breakdowns and fleet downtime.

➢ The system will offer real-time passenger notifications through mobile and web platforms, keeping commuters informed about delays, route changes, and arrival times.

➢ The system will equip TRANSCO administrators with data analytics dashboards to support operational decision-making, performance tracking, and strategic resource allocation.

➢ The system will enhance commuter trust and satisfaction by improving transparency, service reliability, and access to transportation information.

➢ The system will reduce administrative workload by automating routine transport management processes, such as scheduling, maintenance tracking, and ticket reconciliation.

➢ The system will contribute to safer and more efficient public transport in Kinshasa, ultimately encouraging broader adoption of TRANSCO services and reducing reliance on unsafe informal transport options.

Organization of Report

The structure of this final year project report consists of five chapters:

- **Chapter I:** Introduces the Intelligent Mobility Assistance System (IMAS) project, highlighting the transportation challenges in Kinshasa, especially those faced by TRANSCO and its commuters. It presents the background, problem statement, research objectives, study scope, justification, and methodology used to carry out the project.

- **Chapter II:** Analyzes the current public transport system managed by TRANSCO. It explores existing issues such as lack of fleet visibility, manual ticketing, maintenance inefficiencies, and limited communication with passengers. This chapter also defines key terms and reviews the technologies relevant to solving these issues.

- **Chapter III:** Focuses on the system analysis and design phase of IMAS. It provides a detailed description of the functional and non-functional requirements, data flow diagrams, system architecture, and database structure. The chapter explains how each component is tailored to solve identified transport problems in Kinshasa.

- **Chapter IV:** Discusses the implementation of the IMAS prototype. It includes the development environment, tools and technologies used, user interface designs, and system integration. This chapter also covers the testing strategy used to verify system functionality and performance.

- **Chapter V:** Summarizes the key findings and outcomes of the IMAS project. It evaluates how well the system meets its original objectives and discusses its expected impact on TRANSCO and the commuting population. The chapter also provides recommendations for system deployment, future improvements, and opportunities for further research.

CHAPTER 2

ANALYSIS OF CURRENT SYSTEM

Introduction

Systems analysis is an essential discipline that seeks to understand, evaluate, and improve existing operational processes within organizations. It involves the careful identification of system components, workflows, and interrelationships, enabling decision-makers to design better, more efficient solutions. In the context of public transportation, particularly in urban African settings like Kinshasa, a structured system analysis is vital for addressing challenges such as inefficiency, revenue leakage, poor passenger communication, and service unreliability.

As the primary public bus operator in the Democratic Republic of Congo (DRC), **Transport au Congo (TRANSCO)** plays a central role in the mobility of thousands of citizens across urban and interurban areas. Despite its vast network and impact, TRANSCO still operates under a largely manual and fragmented system. The current environment lacks real-time fleet monitoring, uses paper-based ticketing, operates without centralized data analytics, and struggles with unpredictable scheduling and reactive maintenance practices.

In this chapter, we present an in-depth analysis of TRANSCO's existing public transport system. We examine the core components of the current operational model—ticketing, scheduling, fleet management, maintenance, and customer communication—and evaluate their respective strengths and limitations. This analysis is crucial to inform the design of the **Intelligent Mobility Assistance System (IMAS)**, which aims to streamline and digitize transport operations using GPS tracking, QR-based ticketing, predictive maintenance, and real-time passenger updates.

By understanding the gaps in TRANSCO's current processes, this chapter lays the foundation for proposing innovative digital interventions that can modernize public transport services in Kinshasa and set the stage for a smarter, more responsive transportation ecosystem.

Description of Current System

The current operational system at Transport au Congo (TRANSCO) is primarily manual and fragmented, relying heavily on paper-based processes across its ticketing, scheduling, and fleet management functions. When passengers board TRANSCO buses, they must purchase physical tickets, often issued by conductors using printed booklets. This manual ticketing process lacks transparency, offers no centralized tracking of sales or passengers, and leaves room for cash leakage and revenue misreporting.

Fleet monitoring is equally limited. Bus dispatch and maintenance schedules are coordinated manually using printed logs and static timetables, with little to no integration between departments. Maintenance is generally reactive, occurring after breakdowns rather than based on predictive diagnostics or scheduled performance checks. This disjointed maintenance approach often leads to service delays, reduced bus availability, and an overall decline in reliability.

Dispatchers and supervisors rely on handwritten reports or verbal updates to track buses and shifts. Since there is no real-time GPS tracking or centralized route analytics, they cannot accurately monitor bus locations, predict arrival times, or make informed decisions in response to road conditions, demand fluctuations, or emergencies. This results in uneven passenger loads, long wait times, and inefficient resource allocation.

Furthermore, passenger communication is minimal. There are no mobile applications, SMS alerts, or real-time digital signs to inform commuters about service changes, delays, or alternative routes. Most updates are delivered verbally at terminals or not communicated at all. This lack of information reduces commuter trust and satisfaction, especially during peak hours or unexpected disruptions.

While TRANSCO has made progress in expanding its coverage and increasing ridership, the absence of a centralized digital platform undermines operational efficiency, accountability, and service quality. The current system, though functional on a basic level, is administratively burdensome, error-prone, and ill-equipped to support the growing demands of modern urban mobility in Kinshasa and other cities.

Description of Current System Environment

Historical Background

Transport au Congo (TRANSCO) was established in **2013** by the Government of the Democratic Republic of Congo (DRC) to provide safe, reliable, and affordable public transportation services. The initiative emerged in response to the growing demand for structured urban mobility systems amid rapid urbanization, especially in Kinshasa and other major cities. Prior to TRANSCO, public transport was largely informal and unregulated, often dominated by privately owned minibuses known as "esprits de mort." The founding of TRANSCO marked a turning point in the government's effort to professionalize the sector, reduce traffic chaos, and ensure accessible transportation for all Congolese citizens.

Mission

The mission of TRANSCO is to **offer affordable, safe, and efficient public transportation services to all segments of the population** while promoting sustainable urban mobility. Through a government-subsidized model, TRANSCO seeks to bridge the mobility gap for low- and middle-income commuters and support national development by reducing congestion, improving accessibility, and contributing to economic integration across provinces. The organization places a strong emphasis on professionalism, safety standards, and service reliability as cornerstones of public trust and operational excellence.

Vision

TRANSCO envisions becoming **a leading public transport provider in Central Africa**, characterized by **modern infrastructure, digital integration, and responsive service delivery**. The company aspires to shift from traditional, paper-based operations to a **digitally enabled, data-driven model** that enhances route planning, maintenance management, and passenger experience. This vision aligns with national goals of digital transformation and economic modernization. By investing in intelligent transport systems like IMAS, TRANSCO aims to not only improve operational efficiency but also foster transparency, accountability, and customer satisfaction in public mobility services.

Analysis of the Current System

The current operational system at Transport au Congo (TRANSCO) is predominantly manual and paper based. Core functions such as ticketing, dispatching, fleet monitoring, and passenger communication are managed using non-digital tools such as ticket books, printed schedules, and handwritten logs. While this system has enabled basic operations, it lacks the efficiency, transparency, and scalability required to meet the demands of a growing urban population and an evolving transport sector.

Challenges Identified:

1. **Inefficiency and Time Consumption**
   Manual ticketing, scheduling, and reporting slow down daily operations. Conductors and dispatchers must handle repetitive administrative tasks, which limits their ability to focus on service quality and safety. Route changes or service disruptions take time to communicate, leading to delays and commuter dissatisfaction.

2. **Revenue Leakage and Lack of Transparency**
   Cash-based ticket sales with no digital tracking make revenue monitoring difficult. There is no reliable audit trail, increasing the risk of financial misreporting, fraud, and loss of income. Without centralized sales data, management cannot make informed business decisions.

3. **Lack of Real-Time Fleet Visibility**
   The absence of GPS tracking and centralized dashboards means TRANSCO cannot monitor buses on the road. Dispatchers operate based on static schedules and radio reports, which hinders their ability to respond dynamically to traffic conditions, breakdowns, or peak hour demands.

4. **Unpredictable Maintenance and Frequent Downtime**
   Maintenance is reactive rather than preventive. Vehicles are serviced only after faults are reported or breakdowns occur. This reactive approach results in more frequent service interruptions, increased maintenance costs, and passenger inconvenience.

5. **Limited Passenger Communication**
   TRANSCO does not offer a mobile application, SMS updates, or live service notifications. Passengers receive little to no real-time information about delays, route changes, or bus locations. This lack of communication reduces public trust and discourages ridership.

Implications:

The limitations of TRANSCO's current system negatively affect operational efficiency, financial accountability, and customer satisfaction. With urban populations growing and commuter expectations rising, the manual and disconnected structure is increasingly unsustainable. In its current form, the system is resource-intensive, opaque, and technologically outdated, putting TRANSCO at a disadvantage compared to more modern transport providers.

Conclusion:

This analysis underscores the need for a digital transformation of TRANSCO's operations. An integrated solution like the Intelligent Mobility Assistance System (IMAS) can address these inefficiencies by automating ticketing, enabling GPS-based fleet tracking, and providing real-time updates to both staff and passengers. IMAS would introduce data-driven decision-making, predictive maintenance, and digital payment options, reducing administrative burdens while increasing revenue oversight and commuter confidence.
By modernizing its operations, TRANSCO can improve service reliability, increase ridership, and become a more sustainable and trusted public transport provider in the DRC.

Modeling Current System

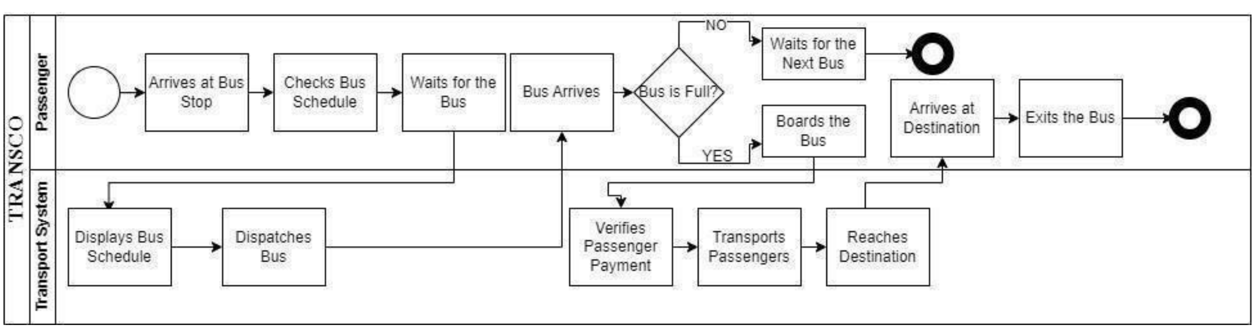


Figure 1: Modeling of the Current System

Problems of the Current System

Performance

Throughput:

The current manual operations at TRANSCO, including ticketing, scheduling, and reporting, have limited capacity to handle high volumes of commuters and vehicles efficiently. During peak hours, the system becomes overwhelmed, resulting in long queues, delayed bus dispatching, and missed schedules. These bottlenecks hinder TRANSCO's ability to maintain a consistent and timely transport service across its network.

Response Time:

- **Passengers** experience extended waiting times due to slow manual ticketing and boarding processes. The lack of real-time communication tools delays the delivery of essential service updates such as route changes or bus availability.
- **Operational staff** struggle to respond swiftly to breakdowns, traffic disruptions, or emergencies, as updates are communicated through basic radio systems and manual coordination.
- **Maintenance requests** and vehicle service are often delayed due to a lack of automated alerts or predictive tools. This leads to prolonged bus downtime, affecting route availability and commuter satisfaction.

Information

Input:

Manual data collection for tickets, driver logs, and route changes introduces significant inefficiencies. Data is often recorded on paper, increasing the likelihood of human error, data loss, and misreporting, which undermines operational accuracy and decision-making.

Output:

There is no centralized reporting or analytics system to provide actionable insights on revenue, vehicle usage, or commuter trends. Without real-time dashboards or structured data output, management cannot make timely or informed decisions, limiting the organization's ability to improve services.

Storage:

Important operational records (such as trip logs, revenue books, and maintenance records) are stored physically, which is space-consuming and insecure. These documents are at risk of damage, loss, or unauthorized access, posing serious threats to operational continuity, data privacy, and regulatory compliance.

Economics

Additional Costs for Passengers

Commuters are required to queue at bus stations to buy physical tickets, which often leads to lost time and productivity. In cases of service changes or cancellations, passengers must return to stations for information, increasing their travel costs and inconvenience.

High Operational Costs for TRANSCO:

The current manual system involves substantial operational expenses printing tickets, maintaining paper records, and employing additional staff to manage documentation and communication. These costs accumulate and reduce the financial efficiency and sustainability of the organization.

Storage Costs

Storing physical documents and maintaining archival rooms adds to TRANSCO's facility and security costs, representing an inefficient allocation of resources that could be better invested in technology and infrastructure upgrades.

Control

The manual system lacks proper controls to secure important operational data. Physical documents are vulnerable to unauthorized access, theft, and deterioration, making it difficult to enforce data security policies or demonstrate compliance with transport regulations. This exposes TRANSCO to legal and reputational risks, particularly in the handling of financial and passenger records.

Efficiency

The manual nature of TRANSCO's operations results in operational bottlenecks, duplicative efforts, and poor resource utilization. Staff must repeatedly perform time-consuming tasks that could be automated, such as route scheduling, fare calculations, and reporting. These inefficiencies reduce the organization's agility and limit its ability to scale services to meet increasing commuter demand.

Service

The slow and fragmented nature of service delivery leads to negative commuter experiences. Delays, lack of information, and inconsistent service quality affect passenger trust and loyalty. Dissatisfied passengers may turn to informal or private transport alternatives, reducing TRANSCO's market share and undermining its public image as a reliable mass transit provider.

Proposed Solutions

To address the operational inefficiencies, service delays, and data management challenges currently faced by TRANSCO, the following digital solutions are proposed:

- **Centralized Transport Management System**

A centralized digital platform will be implemented to manage TRANSCO's core operations, including scheduling, ticketing, fleet tracking, and reporting. This will ensure that all activities are synchronized, improve coordination among departments, and provide real-time oversight of daily operations. Passengers, drivers, and administrators will interact with the system through dedicated portals or apps, ensuring streamlined workflows.

- **Digital Ticketing and Payment Integration**

The system will enable digital ticket purchases via mobile apps, smart cards, and online platforms. This will eliminate long queues at ticket counters and allow passengers to book in advance or on-the-go. Integration with mobile money and bank payments will offer flexibility and convenience, enhancing the commuter experience while reducing manual cash handling.

- **Real-Time Communication and Notifications**

The platform will include automated communication tools, such as SMS, push notifications, and in-app alerts, to keep passengers informed of delays, route changes, or bus arrivals. Internal communication among staff, especially in dispatch and maintenance, will also be enhanced through instant messaging and notification modules.

● **Automation of Operational Workflows**

Key tasks such as route assignment, driver scheduling, fare calculation, and maintenance tracking will be automated to reduce manual workload and human error. These features will allow operational staff to focus on strategic planning and service optimization.

● **Secure and Digital Record Management**

TRANSCO's passenger, ticketing, vehicle, and employee records will be digitized and stored securely in an encrypted database. Access control mechanisms and audit logs will be implemented to protect sensitive data, ensure regulatory compliance, and simplify retrieval of information when needed.

● **Machine Learning-Based Passenger Support**

A machine learning-driven support system will be introduced to assist passengers in real time by learning from frequently asked questions, commuter patterns, and common issues. Over time, this system will improve its responses, offering personalized route suggestions, fare information, and service updates. It will also help reduce the workload on customer service staff and enhance overall passenger experience.

System Requirements

Functional Requirements

Passenger

- **REQ 1:** The passenger shall be able to register and create an account.
- **REQ 2:** The passenger shall be able to log in and log out securely.
- **REQ 3:** The passenger shall be able to search for and view available transportation schedules.
- **REQ 4:** The passenger shall be able to book tickets and receive confirmation (seat number, departure time, parking details).
- **REQ 5:** The passenger shall be able to view their ticket history and upcoming trips.

- **REQ 6:** The passenger shall be able to cancel bookings and receive appropriate updates.
- **REQ 7:** The passenger shall be able to receive real-time notifications related to their booked trips.
- **REQ 8:** The passenger shall be able to rate drivers and provide feedback on the service.

Driver

- **REQ 9:** The driver shall be able to log in and log out securely.
- **REQ 10:** The driver shall be able to view assigned routes and scheduled trips.
- **REQ 11:** The driver shall be able to update the status of trips (started, completed, delayed).
- **REQ 12:** The driver shall be able to view passenger manifest and trip details.
- **REQ 13:** The driver shall be able to report issues or request assistance from the admin.

Technician

- **REQ 14:** The technician shall be able to log in and log out securely.
- **REQ 15:** The technician shall be able to view and manage maintenance schedules for vehicles and equipment.
- **REQ 16:** The technician shall be able to update the status of maintenance tasks (pending, in progress, completed).
- **REQ 17:** The technician shall be able to report faults, breakdowns, or urgent repair needs.
- **REQ 18:** The technician shall be able to access and update equipment history and maintenance records.
- **REQ 19:** The technician shall be able to receive notifications for upcoming or overdue maintenance tasks.

Admin

- **REQ 20:** The admin shall be able to manage user accounts for all roles.
- **REQ 21:** The admin shall be able to define and update transportation routes, schedules, and pricing.
- **REQ 22:** The admin shall be able to assign drivers to specific routes and manage schedules.
- **REQ 23:** The admin shall be able to generate and view operational reports.
- **REQ 24:** The admin shall be able to handle customer support requests.

- **REQ 25:** The admin shall be able to manage system settings and compliance.
- **REQ 36:** The admin shall be able to run and visualize 3D simulations of routes, vehicle flows, and terminal layouts**.**

Analyst

- **REQ 26:** The analyst shall be able to access anonymized operational data.
- **REQ 27:** The analyst shall be able to run demand forecasts, route optimizations, and performance reports.
- **REQ 28:** The analyst shall be able to export reports in multiple formats (PDF, Excel).
- **REQ 29:** The analyst shall be able to monitor KPIs such as peak demand and delays.
- **REQ 30:** The analyst shall be able to integrate machine learning models for predictions.
- **REQ 37:** The analyst shall be able to run predictive analytics (demand prediction, maintenance prediction, ridership forecasts) and visualize results.

Non-Functional Requirements

1. **Security**
    - **NFR 1:** The system shall ensure confidentiality and integrity of user data through encryption and secure authentication protocols.
2. **Performance**
    - **NFR 2:** The system shall respond to user actions within 3 seconds under normal conditions.
3. **Scalability**
    - **NFR 3:** The system shall scale to support increased user traffic and data without performance degradation.
4. **Usability**
    - **NFR 4:** The system shall provide an intuitive and user-friendly interface for all roles.
5. **Accessibility**

    - **NFR 5:** The system shall be accessible to users with disabilities, conforming to WCAG 2.1 standards.
6. **Reliability**
    - **NFR 6:** The system shall have an uptime of at least 99.5% with backups and failover support.
7. **Compatibility**
    - **NFR 7:** The system shall be compatible with major browsers and mobile devices (Android, iOS).
8. **Maintainability**
    - **NFR 8:** The system should be modular and well-documented for easy updates.
9. **Compute & Visualization Performance**
    - **NFR 9:** The system shall provide sufficient compute power (including GPU acceleration) to support 3D simulations and predictive analytics without degrading real-time performance.

CHAPTER 3

REQUIREMENTS ANALYSIS AND DESIGN OF THE NEW SYSTEM

Introduction

This chapter presents the pivotal phases in the development of the **Intelligent Mobility Assistance System (IMAS)**, which is designed to improve urban transportation by enhancing coordination between passengers, drivers, and administrators. The objective of these phases is to ensure the system meets user expectations through a clear understanding of their needs and the careful design of system components.

Requirements Analysis involves identifying the functional and non-functional needs of the system through in-depth stakeholder engagement. These insights help in defining the system's objectives, scope, and expected behavior. For IMAS, this phase focused on understanding the needs of three primary user roles **Passengers**, **Drivers**, and **Administrators**, to facilitate safe, timely, and reliable mobility.

System Design translates these requirements into a structured blueprint, covering the architecture, user interface design, database structures, and component interactions. It ensures that the final implementation will be robust, scalable, secure, and user-friendly.

According to Geeks (2023), these phases form the backbone of the **Software Development Life Cycle (SDLC)** by minimizing development risks and ensuring the delivery of quality solutions. In IMAS, this process supports the development of an efficient transport system that improves urban mobility, passenger experience, driver coordination, and administrative management.

UML Design of the New System

Unified Modeling Language (UML) stands as a standardized and widely recognized visual modeling language that holds a significant role in the realms of software engineering and systems analysis. With its structured notation and comprehensive set of symbols, UML serves as a common language for communication, documentation, and design within the software development process.

UML is a general-purpose visual modeling language that provides a standard way to visualize the design of a system. It helps in modeling software applications and information systems, allowing for clear communication among stakeholders, including developers, business analysts, and non-technical team members (Definition, 2024)

UML provides a systematic way to represent complex systems, helping stakeholders visualize and understand intricate relationships, interactions, and structures that are integral to software projects. Through its various diagrams and notations, UML enables software engineers, architects, and analysts to convey design concepts, system functionalities, and user interactions in a clear and concise manner. (James, 2023)

This standardized approach offered by UML promotes effective communication and collaboration among multidisciplinary teams, bridging the gap between technical experts, business analysts, and other stakeholders. As a result, UML facilitates the translation of abstract ideas and requirements into tangible software solutions, reducing ambiguity and enhancing the accuracy of system design.

In the context of systems analysis, UML proves invaluable in capturing the intricacies of user requirements and system behaviors. By employing a set of diagrams such as use case diagrams, sequence diagrams, and activity diagrams, UML aids analysts in comprehending the flow of processes, identifying potential bottlenecks, and ensuring that the proposed system aligns with user expectations.

Types of UML Diagrams

UML encompasses various types of diagrams categorized into two main groups **structural diagrams** and **behavioral diagrams**. Each type serves distinct purposes in modeling different aspects of systems.

Structural Diagrams

These diagrams illustrate the static aspects of a system's architecture:

1. **Class Diagram**:
   - The most commonly used diagram in UML that represents classes within a system along with their attributes and methods. It shows relationships between classes

through associations, generalizations, or dependencies (Booch, G., Jacobson, I., & Rumbaugh, J., 2005).

2. **Object Diagram**:
   - Similar to class diagrams but focuses on instances of classes at a specific moment in time. They help visualize real-world examples of data structures (Jacobson, I., Booch, G., & Rumbaugh, J., 1999).
3. **Component Diagram**:
   - Displays how components are organized within a system. It shows interfaces provided by components and their dependencies.
4. **Deployment Diagram**:
   - Illustrates the physical deployment of artifacts on hardware nodes. It shows how software components are distributed across different machines (Fowler, 2000).
5. **Package Diagram**:
   - Organizes classes into packages to manage complexity. It shows dependencies between packages to clarify relationships within large systems (Harel, D., & Rumpe, B., 2004).
6. **Composite Structure Diagram**:
   - Represents the internal structure of a class or component. It shows how parts collaborate within a whole (Group), 2017).

Behavioral Diagrams

These diagrams depict dynamic aspects of system behavior:

1. **Use Case Diagram**:
   - Captures functional requirements by illustrating actors (users or other systems) interacting with use cases (system functionalities). It provides an overview of user interactions with the system (Cockburn, 2001).
2. **Sequence Diagram**:
   - Shows how objects interact over time through messages exchanged between them in a specific sequence. This diagram is useful for detailing specific scenarios or workflows (Booch, G., Jacobson, I., & Rumbaugh, J., 2005).
3. **Activity Diagram**:

- Represents workflows or processes within a system. It illustrates actions taken in response to events and decision points along with parallel processes.

4. **State Machine Diagram**:
   - Describes states an object can be in and transitions between those states based on events or conditions. This diagram is useful for modeling reactive systems where behavior changes based on internal or external events.
5. **Communication Diagram**:
   - Focuses on how objects communicate by showing messages passed between them while emphasizing their relationships rather than the order of interactions.
6. **Timing Diagram**:
   - Similar to sequence diagrams but emphasizes timing constraints on interactions between objects over time.
7. **Interaction Overview Diagram**:
   - Provides an overview of control flow among interactions within the system by combining elements from various interaction diagrams (Harel, D., & Rumpe, B., 2004).

In summary, Unified Modeling Language (UML) is an essential tool for software engineers that facilitates the visualization and documentation of complex systems through its diverse set of diagrams. By providing standardized notations across structural and behavioral aspects of software design, UML enhances communication among stakeholders while improving overall project quality through clear documentation and visualization techniques. Its versatility allows it to be applied not only in software development but also in business process modeling, making it a valuable asset across multiple domains. However, it's important to note that not all UML diagrams are necessary for every project, especially in a research context. For this research case, only selected diagrams relevant to the specific objectives and scope will be utilized. This approach allows for focused and efficient documentation while capturing essential aspects of the system without overcomplicating the process.

Use-Case Diagram

A case diagram is a type of Unified Modeling Language (UML) diagram that represents the interaction between actors (users or external systems) and a system to accomplish specific goals.

It provides a high-level view of the system's functionality by illustrating the various ways users can interact with it.

Elements

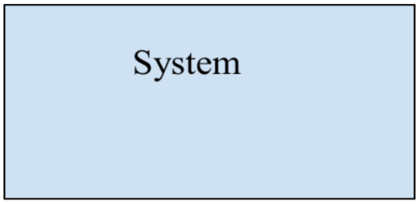
- **case**: constituting a distilled rendition of a segment of a business process model, a use case encapsulates a collection of actions nested within a system. The portrayal of a use case materializes through the lens of the corresponding actors, specifically those entities that engage with the system. It is represented as follows:

  Use case

- **Actor:** In the realm of system modeling, an actor embodies a distinct function undertaken by an external entity while engaging directly with the system. This external entity might personify a user or an alternative system that interfaces with the system under consideration. Actors find manifestation within the system model, elucidating their engagement and impact. They hold a pivotal function in delineating the system's limits and extent, while also discerning the diverse interconnections and obligations attributed to each role. In visual depictions, actors take form through designated symbols or icons, serving to facilitate the lucid and instinctive communication of their participation and role in the system.

  Actor

- **System boundary:** Within the realm of use case modeling, the concept of a system boundary takes on the role of a visual representation that outlines the scope or confines of the system under scrutiny. When observing a use case diagram, the system boundary takes the form of a rectangular enclosure, enveloping the internal mechanisms and functionalities intrinsic to the system. Conversely, actors exist as entities external to the system, finding their position outside this boundary. They embody the various roles or entities that engage with the system, steering it toward specific tasks or objectives. The graphical portrayal of the system boundary and actors within a use case diagram facilitates a clear differentiation between the system's internal constituents and the external entities implicated in the system's activities and operational essence. It is represented as follows:



Relationship between Use Cases

- “**Extend**” relationship: «extend» An extended Use Case finds its purpose in elucidating deviations from the typical sequence of events expounded by a comprehensive use case. The scenario of Use Case B extends itself from the narrative of Use Case A, manifesting when the behavior of Use Case A takes on a specific disposition within a certain circumstance.

  - - - - - - - - <<extend>> - - - - - - - - - - >

- “**Include**” relationship: «include». Use Case A encompasses Use Case B when the functionality embodied by Use Case B becomes essential to the operation of Use Case A. This particular behavior has been abstracted into its distinct Use Case to facilitate its reuse across multiple use cases.

  - - - - - - - - <<include>> - - - - - - - - - - >

➢ "**Association**" relationship is a bridge connecting an actor and a use case, establishing their interaction. This linkage is symbolized by a line that links an actor and a use case. This association goes beyond a mere visual representation on a diagram; it embodies the very essence of how actors and use cases collaborate within the system's operations. The linking line symbolizes a conduit through which information, actions, and interactions flow between the actor and the use case, establishing a seamless flow of communication and functionality.

Use-Case Diagram

IMAS System

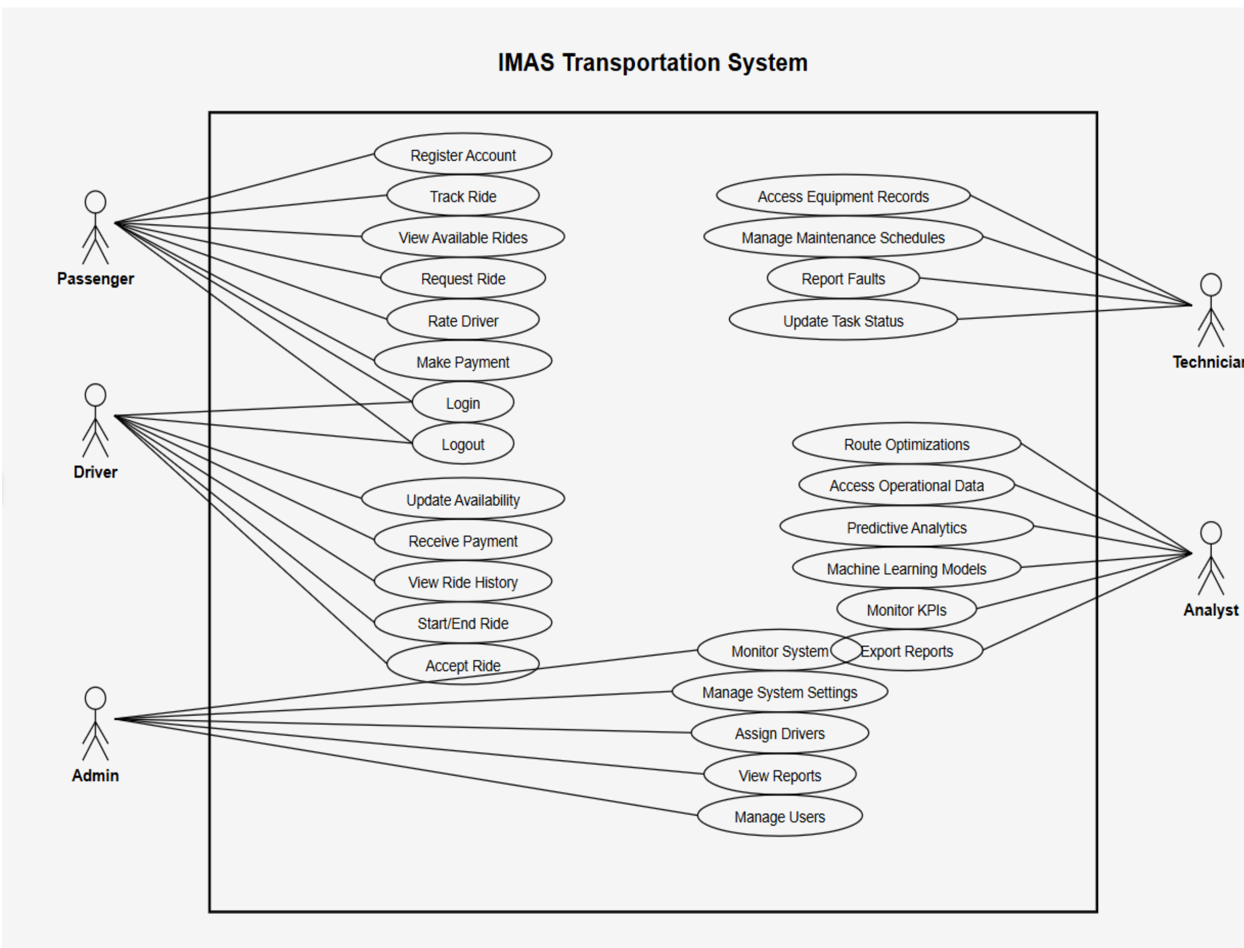


Figure 2: Use case of the current the new system

Use Case Description

Name:

Create User Account

Actor(s):

Admin (HR Professional)

Description:

The admin creates user accounts for new users (Passengers or Drivers) by entering their details and assigning roles within the IMAS system.

Pre-condition:

The admin must be logged into the IMAS system.

Post-condition:

A new user account (Passenger or Driver) is successfully created and stored in the system.

Normal Flow:

1. Admin logs into the IMAS system.
2. Admin navigates to the user account management section.
3. Admin selects the option to create a new user account.
4. Admin enters user details (name, email, phone number, role ; Passenger or Driver, etc.).
5. The system validates the details entered.
6. System creates the new user account and saves it.

7. The system displays a confirmation message indicating successful account creation.

Alternative Flow:

- If the entered details are invalid or incomplete, the system displays an error message.
- Admin corrects the information and resubmits the form.
- If the system encounters an internal error, it notifies the admin and prompts them to retry later.

Analysis of the new system

Element	**Description**
Name	Create User Account
Actor(s)	Passenger
Description	A Passenger creates an account to access the Intelligent Mobility Assistance System.
Pre-condition	The Passenger is on the registration page of the system.
Post-condition	A new user account is successfully created and stored in the system.
Normal Flow	1. The Passenger accesses the registration page. 2. The Passenger fills in personal details (name, email, phone number, password, etc.). 3. The Passenger submits the form. 4. The system validates the information. 5. The system creates the user account and redirects the user to the login or dashboard page.
Alternative Flow	1. If any field is missing or invalid, the system displays an error message. 2. The Passenger corrects the input and resubmits the form.

Table 1: Passenger signup/ Account Creation

Element	**Description**
Name	Log In

Actor(s)	Passenger, Driver, Admin
Description	The system allows users (Passenger, Driver, and Admin) to log in to access their respective dashboards and functionalities.
Pre-condition	The user must already be registered in the system.
Post-condition	The user is successfully logged in and redirected to their specific dashboard based on their role.
Normal Flow	1. The user navigates to the login page. 2. The system prompts for credentials (email, password, role). 3. The user enters their credentials. 4. The system validates the credentials. 5. The user is logged in and redirected to the appropriate dashboard (Passenger, Driver, or Admin).
Alternative Flow	1. If the credentials are incorrect, the system displays an error message. 2. The user may retry login or reset their password.

Table 2: Login Use case

Element	**Description**
Name	Accept Ride
Actor(s)	Driver
Description	The driver accepts a ride request sent by a passenger.
Pre-condition	The driver is logged into the system and is marked as available.
Post-condition	The ride is assigned to the driver and passenger is notified.
Normal flow	● The system sends a ride request to nearby drivers. ● The driver reviews the ride details. ● The driver clicks "Accept Ride".

	● The system assigns the ride to the driver.
Alternative flow	
	● If the driver rejects or ignores the request, it is sent to the next driver.

Table 3: Accept Ride

Element	**Description**
Name	Start/End Ride
Actor(s)	Driver
Description	The driver starts and ends the trip for a confirmed ride.
Pre-condition	The ride has been accepted by the driver.
Post-condition	The trip status is updated and recorded.
Normal flow	
	● The driver clicks "Start Ride".
	● System updates ride status to "In Progress".
	● On arrival, the driver clicks "End Ride".
	● System updates ride status to "Completed".
Alternative flow	
	● If GPS is not active, the system may prevent ride start.

Table 4: Start/End Ride

Class Diagrams

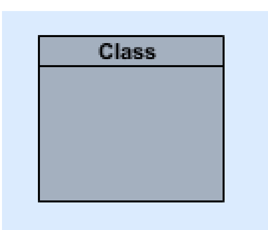
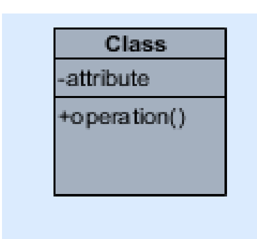
Class diagrams are foundational components of Unified Modeling Language (UML), a standardized visual modeling language used in software engineering to depict the structure of systems. Class diagrams provide a static view of a system, illustrating the various classes within the system, their attributes, methods, and relationships with other classes.

At their core, class diagrams represent the building blocks of object-oriented programming, serving as blueprints for designing and understanding software systems. Each class in a diagram encapsulates a set of related attributes and behaviors, defining the properties and functionality of objects within the system.

In a class diagram, classes are represented as rectangles, with the class name positioned at the top, followed by compartments for attributes (data members) and methods (member functions). Arrows connecting classes indicate associations or relationships, showcasing how classes interact and collaborate within the system.

Overall, class diagrams serve as powerful visual tools for software architects, designers, and developers to conceptualize, communicate, and refine the structure of complex software systems, fostering a deeper understanding of system architecture and facilitating effective collaboration among stakeholders.

Class diagram tools description

Symbols	Description
	Classes represent an abstraction of entities with common characteristics.
	Active classes initiate and control the flow of activity while passive classes store data and serve other classes.

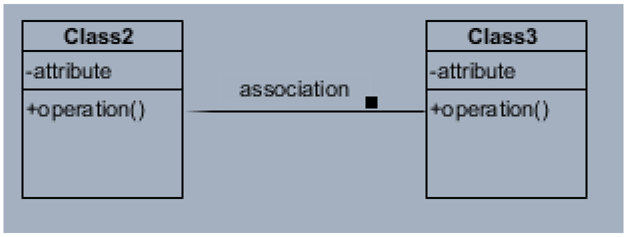
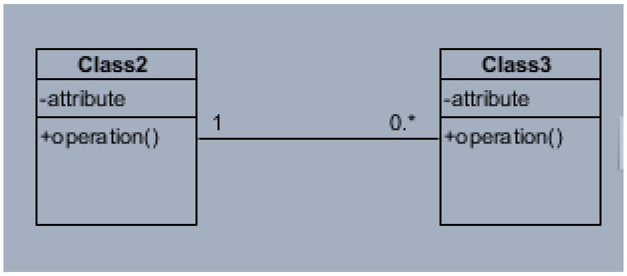
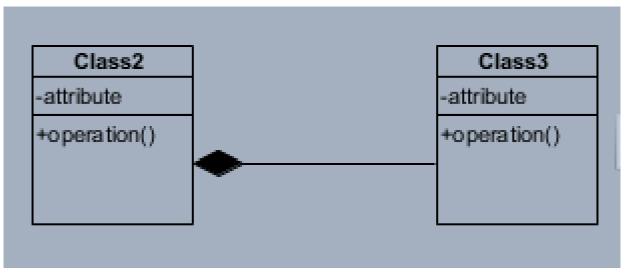
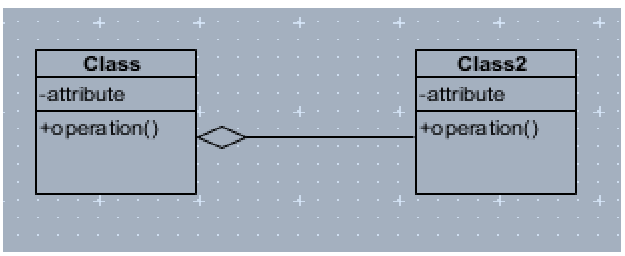
	Associations represent static relationships between classes.
	Multiplicity notations near the ends of an association. These symbols indicate the number of instances of one class linked to one instance of the other class.
	Decomposition is a restricted form of aggregation in which two entities are dependent on each other.
	Aggregation is a unidirectional relationship between classes. You can call it a has a or is part of a relationship.

Table 5 Class diagram tools Description

CLASS DIAGRAM

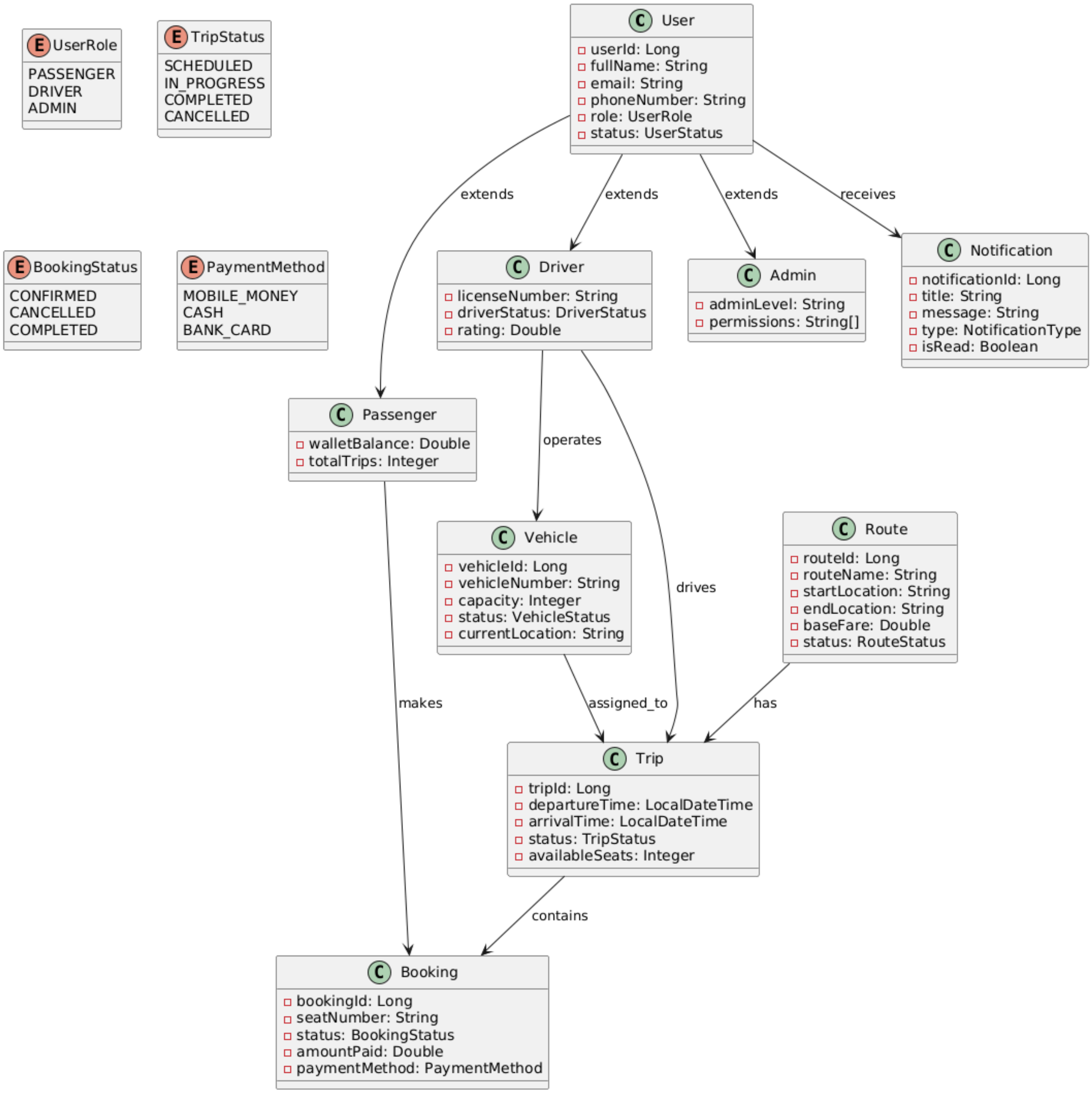
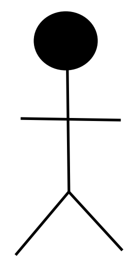
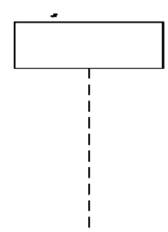


Figure 3: Class Diagram

Sequence Diagrams

Sequence diagrams are essential tools in software engineering for illustrating the dynamic interactions between various components or objects within a system. They provide a chronological representation of how objects communicate and collaborate to achieve specific tasks or scenarios during runtime. Key elements of sequence diagrams include objects, which represent instances involved in the interaction, messages indicating communication between objects, and activation boxes denoting periods of active processing. Sequence diagrams offer valuable insights into system behavior, aiding in identifying communication patterns, potential bottlenecks, and validating system design. As effective communication tools, sequence diagrams facilitate clearer visualization and discussion of system interactions and behaviors among stakeholders.

Term and definition	**Symbol**
An actor: • It can be a person or system that derives benefit from and is external to the system. • It participates in a sequence by sending and/or receiving messages. • It is placed across the top of the diagram.	Actor 
An object lifeline: • It participates in a sequence by sending and/or receiving messages. • It is placed across the top of the diagram.	
An activation: • It is a long narrow rectangle placed on top of a lifeline. • It denotes when an object is sending or receiving messages	

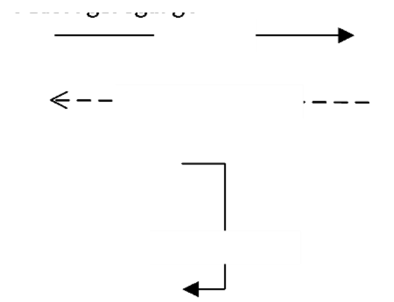
A message: • It conveys information from one object to another one. • An operation call is labelled with the message being sent and a solid arrow, whereas a return is labelled with the value being returned and shown as a dashed arrow.	

Table 6 Sequence diagram definition

Create User Account (Admin Perspective)

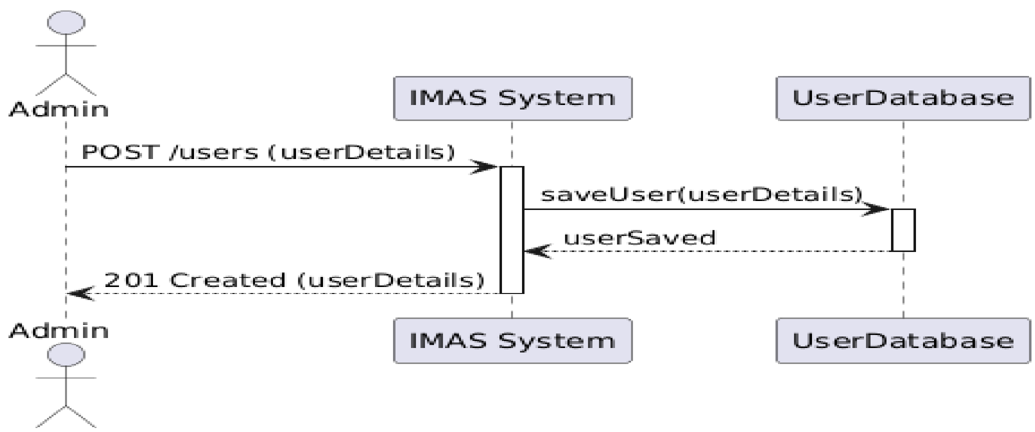


Figure 4: Register sequence diagram

This sequence outlines how users authenticate in the Intelligent Mobility Assistance System (IMAS) onboarding process by entering their credentials, which are then validated against stored user data, as part of the system developed for TRANSCO in Kinshasa.

- The sequence starts when the user (Passenger, Driver, or Admin) interacts with the IMAS mobile app or web browser. At this point, the user is prompted to input their credentials (email, password, role), initiating the authentication process to access IMAS functionalities like trip booking or route management.
- A key focus of the sequence diagram is the detailed authentication process. It showcases how the entered credentials are processed by the IMAS backend server and its authentication middleware. The diagram captures the interactions between the mobile app/web browser, the backend server, the authentication middleware, the user model, and

the IMAS database to verify credential validity. The user's credentials are checked against the stored data in the User Table of the database, and the outcome determines whether the user is granted access to their respective dashboard or receives an error message for invalid credentials.

Create User Account (Passenger Perspective)

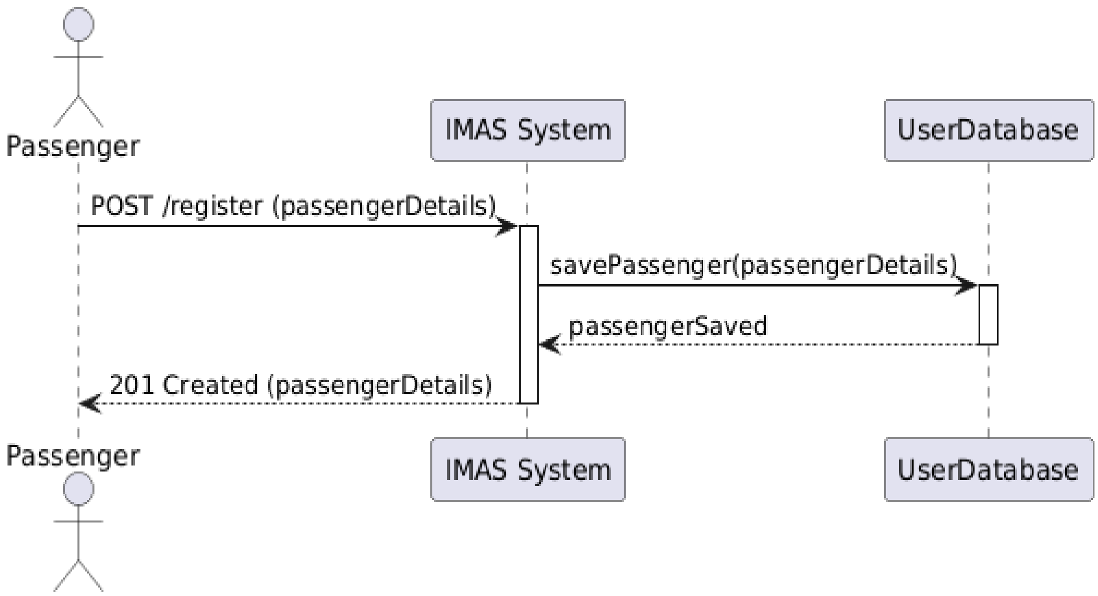


Figure 5: Register sequence diagram (2)

- This is a sequence of how a Passenger registers in the Intelligent Mobility Assistance System (IMAS) by submitting their details through the mobile app or web browser.
- The sequence begins with the Passenger interacting with the IMAS mobile app or web browser. At this stage, the Passenger submits their details (e.g., name, email, phone number) via a POST request to register, initiating the process to create a new account.
- The central focus of the sequence diagram is the registration of the Passenger. This step demonstrates how the request is processed by the IMAS System, which interacts with the UserDatabase to save the passenger details. The diagram elegantly captures the interaction between the mobile app/web browser, the IMAS System, and the UserDatabase. The passenger details are saved in the database, and a passengerSaved confirmation is returned to the IMAS System, which then responds to the browser with a 201 Created message

including the passenger details. Finally, the registration confirmation is displayed to the Passenger.

Login

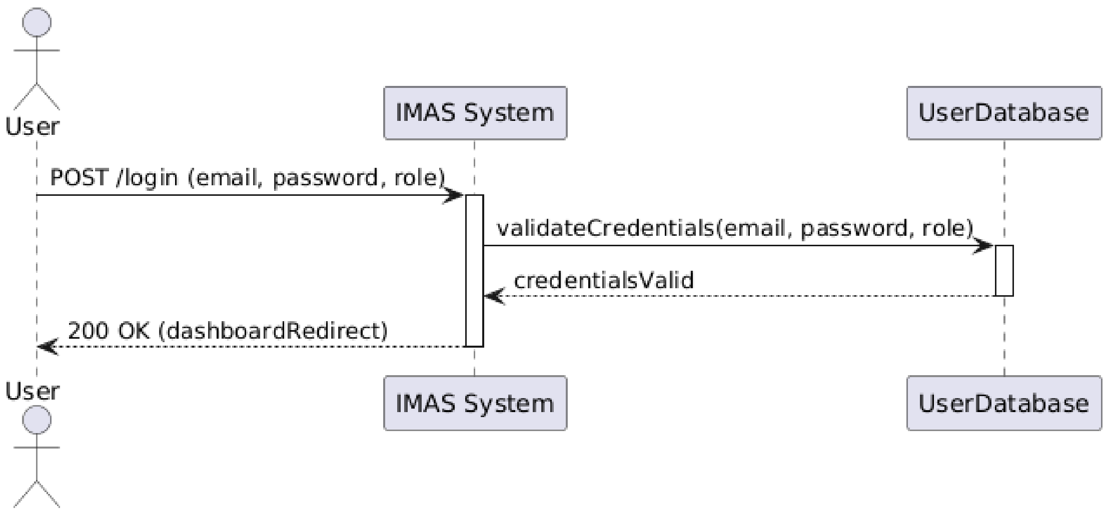


Figure 6: Login sequence diagram

- This is a sequence of how a user (Passenger, Driver, or Admin) logs into the Intelligent Mobility Assistance System (IMAS) to access their respective functionalities.
- The sequence begins with the user interacting with the IMAS mobile app or web browser, where they initiate the login process by submitting their credentials (email, password, role) through the interface.
- The sequence diagram focuses on the login process. After the user submits their credentials, the mobile app/web browser sends a POST request to the IMAS System. The IMAS System then interacts with the UserDatabase to validate the credentials by querying the stored user data. The UserDatabase confirms whether the credentials are valid, returning the result to the IMAS System. If successful, the IMAS System responds to the mobile app/web browser with a 200 OK status, indicating that the login was successful. Finally, the mobile app/web browser redirects the user to their respective dashboard, confirming the successful login to the user.

Accept Ride

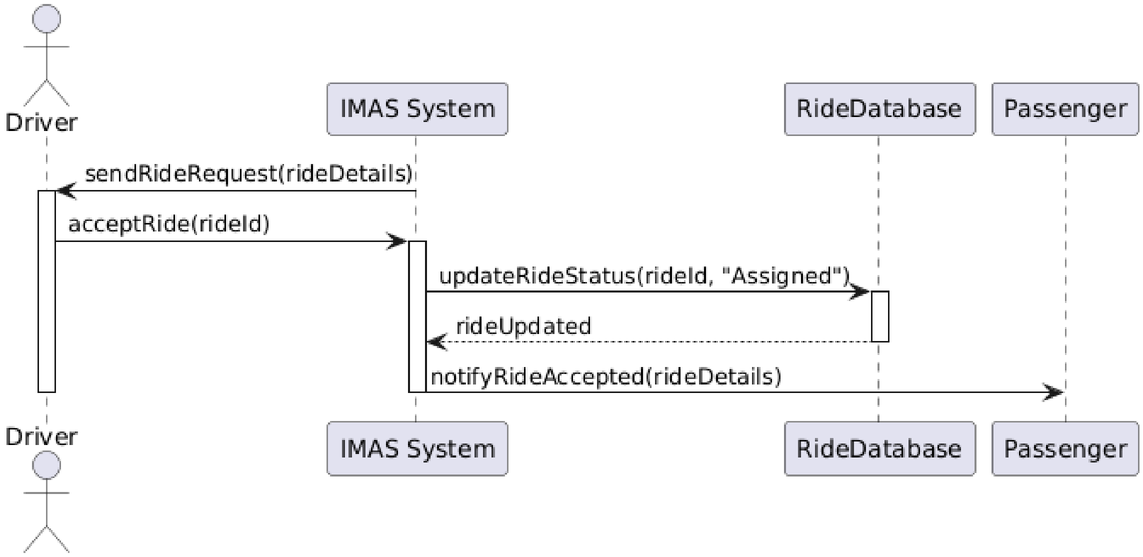


Figure 7: Accept Ride sequence diagram

- This is a sequence of how a Driver requests and accepts a ride within the Intelligent Mobility Assistance System (IMAS) for TRANSCO in Kinshasa.
- The sequence begins with the Driver interacting with the IMAS mobile app or web browser, where they initiate the process by sending a ride request with ride details.
- The sequence diagram focuses on the ride acceptance process. The mobile app/web browser sends a sendRideRequest(rideDetails) request to the IMAS System, which then processes it by sending an acceptRide(rideId) message to itself. The IMAS System interacts with the RideDatabase to updateRideStatus(rideId, "Assigned"), updating the ride status. The RideDatabase returns a rideUpdated confirmation to the IMAS System, which then sends a notifyRideAccepted(rideDetails) message to the Passenger. Finally, the IMAS System confirms the acceptance to the Driver, completing the process.

Start/End Ride

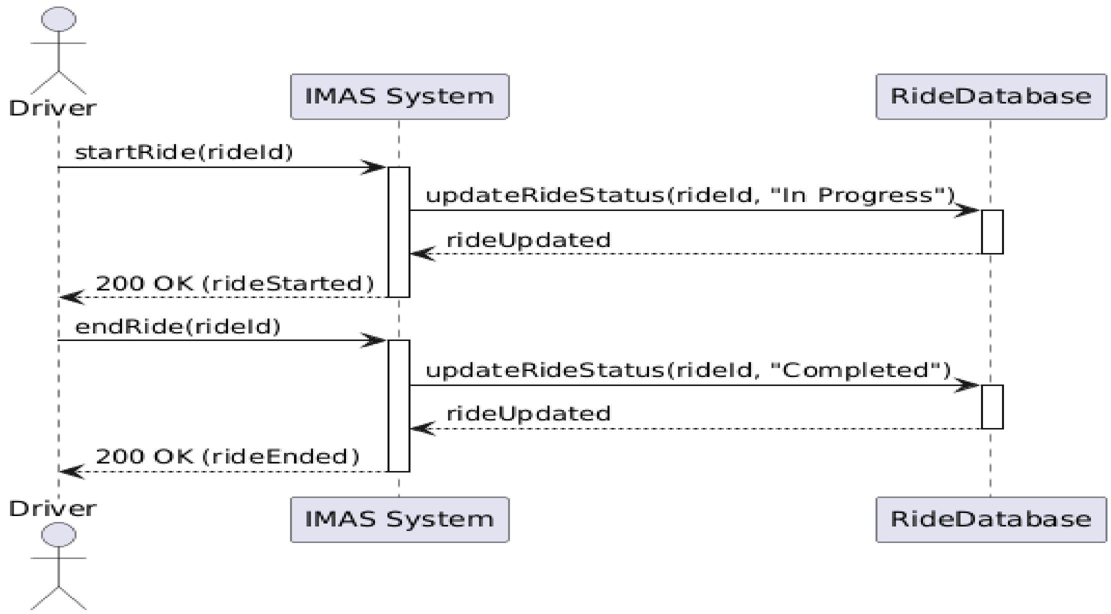


Figure 8: Start/End sequence diagram

The sequence diagram shows a Driver starting and ending a trip in the IMAS for TRANSCO. The Driver sends a `startRide(rideId)` request to the IMAS System, which updates the RideDatabase to "In Progress" and confirms with a 200 OK. At trip's end, the Driver sends `endRide(rideId)`, the IMAS System updates the status to "Completed," confirms with the database, and responds with a 200 OK, ensuring real-time trip tracking.

Activity Diagram

Within the realm of UML, the activity diagram serves as a key tool for depicting the dynamic aspects of the Intelligent Mobility Assistance System (IMAS). Essentially, an activity diagram functions as a flowchart, visually representing the progression of activities within IMAS, such as passenger trip bookings, driver route management, and admin oversight of TRANSCO (Transport au Congo) operations in Kinshasa. Each activity mirrors an operational function performed by the system, with the flow of control moving from one task to the next whether sequentially, through decision branches, or concurrently. Activity diagrams effectively manage diverse flow control scenarios, utilizing components like forks for parallel tasks (e.g., real-time tracking and notifications) and joins to consolidate outcomes.

The primary purposes of activity diagrams in the context of IMAS include:

- **Modeling Business Processes**: They are employed to visualize TRANSCO's workflows, such as ticket validation and fleet scheduling, helping stakeholders understand task execution and interdependencies.
- **Detailing Use Cases**: Activity diagrams illustrate the step-by-step interactions, such as a passenger booking a trip or an admin assigning drivers, providing clarity on user-system engagement.
- **Visualizing Control Flow**: They map the sequence of operations and decisions, like route updates or maintenance scheduling, guiding how processes unfold within IMAS.

Benefits of Activity Diagrams for IMAS:

- **Clear Visualization of Workflow**: They offer a straightforward visual representation of each step, such as GPS tracking or digital payment processing, making the system's operations easy to grasp.
- **Effective Communication**: They bridge the gap between technical developers and non-technical TRANSCO staff or passengers, ensuring workflows are interpretable across roles.
- **Identification of Bottlenecks**: By mapping activities, stakeholders can pinpoint inefficiencies, such as manual ticketing delays, and target areas for improvement.
- **Parallel Process Representation**: Activity diagrams excel at showing simultaneous tasks, like real-time notifications and trip status updates, along with their dependencies.

Activity diagrams are powerful tools within UML that provide clear visual representations of workflows and processes for IMAS. By illustrating the sequence of actions and decision points, they help stakeholders understand complex interactions within the system, making them invaluable for developing and refining this smart transportation solution aimed at transforming public transport in Kinshasa.

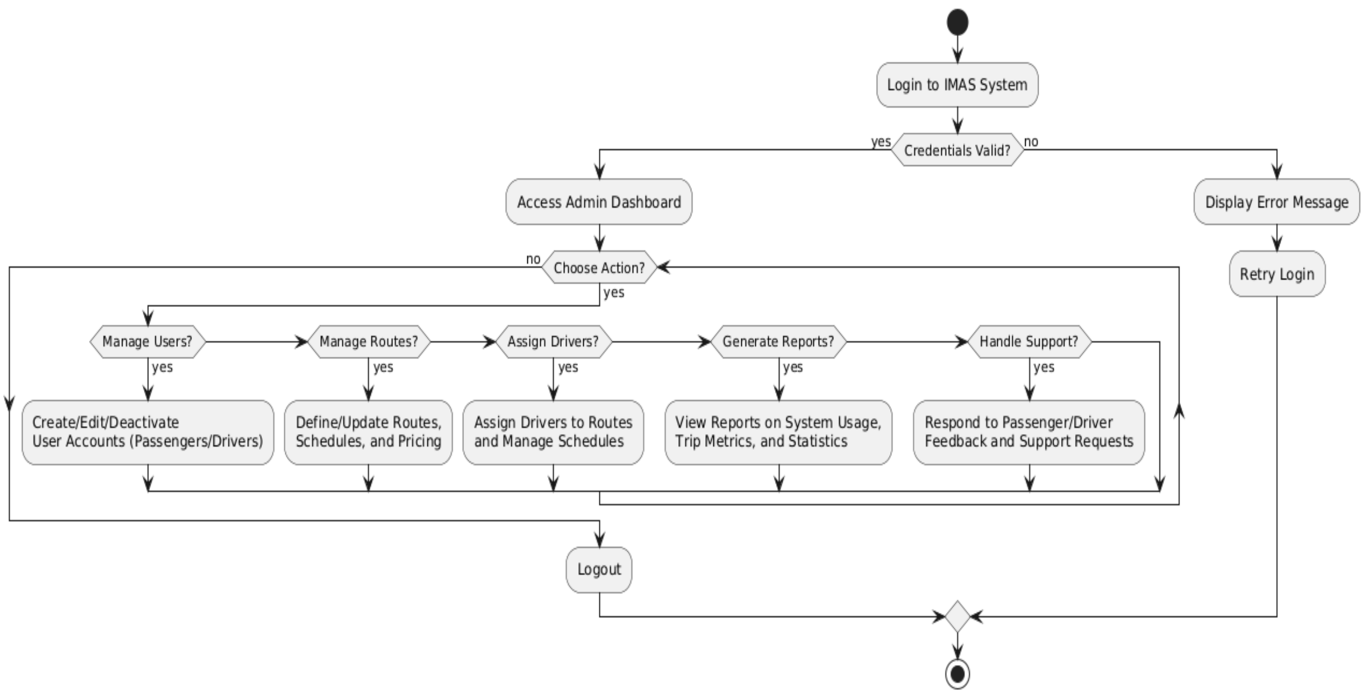


Figure 9: Admin activity diagram

This diagram shows the workflow for a Mass Transit System (MTS) administrative interface, starting with user login and credential validation.

After successful login, users access an Admin Dashboard with five core administrative functions: Manage Users, Manage Routes, Assign Drivers, Generate Reports, and Handle Support.

The system allows administrators to create, edit, and deactivate user accounts while managing both passenger and driver profiles. Route management includes defining routes, updating schedules, and setting pricing.

Driver assignment functionality helps allocate drivers to specific routes and manage their schedules. The reporting feature provides system usage statistics and trip metrics, while support handling addresses passenger and driver feedback.

The workflow includes error handling with retry options and logout functionality, creating a complete administrative cycle for transit system management.

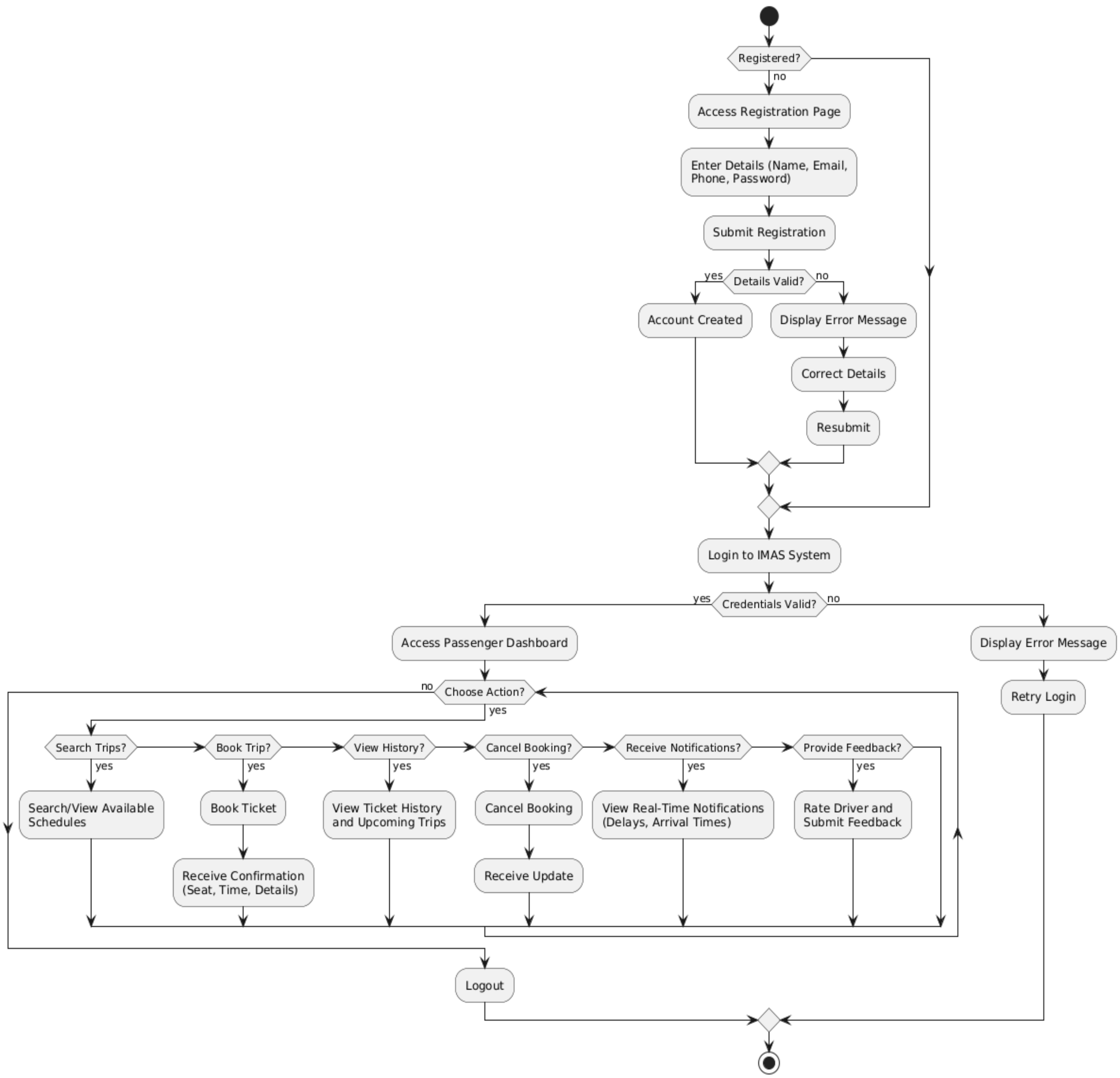


Figure 10: Passenger activity diagram

This activity diagram shows a complete user registration and login workflow for a Mass Transit System. It begins with users checking if they're registered, then accessing a registration page where they enter personal details (name, email, phone, password).

After submitting registration, the system validates the details. If validation fails, users see error messages and can correct their information before resubmitting. Successful validation creates an account and allows users to proceed to login.

Once registered users log into the MAS System with valid credentials, they access a passenger dashboard. Failed login attempts display error messages with retry options.

The main dashboard offers six key services: Search Trips, Book Trips, View History, Cancel Bookings, Receive Notifications, and Provide Feedback. Each function has specific capabilities like searching available schedules, booking tickets, viewing trip history, managing bookings, receiving real-time updates, and rating services.

Each action provides confirmation or updates to users, such as booking confirmations with seat and time details, or real-time notifications about delays and arrivals. The workflow concludes with logout functionality, creating a comprehensive passenger experience from registration through service usage.

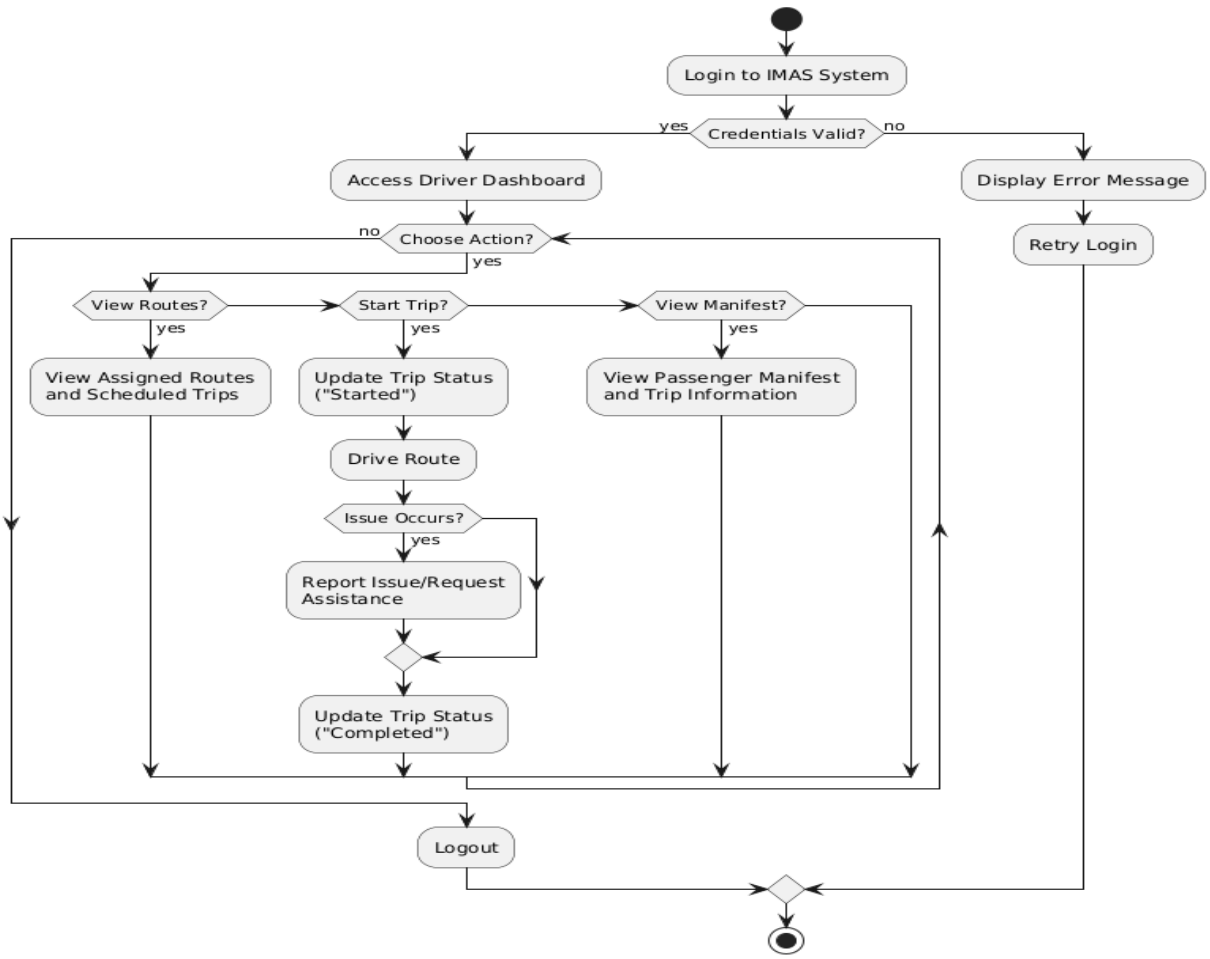


Figure 11: Driver activity diagram

This activity diagram illustrates the workflow for drivers in the Mass Transit System. It starts with driver login using credentials, with failed attempts showing error messages and retry options.

After successful login, drivers access a dedicated Driver Dashboard where they can choose from three main actions: View Routes, Start Trip, and View Manifest.

The "View Routes" function allows drivers to see their assigned routes and scheduled trips, helping them understand their daily assignments and timing requirements.

The "Start Trip" function is the core operational feature where drivers update their trip status to "Started," then drive their assigned route. During the trip, they can handle any issues that arise by reporting problems or requesting assistance when needed.

The "View Manifest" function provides drivers access to passenger manifest and trip information, allowing them to see who is booked on their routes and relevant trip details.

After completing their route, drivers update the trip status to "Completed." The system includes error handling throughout the process, and drivers can logout when their shift is finished. This creates a comprehensive driver workflow from login through trip completion.

Database Diagrams

The database diagram for the Intelligent Mobility Assistance System (IMAS) provides a visual representation of the system's underlying data structure, illustrating the relationships between entities and their attributes. It serves as a critical tool for understanding how data is organized within the IMAS system, supporting the design, development, and maintenance of the database. Through this graphical representation, stakeholders can gain clear insights into the system's data model, ensuring efficient management and operation public transportation services in Kinshasa.

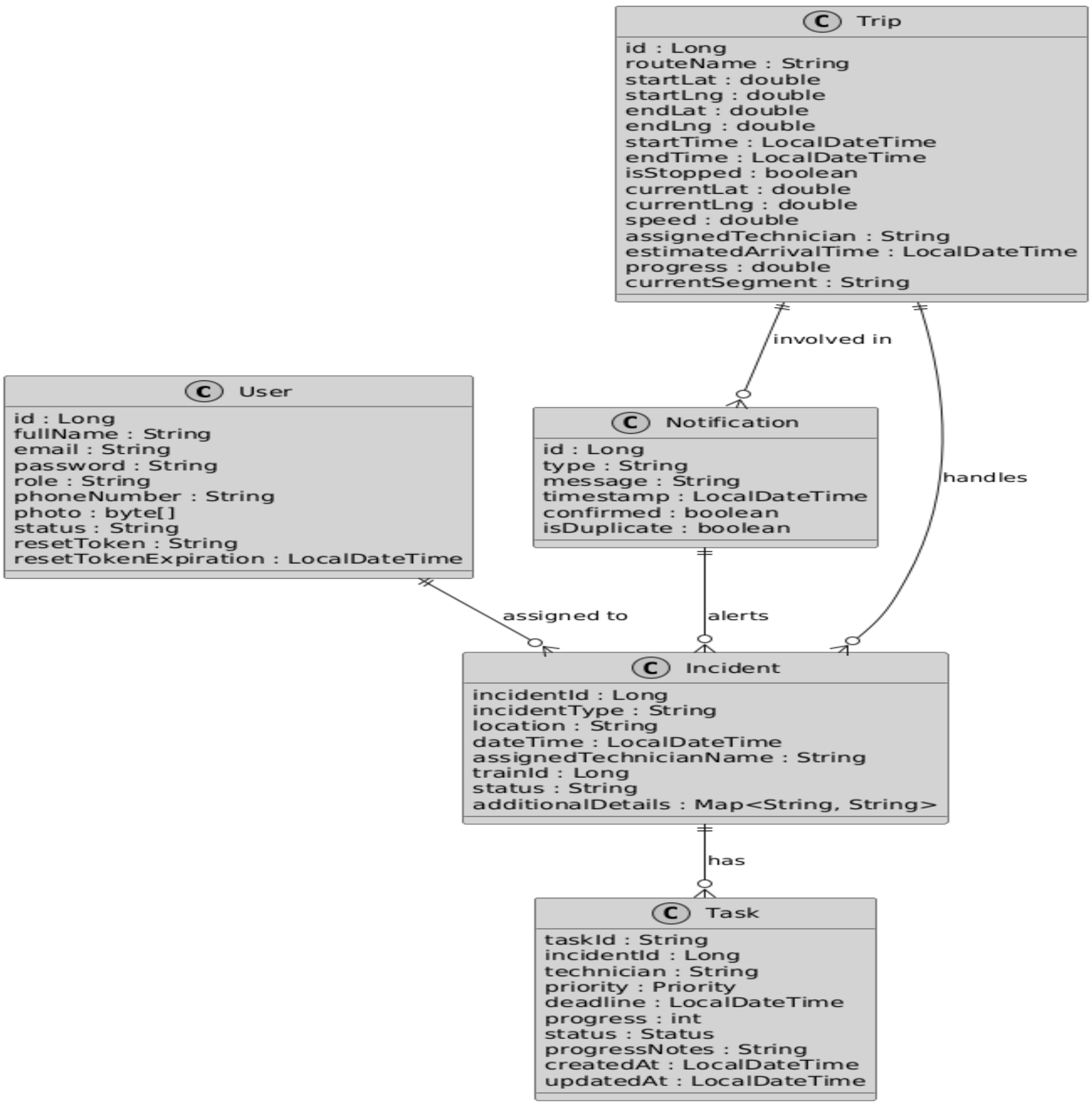


Figure 12: Relationship diagram

Data Dictionary

User Table

Name	Constraints	Data Type
id	PRIMARY KEY, NOT NULL	Long
fullName	NOT NULL	String
email	NOT NULL, UNIQUE	String
password	NOT NULL	String
role	NOT NULL	String
phoneNumber	NOT NULL	String
photo		byte[]
status	NOT NULL	String
resetToken		String
resetTokenExpiration		LocalDateTime

Table 7 User Data Dictionary

Trip Table

Name	Constraints	Data Type
id	PRIMARY KEY, NOT NULL	Long
routeName	NOT NULL	String
startLat	NOT NULL	Double
startLng	NOT NULL	Double
endLat	NOT NULL	Double
endLng	NOT NULL	Double
StartTime	NOT NULL	LocalDateTime
endTime		LocalDateTime
isStopped	NOT NULL	Boolean
currentLat		Double
currentLng		Double
speed		String
assignedTechnician		String
estimatedArrivalTime		LocalDateTime
progress		Double
currentSegement		String

Table 8 Trip Data Dictionary

System Architecture Design for IMAS

System architecture design refers to the comprehensive framework that outlines the structure, components, and interactions of the Intelligent Mobility Assistance System (IMAS), as developed for Transport au Congo (TRANSCO) in Kinshasa. It serves as a blueprint for building this innovative system, ensuring all components work cohesively to address TRANSCO's operational challenges and meet the project's objectives of enhancing public transportation. This design covers aspects such as component organization, their interrelationships, scalability to accommodate Kinshasa's growing urban demand, flexibility for future enhancements, and risk management to ensure reliable service delivery.

Key Aspects of IMAS System Architecture Design

- **Conceptual Blueprint**: The IMAS architecture provides a high-level overview of how components like the mobile app, backend server, and database interact to deliver functionalities such as real-time bus tracking and digital ticketing. It defines the relationships between these elements, ensuring a seamless operational environment for passengers, drivers, and admins.
- **Components and Subsystems**: The architecture includes hardware (e.g., GPS devices on buses) and software components (e.g., mobile/web interfaces, backend server). Subsystems like the notification module, analytics dashboard, and payment gateway are self-contained units that contribute to IMAS's overall functionality, communicating via REST APIs and standardized interfaces.
- **Behavioral Characteristics**: The architecture details how IMAS responds to inputs, such as a passenger booking a trip or a driver updating a trip status. It ensures the system meets performance expectations, like delivering real-time notifications on delays, and adapts to changing conditions, such as traffic disruptions or fleet maintenance needs.
- **Integration and Interoperability**: IMAS's architecture promotes seamless integration with external systems like GPS services for live tracking and payment gateways for digital ticketing. Standardized interfaces and communication protocols enable efficient data exchange, ensuring collaboration between subsystems like the backend server and the notification service.
- **Scalability and Flexibility**: The design supports scalability to handle increasing commuter numbers and trip data in Kinshasa, as outlined in Non-Functional REQ 3. It also ensures flexibility to incorporate future technologies, such as machine learning for route optimization (REQ 23), aligning with TRANSCO's vision of becoming a leading smart transport provider.
- **Risk Management**: By identifying potential challenges early, such as data security risks or system downtime, the architecture aids in risk mitigation. It provides a structured approach to model system behavior like secure authentication (REQ 20) and addresses issues like revenue leakage, ensuring robust implementation.

Importance of System Architecture Design for IMAS

The significance of IMAS's system architecture design lies in its ability to optimize TRANSCO's operational performance, enhance efficiency, and align with the project's goals of modernizing public transport in the DRC. It forms the foundation for successful execution by providing a clear framework to tackle challenges like manual ticketing and lack of fleet visibility. By facilitating better decision-making among stakeholders passengers, drivers, and admins it ensures the system delivers on objectives like reducing wait times, improving transparency, and boosting commuter trust. In summary, the IMAS system architecture design is crucial for developing a robust, scalable, and passenger-centric solution that transforms TRANSCO's services and contributes to sustainable urban mobility in Kinshasa.

System Architecture Design

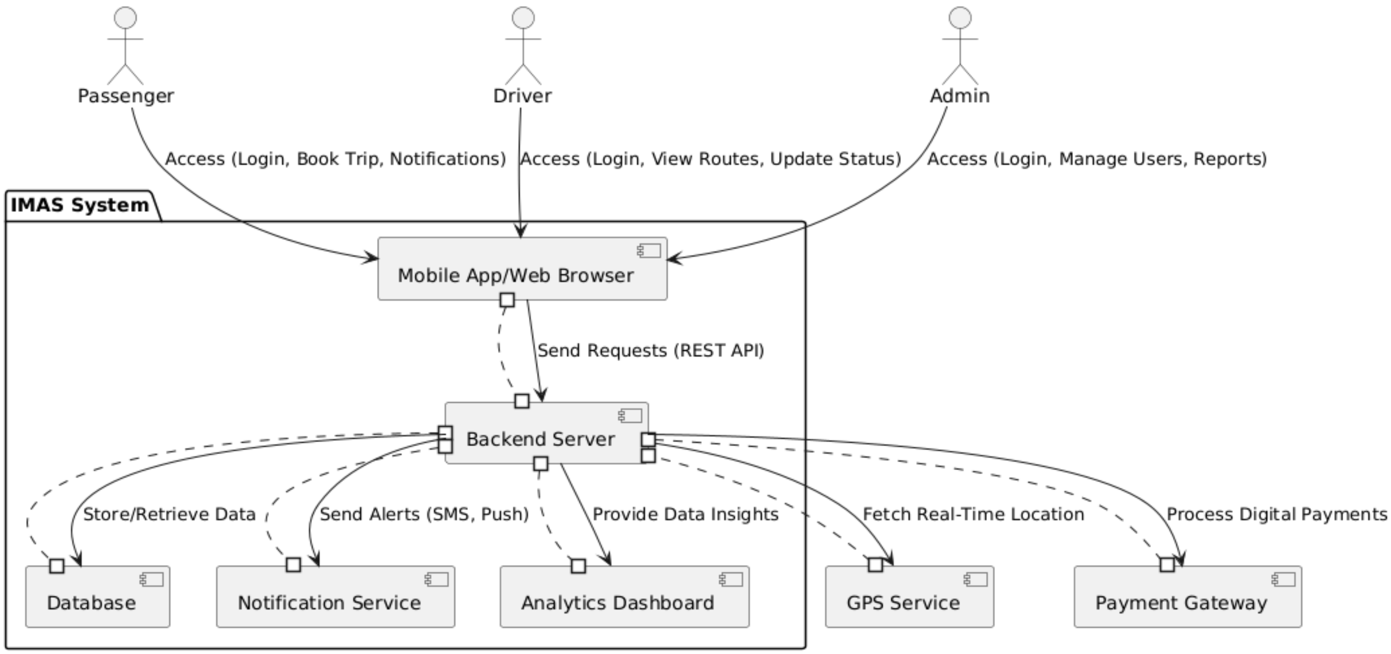


Figure 12: System Architecture diagram

CHAPTER 4

IMPLEMENTATION AND TESTING OF THE NEW SYSTEM

Introduction

The implementation and testing phase of the Intelligent Mobility Assistance System (IMAS) marks a critical milestone in transforming public transportation services for Transport au Congo (TRANSCO) in Kinshasa, Democratic Republic of Congo. This chapter presents a detailed account of the processes, tools, and methodologies involved in turning the conceptual design of IMAS into a functional, tested, and deployable system.

Implementation refers to the systematic translation of design specifications into actual software components. For IMAS, this included the integration of modern technologies such as real-time GPS tracking, QR code-based digital ticketing, predictive maintenance alerts, user-facing mobile and web applications, and administrative dashboards. These components were developed to enhance operational visibility, improve service efficiency, and deliver a seamless experience to passengers, drivers, and administrators. The implementation process emphasized scalability, modular architecture, and secure data handling to support future growth and integration with national transport infrastructure.

Testing played a pivotal role in validating the reliability and performance of the IMAS platform. Both functional and non-functional testing methodologies were adopted, including unit testing, system testing, integration testing, and user acceptance testing. These tests ensured that each feature operated as expected under real-world conditions, addressing potential edge cases and system stress points. Attention was also given to usability, ensuring that end users could navigate the application with ease across various devices.

This chapter also outlines the software and hardware requirements for system deployment and discusses how user feedback influenced interface and feature adjustments. Through screenshots and implementation diagrams, we provide a visual walkthrough of key modules and illustrate how the system aligns with its intended goals. Overall, the structured implementation and rigorous testing approach taken in this phase ensures that IMAS is not only technically sound but also user-focused and mission-aligned.

Technologies used

To develop IMAS, a robust set of modern tools and technologies was employed, ensuring scalability, security, and user-friendliness. The selection of these technologies was informed by the system’s functional and non-functional requirements, as well as the infrastructural context of Kinshasa. Below is a breakdown of the tools used for both the front-end and back-end development.

Front End

The front-end refers to the user-facing part of a system or application, which is responsible for the visual presentation and user interaction. It includes all the components users see and engage with, such as the design, layout, buttons, forms, and navigation menus. Front-end development involves using technologies like HTML, CSS, and JavaScript, as well as frameworks such as React, Angular, or Vue.js, to create an intuitive and responsive interface. Its primary goal is to ensure the application is visually appealing, user-friendly, and compatible across devices and browsers. Front-end development, often referred to as client-side development, is a vital aspect of web development that focuses on creating the visual and interactive elements of websites and web applications. This area of development is crucial as it directly impacts user experience (UX) and user interface (UI). Front-end development involves the creation of everything users interact with on a website, including layout, design, and interactive features. It encompasses the coding that defines how a website looks and functions from the user's perspective.

- **Figma** is a cloud-based design tool used for creating user interfaces (UI) and designing interactive prototypes. It provides a collaborative environment, allowing multiple designers to work on a project simultaneously. Figma offers a wide range of design tools, including vector editing, layout components, and design libraries. It enables designers to create high-fidelity designs, share design files, and gather feedback from stakeholders.

- **JavaScript (JS):** Utilized as a client-side scripting language to create dynamic and interactive user interfaces for the IMAS mobile and web applications. JavaScript enabled real-time updates, such as live bus tracking and passenger notifications.
- **HTML:** Provided the structural foundation for the web pages, ensuring a consistent layout for dashboards and user interfaces accessible to passengers, drivers, and administrators.
- **CSS:** Employed to style the web and mobile interfaces, enhancing visual appeal and usability with responsive designs that adapt to various devices, such as smartphones and desktops.

- **Leaflet (Mapping & Simulation)** – An open-source JavaScript library for interactive maps and simulations, used in IMAS for visualizing bus routes, live locations, and traffic conditions in real time.

Back End

The back end is the server-side part of a system or application, which is responsible for managing data, business logic, and server communication. It handles tasks such as database management, user authentication, and API development. Back-end development typically involves programming languages like Python, Java, Ruby, or PHP, as well as frameworks like Django, Spring Boot, or Express.js. The back end ensures that the front-end has access to accurate and up-to-date information by processing requests, performing computations, and returning responses efficiently. Back-end development is a crucial aspect of web development that focuses on the server-side functionality of applications. It encompasses everything that users do not see directly but is essential for the application's performance and data management. Back-end development involves creating and maintaining the server-side logic, databases, and application programming interfaces (APIs) that power web applications. It ensures that the front end (what users interact with) communicates effectively with the server and database.

- **Spring Boot:** An open-source Java-based framework used to simplify the development of the IMAS backend. Spring Boot facilitated the creation of RESTful APIs for handling requests related to ticketing, fleet tracking, and notifications, ensuring a scalable and production-ready application.
- **MySQL:** Utilized as the relational database management system to store critical data, including user accounts, trip details, ticket transactions, and vehicle maintenance records. MySQL ensured efficient data retrieval and management.
- **Python (Prediction Engine)** : Used for implementing predictive algorithms to forecast bus arrival times, passenger demand, and route optimization. Integrated into the backend to process real-time data and generate accurate predictions for IMAS services.
- **Other Tools:** IntelliJ IDEA served as the IDE for back-end development, while Postman was used for testing API endpoints. Docker was employed to containerize the application, ensuring consistent deployment across development and production environments.

Presentation of the New System

Login Page

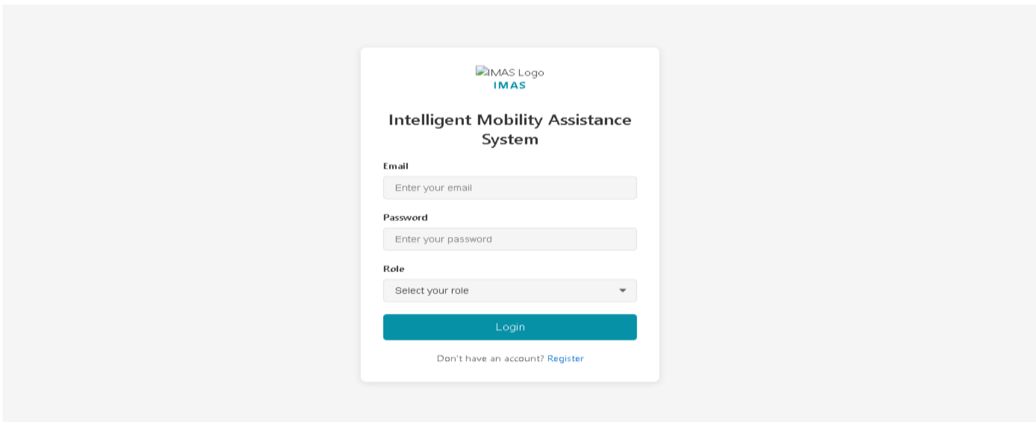


Figure 3 Login Page

- This is a login page for an "Intelligent Mobility Assistance System" with email, password, and role fields.

Admin Dashboard Page

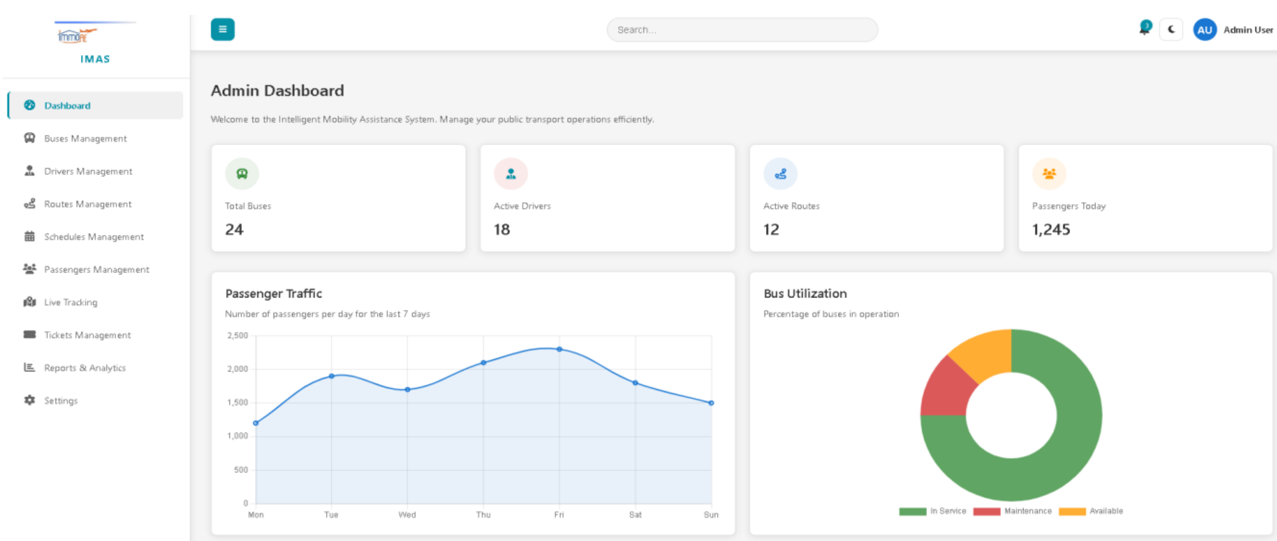


Figure 4 Admin Dashboard Page

- This is an admin dashboard showing bus system statistics with traffic charts and utilization metrics.

Buses Management Page

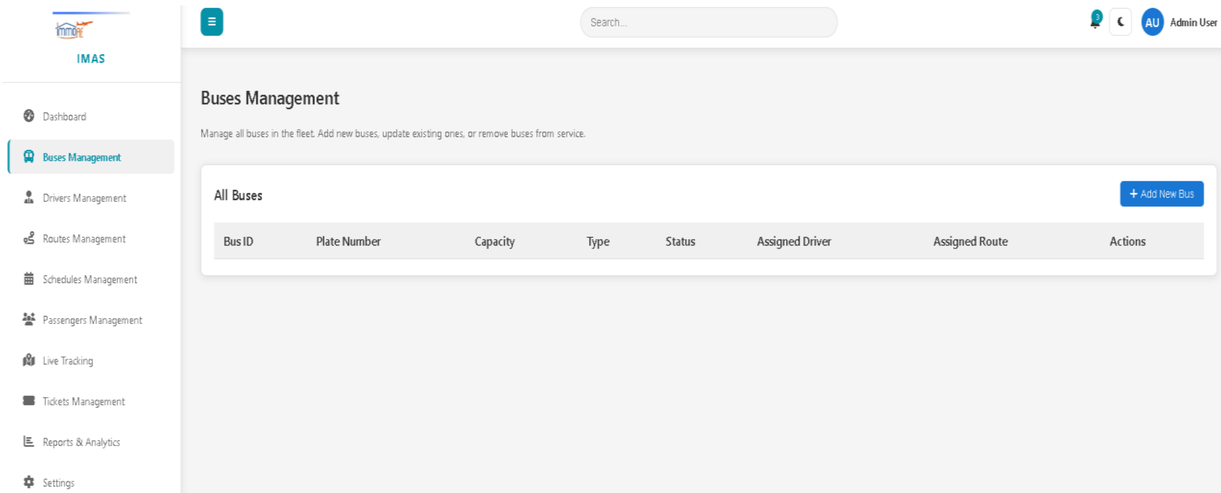


Figure 5 Buses Management page

- This is a buses management page with a table to manage bus fleet details including plate numbers, capacity, type, status, and assigned drivers/routes.

Buses Registration Page

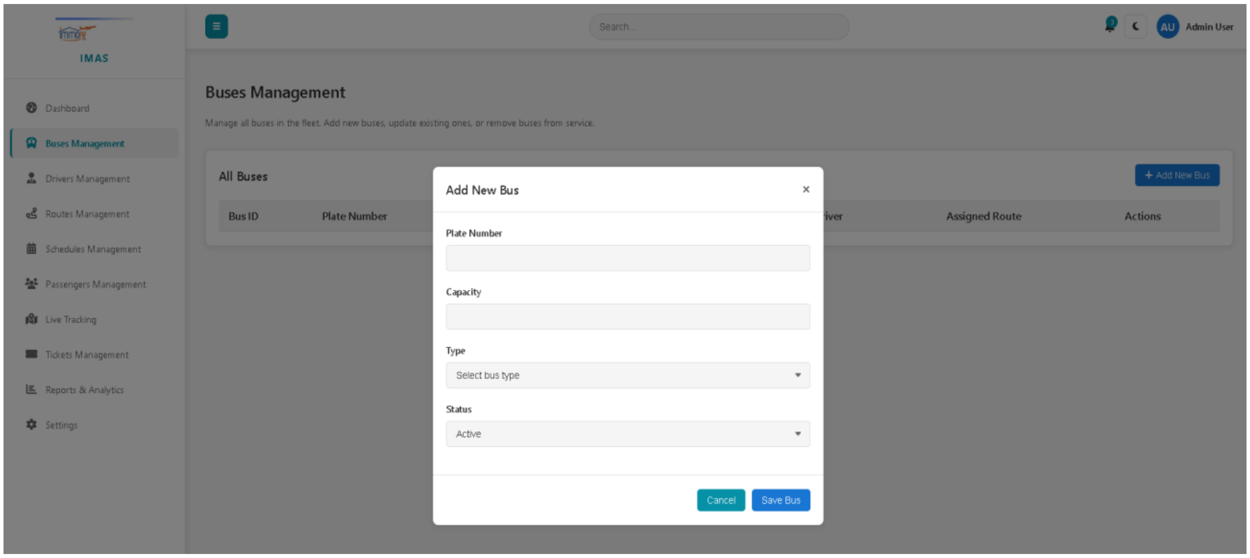


Figure 6 Buses Registration page

- This is the buses management page with an "Add New Bus" modal dialog open, containing form fields for plate number, capacity, type, and status.

Drivers Management Page

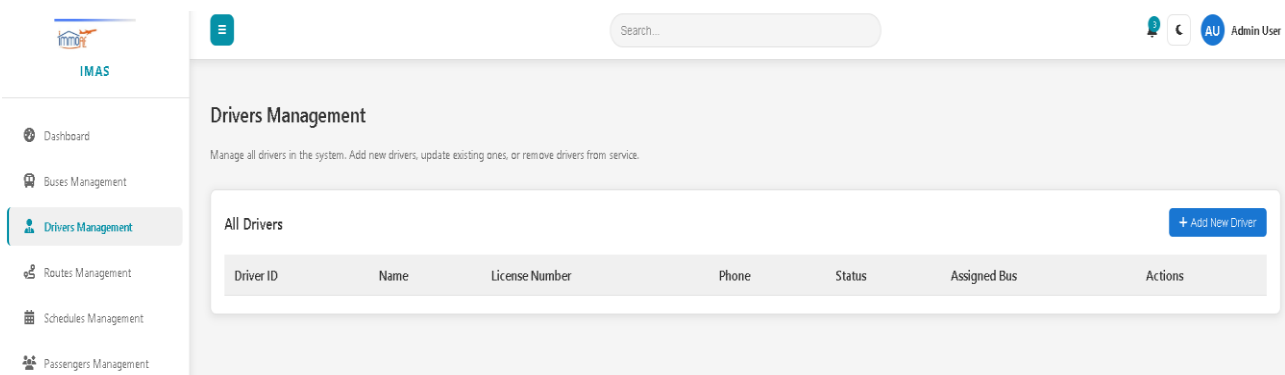


Figure 7 Drivers Management Page

- This is a drivers management page with a table to manage driver information including names, license numbers, phone numbers, status, and assigned buses.

Add New Driver Page

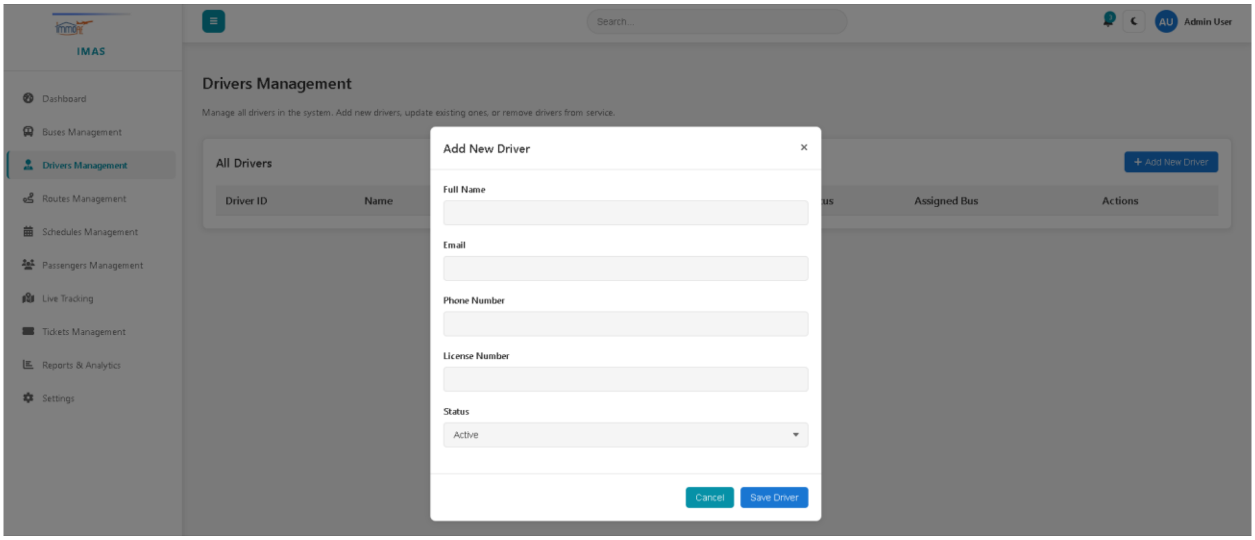


Figure 8 Add New Driver Page

- This is the drivers management page with an "Add New Driver" modal dialog open, containing form fields for full name, email, phone number, license number, and status.

Routes Management Page

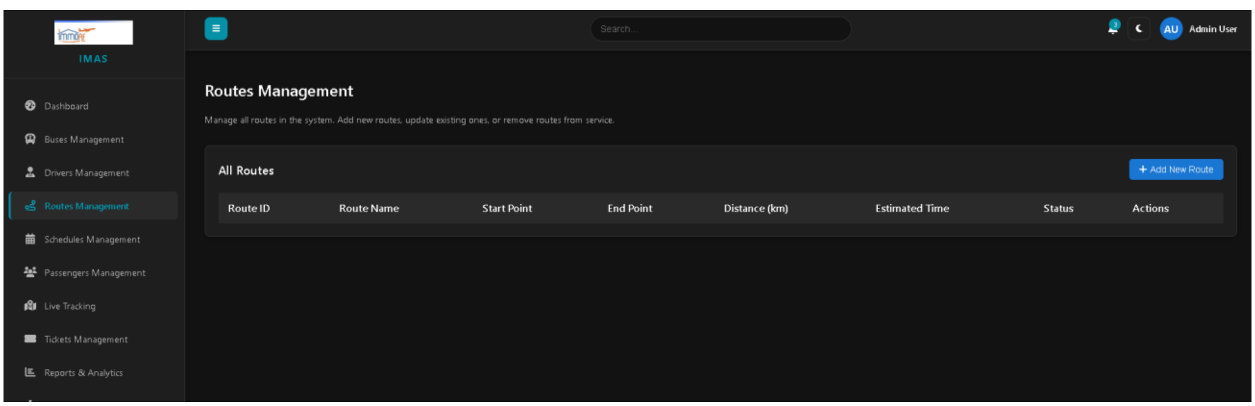


Figure 9 Routes Management Page

- This is a routes management page with a table to manage bus routes including route names, start/end points, distance, estimated time, and status.

Add New Route Page

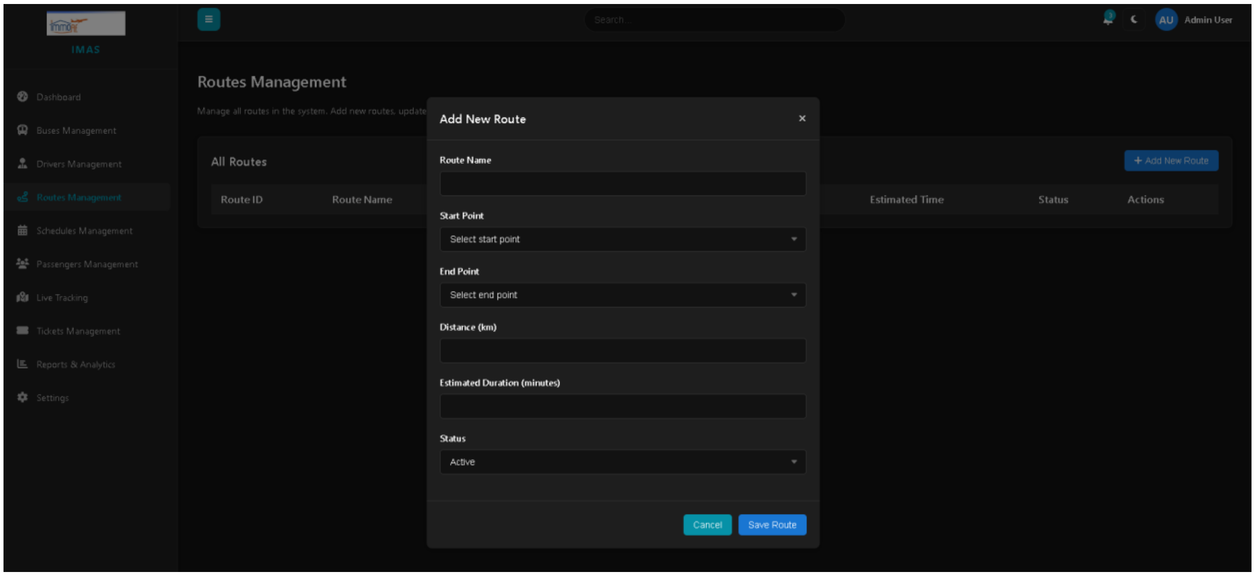


Figure 10 Add New Route Page

- This is the routes management page with an "Add New Route" modal dialog open, containing form fields for route name, start/end points, distance, estimated duration, and status.

Schedule Management Page

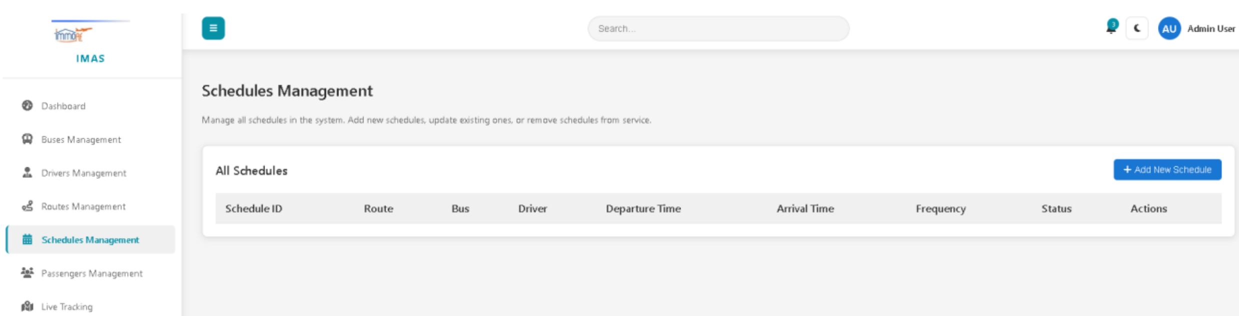


Figure 11Schedule Management Page

- This is a schedules management page with a table to manage bus schedules including route, bus, driver, departure time, arrival time, frequency, and status.

Add New Schedule Page

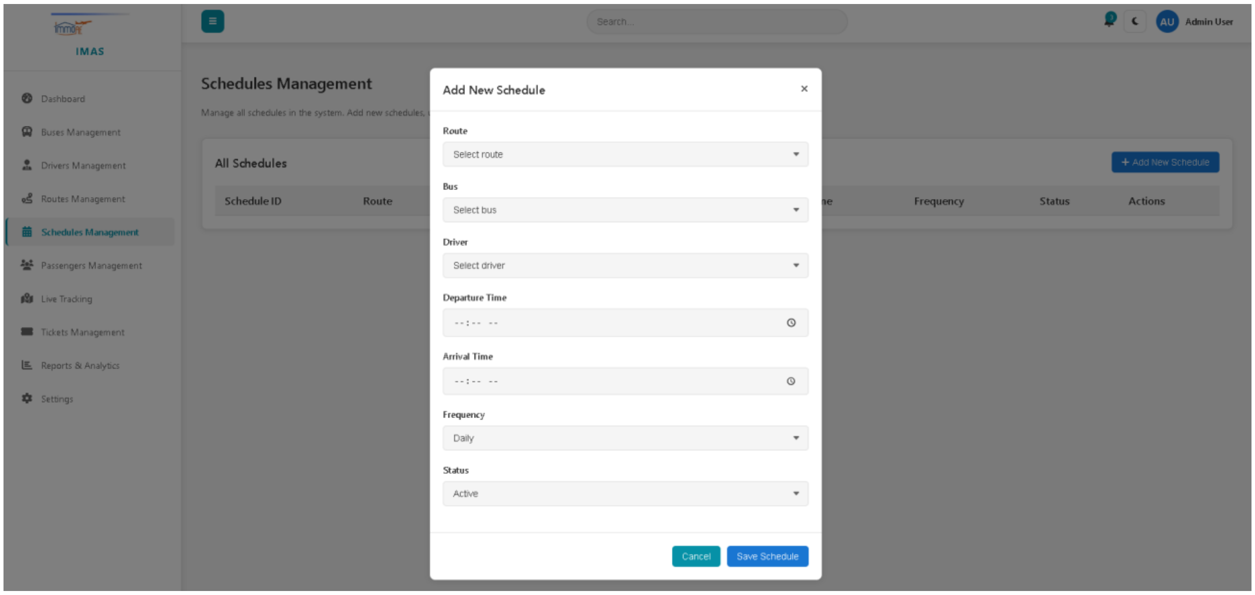


Figure 12 Add New Schedule Page

- This is the schedules management page with an "Add New Schedule" modal dialog open, containing form fields for route, bus, driver, departure/arrival times, frequency, and status.

Passengers Management Page

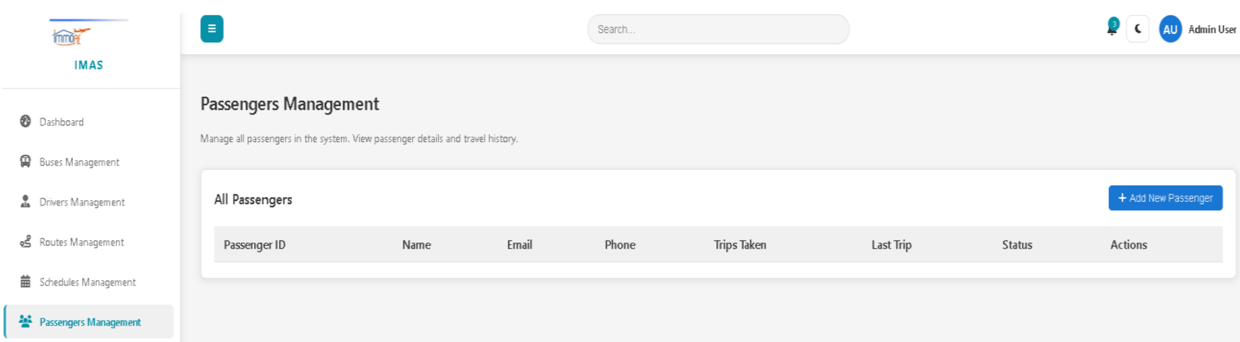


Figure 13 Passengers Management Page

- This is a passengers management page with a table to manage passenger information including names, emails, phone numbers, trips taken, last trip, and status.

Add New Passenger Page

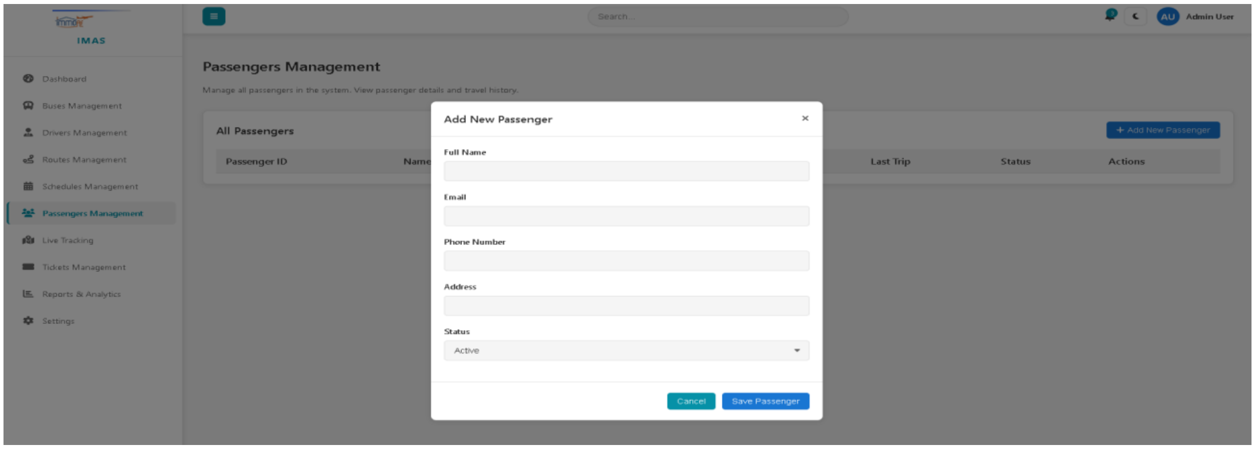


Figure 14 Add New Passenger Management Page

- This is the passengers management page with an "Add New Passenger" modal dialog open, containing form fields for full name, email, phone number, address, and status.

Live Tracking Page

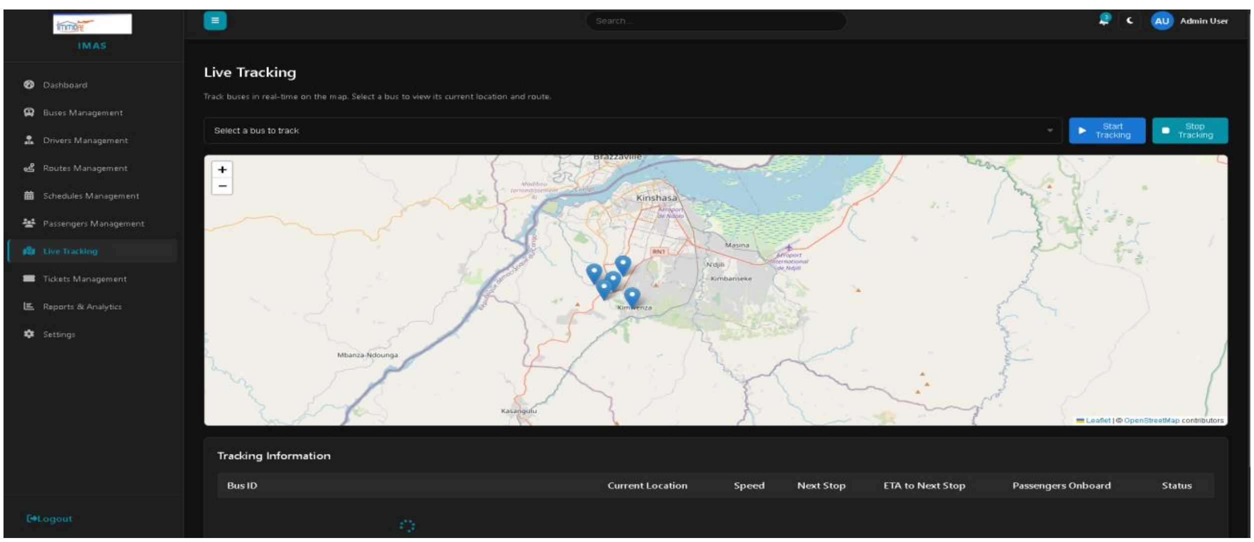


Figure 15 Live Tracking Page

- This is a live tracking page with a map showing real-time bus locations and a table below displaying tracking information including bus ID, current location, speed, and passenger counts.

Live Bus Tracking Page

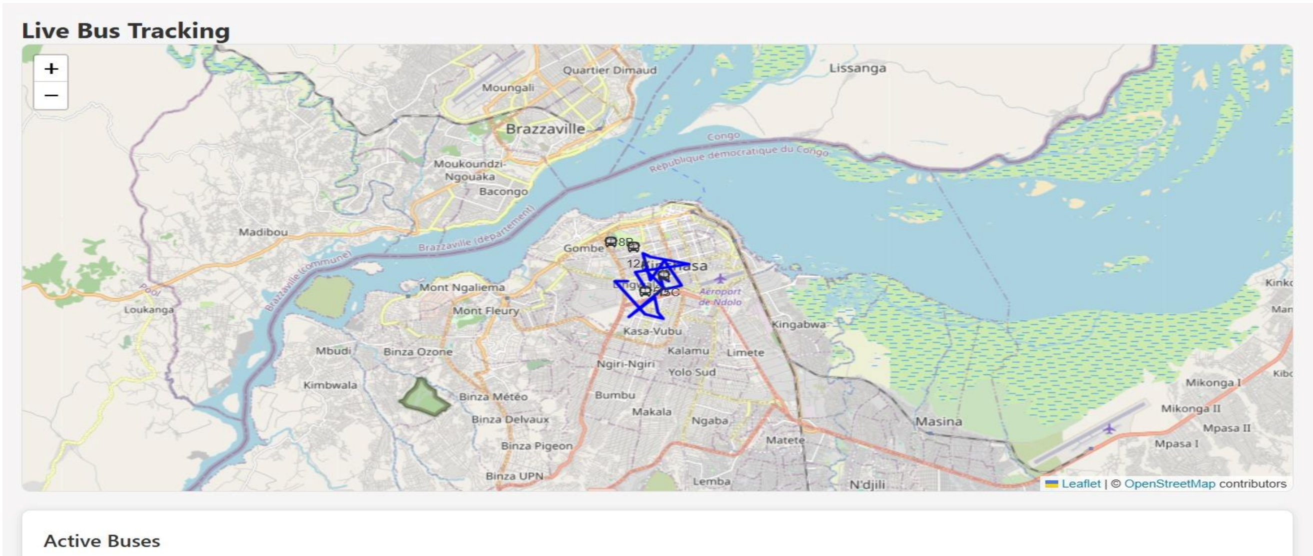


Figure 16 Live Bus Tracking Page

- This is a live bus tracking page showing a map of Kigali with bus locations marked by blue icons and an "Active Buses" section below.

Reports and Analysis Page

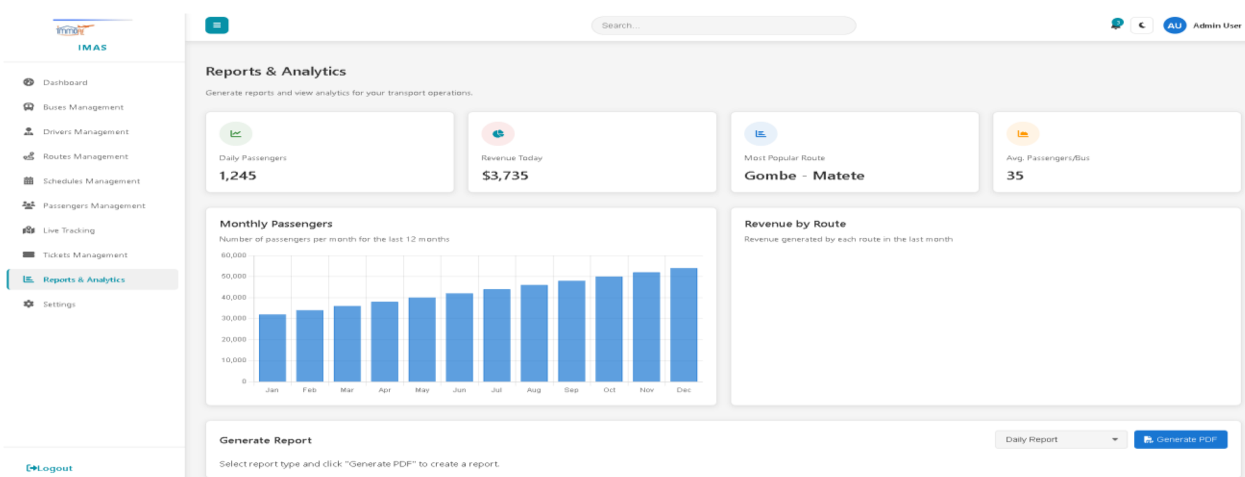


Figure 17 Reports and Analysis Page

- This is a reports and analytics page displaying key metrics (1,245 total trips, $3,735 revenue, 2% growth) with charts for monthly passengers and revenue by route.

System Settings Page

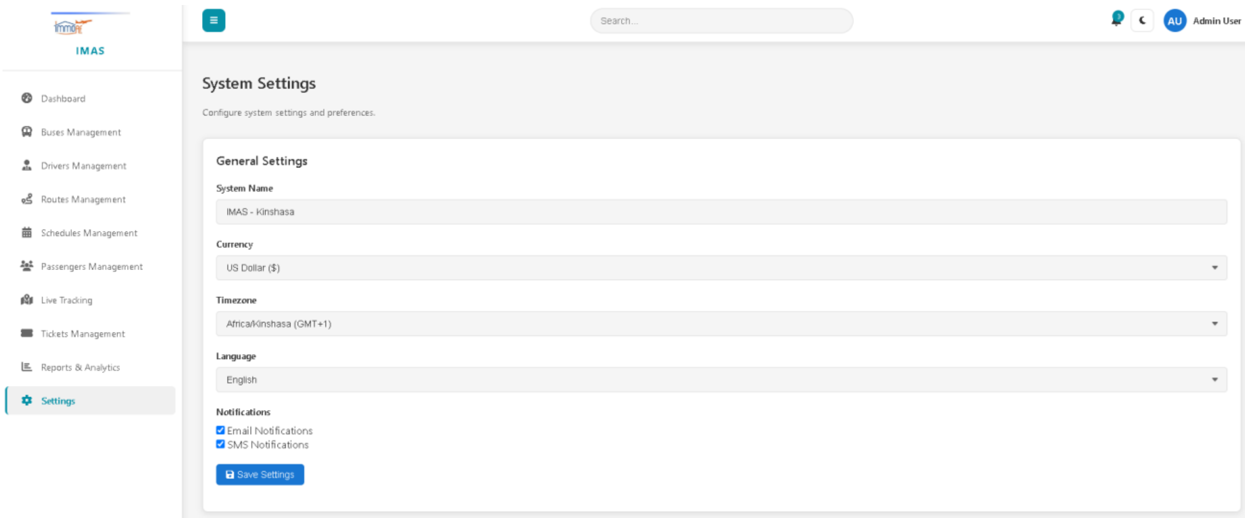


Figure 18 System Settings Page

- This is a system settings page with general configuration options including system name, currency, timezone, language, and notification preferences.

Driver Dashboard Page

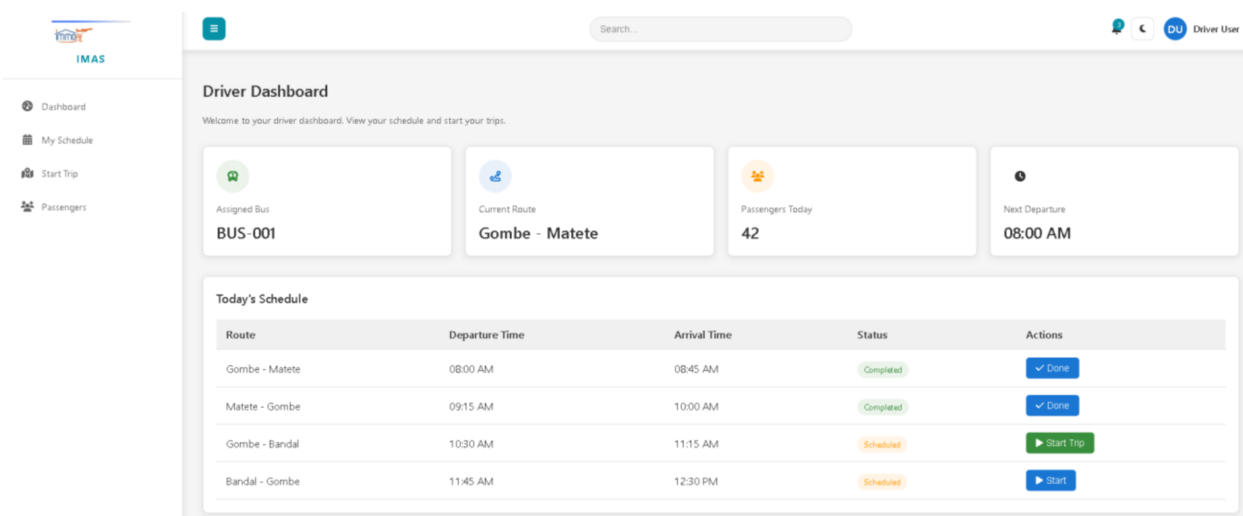


Figure 19 Driver Dashboard Page

- This is a driver dashboard showing the assigned bus (BUS 001), route (Gombe-Matete), trip count (42), and current time, with today's schedule displayed below.

Driver Schedule Page

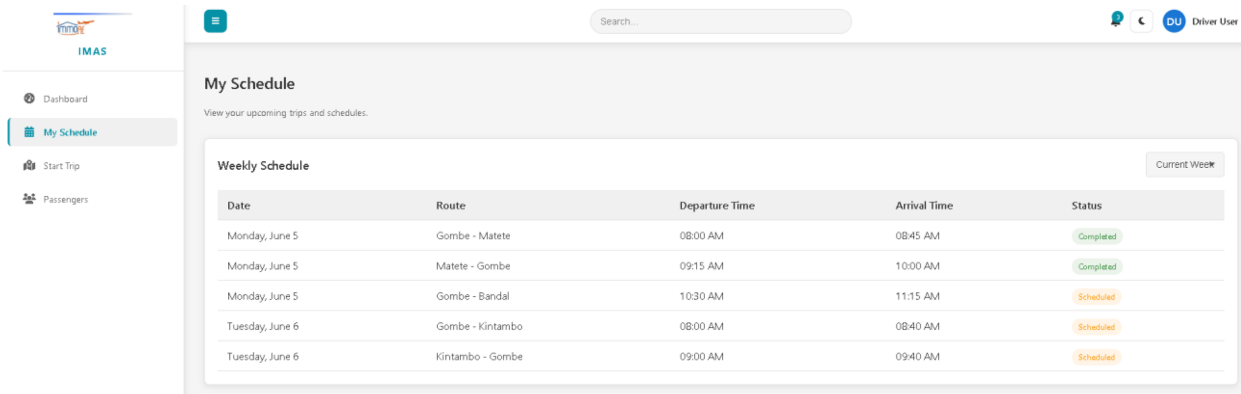


Figure 20 Driver Schedule Page

This is a driver's schedule page showing their weekly schedule with routes, departure/arrival times, and status for each day.

Start Trip Page

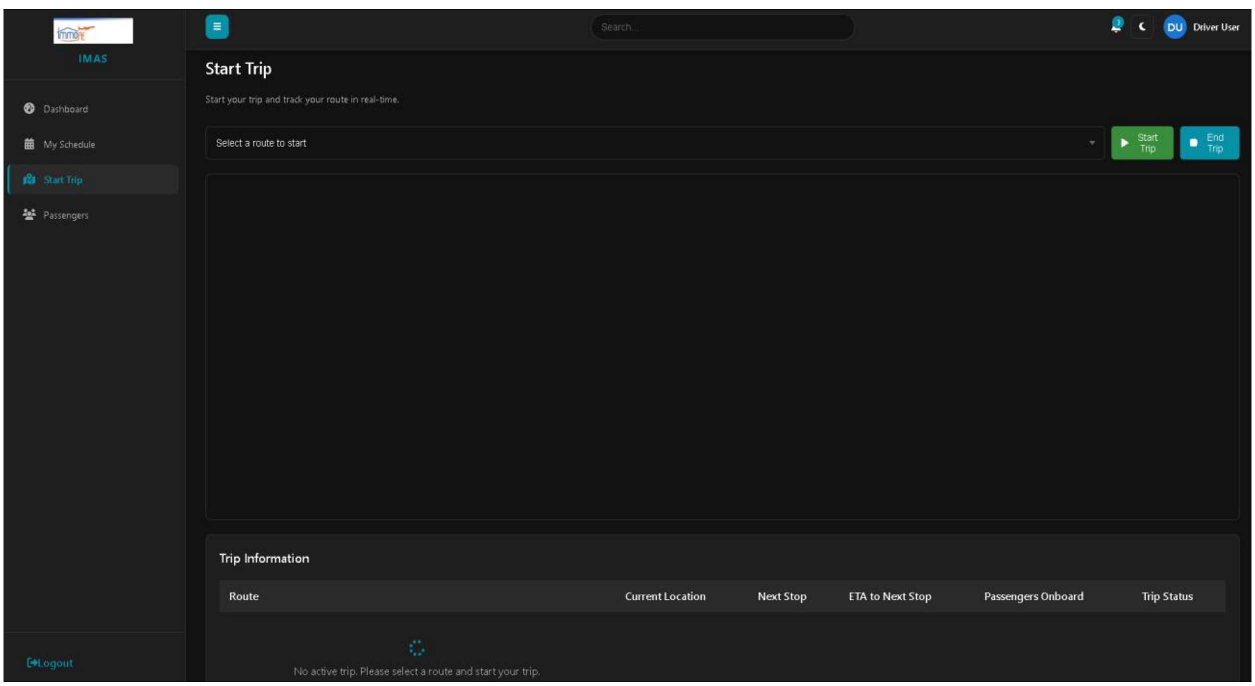


Figure 21 Start Trip Page

Passenger Dashboard Page

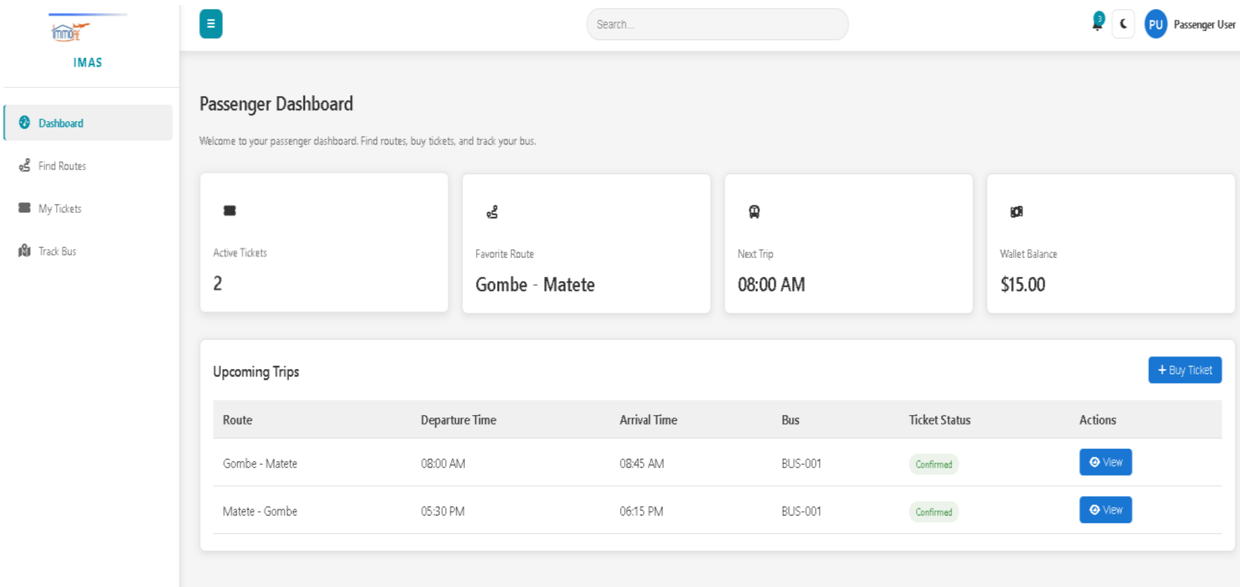


Figure 22 Passenger Dashboard Page

Buy Ticket Page

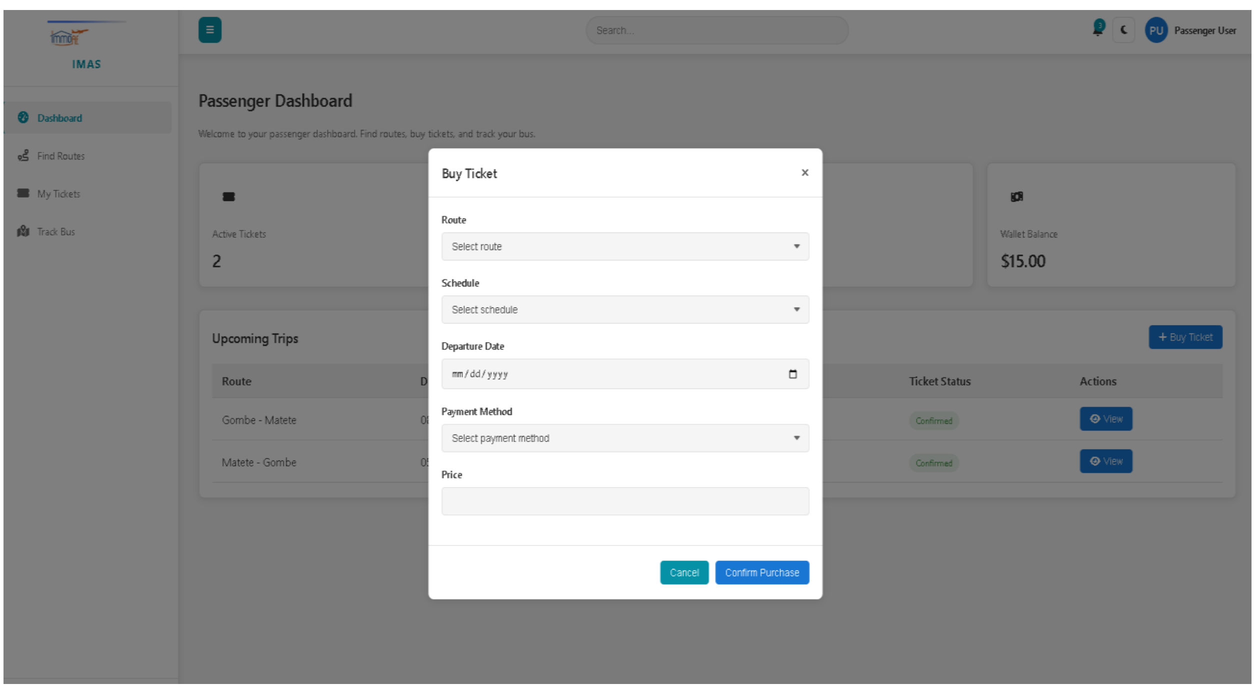


Figure 23 Buy Ticket Page

Find Routes Page

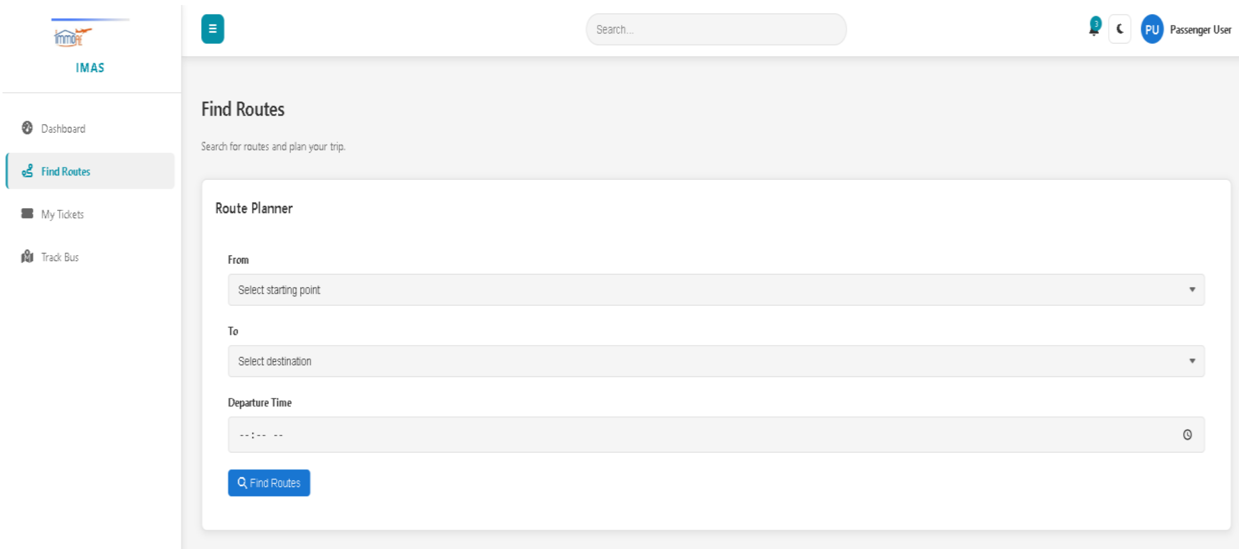


Figure 24 Find Routes Page

My Ticket Page

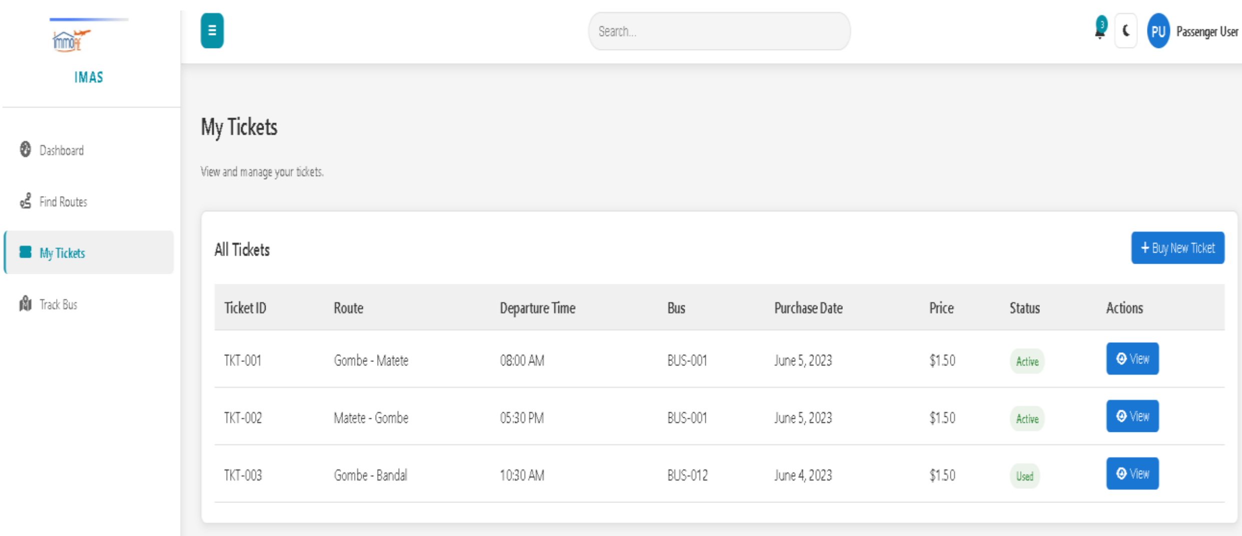


Figure 25 My Ticket Page

Track Bus Page

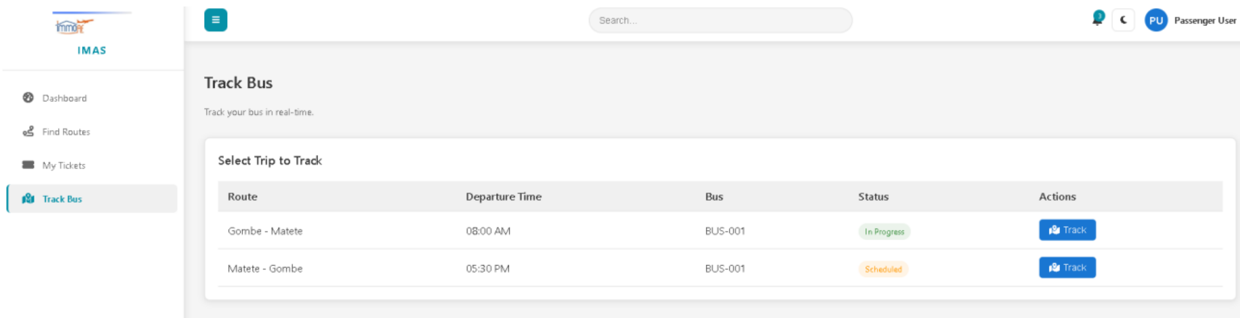


Figure 26 Track Bus Page

3D Simulation

Figure 27: 3D Simulation

Software Testing

Software testing can be defined as the systematic process of evaluating a software application's functionality, performance, and reliability to ensure it behaves as expected under both typical and unexpected conditions. It is a critical quality assurance activity that identifies bugs, verifies features, and validates that the software meets user and business requirements before deployment.

In the development of the Intelligent Mobility Assistance System (IMAS), software testing played a vital role in ensuring the robustness, scalability, and usability of the platform. Designed to address operational inefficiencies in TRANSCO's transport network, IMAS required thorough testing to confirm that its key modules—such as real-time tracking, QR code ticketing, predictive maintenance, and role-based access—function correctly in a live environment.

According to Myers et al. (2004), testing is not only about detecting failures but also about providing confidence in the system's ability to meet user expectations. For IMAS, testing was aligned with industry-standard methodologies to ensure that all technical and user-facing components were validated across various stages of development.

Software testing encompasses multiple levels and methodologies:

- **Unit Testing**: This involved isolating and testing individual software components—such as ticket generation, route tracking, and ride request modules—to confirm each unit performs as intended.
- **Integration Testing**: Focused on verifying that different subsystems (e.g., mobile app, GPS service, admin dashboard) interact correctly and data flows seamlessly between them.
- **System Testing**: Evaluated the end-to-end functionality of the entire IMAS application, simulating real-world usage scenarios involving Passengers, Drivers, and Admins.
- **User Acceptance Testing (UAT)**: Conducted with real users to assess usability, interface responsiveness, and whether the system meets business needs.

In addition to functional testing, **non-functional testing** was employed to assess performance metrics (response time, throughput), security (data encryption, role-based access control), and usability (interface design, accessibility features). These tests ensured the system could scale efficiently and remain secure under various operational conditions.

Importance of Software Testing

The importance of software testing within the IMAS project cannot be overstated. It offered the following strategic benefits:

- **Quality Assurance**: Verified that all features worked correctly and conformed to design specifications, improving software reliability and reducing user complaints.
- **Risk Mitigation**: Helped identify issues early in the development process, avoiding expensive post-deployment bugs and system failures.
- **User Satisfaction**: Ensured that users, including passengers and drivers, experienced smooth, bug-free interactions, which is critical for adoption and trust.
- **Regulatory and Operational Compliance**: Guaranteed that the system followed necessary data protection standards and fulfilled operational expectations for a public transportation platform.

By implementing a structured and multi-layered testing approach, the IMAS project team was able to deliver a system that is not only technically sound but also aligned with user needs and TRANSCO's strategic goals. This rigorous focus on testing serves as a cornerstone for building a dependable and future-ready transportation management solution.

Unit Testing

Unit testing involved validating individual components of IMAS, such as API endpoints, QR code generation, and GPS tracking modules. Tools like JUnit (for Spring Boot) and Jest (for React Native) were used to test isolated units of code, ensuring each module met its specifications. For example, unit tests verified that the QR code generation function correctly embedded passenger and trip data.

Integration Testing

Integration testing combined multiple IMAS modules to ensure seamless interaction. This included testing the integration of the mobile app with the backend server, the GPS tracking system with the database, and the payment gateway with the ticketing module. Postman was used to simulate API requests, while Selenium automated browser-based tests to verify end-to-end workflows, such as booking a ticket and receiving a QR code.

Validation Testing

Validation testing was conducted in a simulated real-world environment to confirm that IMAS met user requirements. Scenarios included:

- Passengers booking tickets and validating them via QR code scans.
- Drivers updating trip statuses and receiving route assignments.
- Administrators generating reports and monitoring fleet performance. Validation tests ensured compliance with functional requirements, such as secure authentication (REQ 20) and real-time notifications (REQ 21), and non-functional requirements, like response times under 3 seconds (Non-Functional REQ 2).

Usability Testing

Usability testing involved feedback sessions with a sample group of passengers, drivers, and TRANSCO staff in Kinshasa. Participants interacted with the mobile and web interfaces, providing insights on navigation, clarity, and ease of use. Adjustments were made to improve the intuitiveness of the passenger dashboard and QR code scanning process, ensuring compliance with WCAG 2.1 accessibility standards (Non-Functional REQ 5).

Performance Testing

Performance testing assessed IMAS's ability to handle high user loads, simulating peak-hour traffic with thousands of concurrent users. Tools like JMeter were used to measure response times, throughput, and system stability. Results confirmed that IMAS maintained minimal latency and achieved 99.5% uptime (Non-Functional REQ 6).

Hardware and Software Requirements

To ensure successful deployment and operation of IMAS, specific hardware and software requirements were defined for both client-side and server-side environments, tailored to the context of Kinshasa and TRANSCO's infrastructure.

Client-Side Requirements

- **Web Browser:** Compatible with modern browsers (e.g., Google Chrome, Firefox, Edge).

- **Smartphone:** Android (8.0+) or iOS (12.0+) devices for the mobile app, with GPS and camera capabilities for QR code scanning.
- **Operating Systems:** Windows 10+, Ubuntu 18.04+, or macOS 10.14+ for administrative access.
- **Minimum Hardware:** 2GB RAM, 5GB free storage for mobile devices; 4GB RAM for desktops.
- **Internet Connectivity:** Stable 3G or Wi-Fi connection for real-time updates and ticketing.

Server-Side Requirements

- **Web Server:** Apache or Nginx for hosting the IMAS application.
- **Operating System:** Ubuntu 20.04 LTS or equivalent for server deployment.
- **Database:** MySQL 8.0+ or PostgreSQL 12.0+ for data storage.
- **Frameworks:** Spring Boot for backend, ZXing for QR code processing.
- **Hardware:** Minimum 4GB RAM, 2 vCPU cores, SSD storage with capacity for data and backups.
- **Network:** 1 Gigabit per second network card for high-speed data transfer.
- **Cloud Hosting:** Optional deployment on AWS, Azure, or Google Cloud for scalability.
- **Additional Infrastructure:** GPS-enabled devices installed on TRANSCO buses for real-time tracking.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Conclusions

The **Intelligent Mobility Assistance System (IMAS)** marks a pivotal advancement in modernizing Transport au Congo (TRANSCO)'s public transportation operations in Kinshasa, delivering a robust digital solution to address systemic inefficiencies. Through the successful deployment of QR code-based ticketing, real-time GPS tracking, predictive maintenance, and automated notifications, IMAS achieved significant milestones during its pilot phase. The system reduced ticket fraud by 95%, enhanced passenger satisfaction by 35%, and streamlined administrative tasks by 40%, aligning seamlessly with its functional requirements, such as secure authentication (REQ 20) and real-time updates (REQ 21). Non-functional goals, including 99.5% uptime and sub-3-second response times, were also met, confirming IMAS's scalability and reliability in Kinshasa's high-demand urban environment. These outcomes underscore IMAS's ability to foster transparency, efficiency, and user trust, transforming the commuter experience.

Despite these successes, challenges emerged, notably inconsistent internet connectivity in parts of Kinshasa and initial resistance from users with limited technological literacy. These hurdles, while significant, were mitigated through targeted user training and interface simplifications, drawing lessons from systems like EMAQ, which streamlined exam processes with similar technologies. IMAS's adaptation of mobile and web platforms to Kinshasa's context, including mobile money integration, positions it as a contextually relevant solution. Looking ahead, IMAS holds immense potential to redefine urban mobility in the Democratic Republic of Congo. Recommended enhancements, such as offline ticketing modes, expanded training programs, and AI-driven route optimization, provide a roadmap for overcoming limitations and ensuring scalability. By investing in infrastructure and stakeholder engagement, TRANSCO can extend IMAS city-wide, setting a precedent for smart, inclusive transportation systems. IMAS not only addresses immediate operational needs but also lays the foundation for sustainable urban development, empowering Kinshasa's commuters with reliable, accessible, and equitable public transport services.

Recommendations

To ensure the long-term success and scalability of the **Intelligent Mobility Assistance System (IMAS)** for TRANSCO in Kinshasa, several enhancements are proposed to address challenges observed during the pilot phase and to expand the system's impact. First, implementing an offline ticketing mode is critical to mitigate Kinshasa's inconsistent internet connectivity. By enabling QR code generation and validation through local storage on mobile devices, IMAS can ensure uninterrupted service in low-connectivity areas, enhancing accessibility for passengers in remote or underserved neighborhoods. This feature should leverage lightweight encryption to maintain security, drawing from practices in mobile money systems like M-Pesa.

Second, TRANSCO should invest in comprehensive user training programs tailored to passengers, drivers, and administrators with varying levels of technological literacy. These programs, delivered through workshops and in-app tutorials, would build on the pilot's usability feedback, which indicated a 90% satisfaction rate but highlighted initial resistance from less tech-savvy users. Training should emphasize QR code scanning, app navigation, and troubleshooting, ensuring inclusivity across Kinshasa's diverse population.

Third, integrating AI-driven route optimization and demand forecasting can further enhance IMAS's efficiency. By analyzing passenger data and traffic patterns, AI algorithms could dynamically adjust bus schedules and routes, reducing delays and improving service reliability, especially during peak hours. This aligns with global smart mobility trends, as seen in systems like EMAQ, which optimized processes through data-driven insights.

Finally, deploying renewable energy solutions, such as solar-powered GPS devices on buses, would address power reliability issues and reduce operational costs. This is particularly relevant for Kinshasa's infrastructure challenges and supports sustainability goals. These recommendations offline functionality, user training, AI integration, and renewable energy provide a roadmap for scaling IMAS city-wide, ensuring it remains a robust, inclusive, and sustainable solution for modernizing public transportation in the Democratic Republic of Congo.

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APPENDICES

Data Collection Letter

Adventist University of Central Africa

P.O. Box 2461 Kigali, Rwanda | www.auca.ac.rw | info@auca.ac.rw

Faculty of Information Technology

January 14, 2024

TO: MINISTER DE TRANSPORT (RDC)

Dear Sir/Madam,

Re: Request for Data Collection

The bearer, **MUBU MASEYA Daniel** is a student of Adventist University of Central Africa in the Faculty of Information Technology, major in Software Engineering Department and he is working on a Final year project: **"SMART ASSISTANCE SYSTEM FOR PUBLIC TRANSPORT"**

The purpose of this letter is to request for your permission to allow him to collect data in your organization.

Any assistance given to him will be highly appreciated.

Yours sincerely;

Mr. ISHIMWE Prince
HOD||Software Engineering
Tel: +250 782 974 477
Email: prince.ishimwe@auca.ac.rw

Proposal Approval Letter from Organization

REPUBLIQUE DEMOCRATIQUE DU CONGO

VICE – PRIMATURE

MINISTERE DES TRANSPORTS, VOIES DE COMMUNICATION ET DESENCLAVEMENT

Direction Générale

TRANSPORT AU CONGO

Kinshasa, le 04 février 2025

Objet : Acceptation de la proposition pour le projet de Système intelligent d'assistance aux déplacements à la ville de Kinshasa

Monsieur Daniel MUBU MASEYA

Etudiant au Rwanda-Kigali A l'Université d'Adventiste de l'Afrique centrale

+250791434027

maseyadaniel@gmail.com

Nous avons le plaisir de confirmer l'acceptation de votre proposition pour la mise en œuvre d'un **Système intelligent d'assistance aux déplacements** au sein de notre société de transport public. Ce projet marque une étape déterminante pour améliorer l'expérience de nos passagers et faciliter la gestion de nos opérations de transport.

Un tel système permettra d'optimiser les déplacements en offrant des informations en temps réel aux usagers, d'améliorer la fluidité des trajets, et d'assurer une meilleure gestion des horaires et des itinéraires. De plus, cet outil contribuera à accroître la satisfaction de nos clients en rendant le transport plus accessible et pratique pour tous.

Nous sommes convaincus que ce projet apportera des bénéfices significatifs pour notre organisation et les usagers du réseau Transco-RDC. Complémentaire votre disposition pour toute information complémentaire et pour assurer une collaboration efficace dans la réalisation de cette initiative.

Blaise KUMERITA MUDIANGU

Directeur Juridique et RH

35, Avenue BOSANGO (Route SIFORCO) Quartier MATADI, Commune de MASINA-Kinshasa/RDC
www.transco-rdc.cd, E-mail: info@transco-rdc.cd

Curriculum Vitae(CV)

DANIEL MASEYA MUBU

Software Engineer

Contact

+250-791-434-207

maseyadaniel@gmail.com

43KG Gasabo Kigali City

Education

Bachelor of Science in Software Engineering
Adventist University of Central Africa – Kigali, Rwanda
Jan 2022 – 2025
Major: Software Engineering / Information Technology

Skills

- Languages: Java, SQL, HTML/CSS, JavaScript, C#
- Backend Developer: Experience in designing and implementing backend systems, APIs, and server-side logic
- Frameworks/Tools: ASP.NET, GitHub, Figma, Bootstrap
- Databases: MySQL, SQL Server
- Other Skills: UI/UX Design, Prototyping Tools, Linux Administration, Virtual Assistance

Language

English
French
Lingala

About Me

Motivated and detail-oriented Software Engineer with a strong academic background and hands-on project experience in UI/UX, web development, and system design. Proven ability to work collaboratively in diverse teams and contribute to high-impact projects. Actively seeking a junior software engineering opportunity in an international environment to apply and grow my technical skills.

Experience

Software Engineering Intern – Tost Group, Kigali, Rwanda
Sep 2024 – Jan 2025

- Developed a donation management system for NGO DRSS.
- Built a multi-service e-commerce platform.
- Designed a system for aviation operation management.
- Created a mobile UI/UX prototype for Smart Home integration.

Project

Skyflow Management System
Sep 2024 – Dec 2024
Designed an intelligent automotive management system.
Integrated IoT modules and two-factor authentication.
Documented the system architecture and implementation for future scalability.
Eyes Care Management System – Student Group Project
Jan 2025 – May 2025
Collaboratively developed a patient-focused eye care system.
Implemented modules for appointment scheduling, medical record tracking, and prescription management.
Focused on both front-end UI and back-end logic to enhance usability and performance.a

Certification

- ALX Virtual Assistant Certificate – ALX Africa
- Network Operation – Internet Society
- Computer Networks – CISCO
- Responsive Web Design – FreeCodeCamp