Sri Lanka Intelligent Bus Navigation and Passenger Information System

24-25-J237

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B.Sc. Special (Honors) Degree in Information Technology

Specialization in Information Technology

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DECLARATION

We declare that this is our own work and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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(Dr. Sanika Wijayasekara)

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ABSTRACT

This research project aims to enhance the public transport experience in Sri Lanka by developing a smart, user-friendly mobile application that offers real-time bus tracking and intelligent passenger assistance. The system integrates GPS-based tracking, linear regression-based ETA prediction, an AI-powered chatbot, and voice interaction features. It addresses several critical issues in Sri Lanka's bus transport system, such as unpredictable arrival times, lack of accessible route information, and insufficient support for visually impaired passengers. The application enables users to view the real-time location of buses and receive accurate, continuously updated Estimated Time of Arrival (ETA) predictions based on live GPS data and historical traffic patterns using a lightweight regression model. It also features a chatbot trained on structured SLTB data to provide instant responses to user queries about routes, stops, and schedules. Furthermore, a key feature of the system is its voice-based interaction capability, specifically designed to assist visually impaired users by allowing them to speak queries and receive spoken feedback, reducing reliance on visual navigation. Tested on Route 177 (Kaduwela to Kollupitiya), the system demonstrated strong performance in real-world conditions. This solution represents a significant step toward inclusive, intelligent public transportation in Sri Lanka, with the potential for national-level scalability.

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LIST OF ABBRIVATIONS

Abbreviation	Description
ETA	Estimated Time of Arrival
GPS	Global Positioning System
STT	Speech-to-Text
TTS	Text-to-Speech
SLTB	Sri Lanka Transport Board
MAE	Mean Absolute Error
RMSE	Root Mean Squared Error
JSON	JavaScript Object Notation (used to structure SLTB route data)
API	Application Programming Interface (used for OpenAI and other integrations)
UI	User Interface
ML	Machine Learning
NLP	Natural Language Processing (used in chatbot communication)

1 INTRODUCTION

1.1 General Introduction

Public transportation plays a vital role in the socio-economic development of countries, particularly in developing nations like Sri Lanka, where a major section of the population rely on bus services for their daily commute. Among the many public transport choices, buses remain the most extensively used due to their price, accessibility, and widespread coverage across urban and rural locations. The bus system in Sri Lanka, managed jointly by the Sri Lanka Transport Board (SLTB) and commercial operators, connects major towns, cities, and outlying villages, making it the backbone of the national transportation infrastructure [1].

However, despite its importance, the bus transportation system has various issues that adversely affect passenger experience and overall system efficiency. These include inconsistent arrival times, a lack of real-time information dissemination, poor route awareness, and insufficient help for differently-abled passengers. Most buses still operate on set schedules that are not changed dynamically to suit actual traffic conditions, leading to passenger annoyance due to unexpected delays and long waiting periods [2].

One of the most affected routes in this context is Route 177, which runs from Kaduwela to Kollupitiya. This route traverses multiple high-density districts and is often congested during peak hours. Due to the absence of dynamic transport systems, passengers on this route frequently confront unexpected journey times, limited signage, and minimal access to route or schedule updates. These challenges are amplified for tourists and new residents, who may be unfamiliar with the transportation system or the local language [3].

In recent years, rising technologies such as artificial intelligence (AI), machine learning (ML), and mobile application development have opened up new opportunities for boosting public transit systems. In example, predictive analytics utilizing linear regression models can forecast bus arrival times based on historical and real-time traffic data. Additionally, AI-powered chatbots and voice-based interfaces can improve the accessibility and engagement of transport-related applications [4], [5]. These technologies not only improve operational efficiency but also considerably enhance the customer experience by eliminating uncertainty and enhancing confidence in public transit.

The integration of such smart technologies has already been successfully demonstrated in countries like Singapore, the United Kingdom, and the United States, where AI-powered transport systems deliver real-time updates, personalized route recommendations, and interactive support for commuters [6], [7]. However, the Sri Lankan public transit system remains mainly isolated from such technological improvements.

Recognizing this gap, this research project aims to design and develop a smart mobile application specifically for Sri Lanka's Route 177. The proposed system will integrate three core components:

1. ETA (Estimated Time of Arrival) Prediction: Utilizing a linear regression model trained on historical and live GPS data to provide dynamic and accurate bus arrival forecasts.

2. AI-Powered Chatbot: Fine-tuned using structured JSON data extracted from official SLTB documents and integrated via the OpenAI API, allowing passengers to query bus schedules, routes, and transfer points using natural language.

3. Voice-Based Functionality: Supporting visually impaired or hands-free users to interact with the application using speech recognition and text-to-speech features, thereby enhancing accessibility and inclusivity.

By combining these elements, the research seeks to offer a user-friendly, intelligent transport application that aligns with modern smart city initiatives and supports a more reliable, efficient, and inclusive public transportation experience for Sri Lankan commuters.

1.2 Background Literature

A examination of global and local literature demonstrates remarkable progress in the digitalization of public transportation networks. Advanced technology such as GPS monitoring, real-time data broadcasting, and AI-powered user interfaces have considerably increased commuter pleasure and operational efficiency in several nations. Studies have indicated that access to real-time transport data reduces travel-related anxiety and promotes customer confidence in public systems [8]. Similarly, predictive analytics tools such as linear regression-based ETA systems can minimize schedule uncertainty and promote better traffic management by informing route planning and bus allocation [9].

However, despite these developments, there remains a considerable gap in the adoption of such technology in underdeveloped countries. In Sri Lanka, for example, present implementations are fragmented, lacking integration, and are not designed with accessibility or localization in mind. Most public transport systems still rely on static schedules, paper announcements, or human verbal updates, which do not reflect live conditions or traffic interruptions. Furthermore, digital technologies like chatbot interfaces, multilingual support, and voice-assisted features are either underdeveloped or altogether lacking.

Incorporating intelligent transport technologies that integrate real-time tracking, regression-based ETA prediction, and conversational interfaces could dramatically bridge this digital divide. These technologies not only improve the operational aspects of transit but also boost inclusivity and convenience especially for differently-abled users and unfamiliar customers such as tourists. The potential of such linked systems is particularly significant in the Sri Lankan context, where modernization efforts are ongoing but remain in early pilot phases [10].

1.2.1 An Overview about Public Transport in Sri Lanka

Sri Lanka's public transport system is a vital pillar of national infrastructure and is used by millions of citizens each day for commuting to work, school, and other daily activities. It is composed primarily of bus and rail services, with buses being the dominant mode of transport due to their extensive route coverage, relatively low cost, and frequent operation. Public transportation in Sri Lanka is managed through a dual system comprising both state-owned services, such as those operated by the Sri Lanka Transport Board (SLTB), and a vast network of private bus operators functioning under regulatory oversight.

As of 2024, SLTB operates more than 5,000 buses across the island, while private operators collectively run approximately 20,000 buses, contributing significantly to the national transport demand. Together, these services account for over 50% of the country's daily passenger movements, making them a backbone of national mobility and economic continuity [11].

The public transport system includes intercity, semi-luxury, expressway, and urban buses. The island's road network is categorized into A-class (major highways), B-class (secondary roads), and smaller provincial roads, all of which are heavily utilized by buses. The Route 177, which connects Kaduwela and Kollupitiya, is one such important route that navigates through densely populated areas of Colombo and its suburbs. This makes it a critical link for thousands of daily commuters, especially workers and students.

Despite its extensive reach and affordability, the Sri Lankan bus system suffers from several structural and operational shortcomings. These include poor maintenance of vehicles, outdated schedules, irregular intervals, overcrowding, and an overall lack of system modernization. The heavy reliance on manual scheduling and a lack of automated systems have contributed to widespread inefficiencies in the sector.

Furthermore, the absence of centralized, real-time tracking and prediction systems results in commuters being uncertain about bus locations and expected arrival times. Most information pertaining to bus routes, stops, and schedules is given by static notices at bus stations or orally by conductors and drivers. This presents hurdles for new travelers, tourists, or visually impaired folks who require accessible and current travel assistance. While there have been some digital attempts like as route maps and schedule uploads on SLTB websites these are rarely updated and do not reflect actual traffic or delays.

Moreover, the country's rapid urbanization and increasing vehicle population have intensified traffic congestion, especially in Colombo and surrounding metropolitan areas. As a result, bus delays are frequent, but they are not effectively communicated to commuters in real time. The current infrastructure lacks integration with smart technologies, such as mobile-based route tracking, predictive analytics, or conversational systems that are increasingly common in public transportation systems across developed nations [12].

The development of a smart, user-friendly transport information platform has the potential to significantly improve travel efficiency, reduce waiting times, and enhance the commuter experience across Sri Lanka. The government has recognized the need for digital transformation in this sector and has included intelligent transport systems in broader smart city plans. However, large-scale implementation remains in early stages, with pilot projects in Colombo not yet scaled to a national level [13].

Introducing intelligent technologies, such as ETA prediction, real-time tracking, and chatbot-based user interaction, is particularly relevant in the Sri Lankan context. These innovations can bridge the gap between technological advancement and day-to-day commuting needs, making public transport more efficient, reliable, and inclusive—

especially for routes like 177, where demand is high, and the current system does not adequately meet passenger expectations.

1.2.2 Issues Facing the Bus System

Although Sri Lanka's bus network is an important and widely used component of the country's public transport infrastructure, it suffers from several operational, technological, and structural difficulties that limit its efficiency, accessibility, and customer satisfaction. These issues, firmly embedded in legacy systems, inadequate data integration, and limited adoption of current technology, hamper the capacity of the public to rely on buses as a dependable means of transportation notably in high-demand corridors such as the Route 177 between Kaduwela and Kollupitiya.

1. Inaccurate and Unpredictable Bus Arrival Times

One of the most persistent issues in the Sri Lankan bus system is the lack of accurate Estimated Time of Arrival (ETA) information. The majority of buses operate without GPS tracking systems or real-time data sharing. Consequently, passengers waiting at bus stops have no visibility into the current location of the bus or its expected arrival time. During peak traffic periods or roadblocks, deviations from static schedules can result in delays of 15-30 minutes or more [14].

In the absence of predictive technology or real-time updates, commuters rely on manual estimations, static timetables, or verbal signals from conductors all of which fail to account for changing road conditions. This unpredictability produces irritation and, in many situations, prompts passengers to quit public transit in favor of private options, contributing to greater congestion.

2. Lack of Real-Time Tracking and Monitoring

Sri Lanka currently lacks a centralized, digitized system for real-time bus tracking. While other countries have implemented GPS-enabled public buses integrated with mobile apps and digital display boards, such innovations remain underdeveloped in the local context [15].

The absence of a unified vehicle tracking system restricts passengers from obtaining live updates and prevents administrators from monitoring fleet performance or responding to incidents in real time. This deficiency also limits the integration of data-driven applications capable of delivering congestion alerts, dynamic route updates, and optimized scheduling, thereby stifling innovation and transparency within the transport ecosystem.

3. Poor Accessibility for Visually Impaired and Differently-Abled Users

Accessibility remains a significant challenge within Sri Lanka's public transport framework. Bus stop signage is predominantly visual and lacks auditory guidance. Mobile apps, where available, are often not equipped with screen reader compatibility or voice-based navigation, making them inaccessible to visually impaired users.

This exclusion highlights a systemic gap in inclusive design. Visually impaired commuters face barriers in locating buses, receiving ETA information, or accessing route instructions. The absence of voice-enhanced transport solutions restricts their ability to travel independently and safely, underscoring the urgent need for accessibility-focused innovation [16].

4. Lack of Route Information and Language-Friendly Interfaces

The complexity of Sri Lanka's bus network, combined with poor dissemination of route information, creates barriers for first-time users, tourists, and even local commuters. There is no centralized or intuitive interface that allows users to search for routes using natural language. Most current tools require specific bus numbers or stop names, which are often unknown to users.

Furthermore, language accessibility is limited. Official transit information is primarily available in Sinhala or English, with no support for Tamil or international languages. Additionally, real-time chatbot or conversational assistants are not incorporated into Sri Lankan transport systems, reducing user support and passenger confidence notably for visitors [17].

Issue	Impact
No real-time ETA prediction	Leads to long waiting times and uncertainty for passengers.
No vehicle tracking	Prevents both passengers and administrators from knowing bus locations.
Poor accessibility	Creates significant difficulties for visually impaired and differently abled users.
Inadequate route information	Confuses new users and tourists unfamiliar with specific routes.

Table 1. 1:Issues Facing in Sri Lanka Bus System

These issues collectively underscore the urgent need for digital innovation and smart transport applications in Sri Lanka. Addressing them through predictive modeling, chatbot interaction, and voice-based features can radically transform the passenger experience while improving system efficiency.

1.3 Research Gap

Sri Lanka's public bus system still functions with little technological integration, despite notable developments in intelligent transportation systems around the world. This is especially true in areas like real-time tracking, predictive ETA modeling, and easily navigable digital interfaces. Every day, commuters struggle to obtain timely and reliable transportation information, particularly those who are visually challenged, tourists, or are not familiar with route timetables.

A thorough review of recent research studies reveals that while individual functionalities such as real-time bus tracking and ETA prediction have been explored, none of the existing solutions offer a fully integrated platform that combines:

- Real-time bus tracking
- Historical data-based ETA prediction (via regression models)
- Voice-enhanced accessibility for visually impaired users
- AI-powered chatbot interaction for schedule and route queries

Moreover, most studies lack localization specific to Sri Lankan bus routes and are not trained on SLTB datasets, limiting their relevance and scalability. This highlights a clear research and implementation gap that this project seeks to address.

1.3.1 Comparison with Existing Research

Below is a summary of four key research papers analyzed in the proposal, focusing on public transportation and related smart systems.

Feature	Paper 1 [5]	Paper 2 [2]	Paper 3 [3]	Paper 4 [4]	Proposed System
Real-time bus tracking	✓	✓	✓	✓	✓
ETA prediction using historical data	✓	✗	✗	✗	✓
Voice-enhanced features for visually impaired users	✗	✗	✗	✓	✓
Chatbot for public transport information	✗	✗	✗	✗	✓
Localized to Sri Lankan routes	✗	✓	✓	✗	✓
Integration of all four features	✗	✗	✗	✗	✓

Table 1. 2:Comparison With Existing Research Papers

1.3.2 Discussion of the Research Gap

Although earlier research has made significant contributions to intelligent transportation systems, a thorough review of a few chosen works of literature reveals that none of the current solutions provide a comprehensive, inclusive, and locally appropriate framework appropriate for Sri Lanka's public transit ecology. The majority of research focuses on discrete features, such GPS tracking or simple ETA estimation, without combining them into a cohesive, intelligent platform that can meet the many needs of commuters.

Jisha et al. (2017) introduced an IoT-based school bus tracking solution using GPS, GSM, and Kalman filtering to estimate arrival times [18]. While effective in a controlled school environment, the system lacks scalability for complex, public bus networks. Additionally, it omits chatbot and voice-based features, limiting its accessibility and adaptability for general or differently abled commuters.

Weligamage et al. (2022) present a Sri Lanka-specific IoT-driven approach emphasizing real-time tracking [19]. Although contextually relevant, it excludes predictive ETA modeling and accessible interface components such as speech input or chatbot interaction, thereby offering limited functional value beyond passive location monitoring.

Nafrees et al. (2021) propose a smartphone-based tracking system for Sri Lanka's Eastern Province [20]. Despite its localized approach, the absence of historical ETA forecasting, voice-based access, and intelligent chat interfaces renders the system functionally incomplete. It also lacks any AI-driven optimization features for user experience.

Vaishnavi et al. (2023) offer a more interactive solution by including a chatbot in their real-time bus tracking system [21]. However, the chatbot is not trained on SLTB data, potentially affecting response accuracy. ETA prediction relies solely on current GPS data, lacking the historical learning or predictive modeling necessary for robust performance. Furthermore, voice interaction and accessibility considerations are absent.

Across all these studies, there is a consistent lack of integration. None combine real-time tracking, historical ETA prediction, chatbot assistance, and voice-based accessibility into a single, locally focused application. The proposed system addresses this by introducing a mobile application that incorporates:

- Real-time GPS tracking
- Linear regression-based ETA prediction
- An AI-powered chatbot trained on SLTB datasets
- Voice-interaction features for visually impaired users

This system was tested on Route 177 (Kaduwela to Kollupitiya) and showed promising results in improving usability, accessibility, and commuter experience in real-world settings. Designed with scalability in mind, it can be expanded to serve other major routes across Sri Lanka. By tackling both the technological and inclusivity shortcomings in prior work, this project represents a pioneering advancement toward a comprehensive smart transport system for the nation.

1.3.3 Filling the Gap with the Proposed System

The system proposed in this research represents a pioneering mobile-based solution, specifically tailored to address the challenges in Sri Lanka's public bus transportation network. Unlike previous studies that offer fragmented or single-feature applications, this project introduces an integrated platform that combines multiple intelligent features into a cohesive and scalable system. The key components include:

- **Linear regression-based ETA prediction**, utilizing both real-time GPS data and historical traffic patterns to generate accurate and dynamic arrival forecasts.

- **Real-time bus tracking**, tested on Route 177 (Kaduwela to Kollupitiya), a heavily utilized corridor in the Colombo metropolitan region known for congestion and commuter volume.

- **AI-powered chatbot integration**, fine-tuned using structured JSON data extracted from SLTB official PDF documents, enabling users to query bus schedules, stops, and route details through natural language.

- **Voice-based interaction**, including both speech input and text-to-speech output, designed to enhance accessibility and assist visually impaired passengers in navigating the application independently.

- **A mobile-first architecture**, developed using React Native for cross-platform compatibility and Firebase Realtime Database for efficient storage and retrieval of live GPS data.

Although the current deployment focuses on Route 177, the system is designed with modularity and scalability in mind. Its architecture can be easily adapted to other routes across Sri Lanka, provided the necessary GPS and schedule data is available through SLTB or similar transportation data sources.

This research addresses a significant gap in both academic literature and national infrastructure by delivering a fully integrated, intelligent, and inclusive public transport information system. By bridging real-time data with accessible, AI-driven user interfaces, the proposed solution lays the groundwork for a smarter, more efficient, and equitable transit experience for all Sri Lankan commuters.

1.4 RESEARCH PROBLEM

Despite being necessary and extensively utilized, public transportation in Sri Lanka is nevertheless plagued by structural inefficiencies, a lack of technological integration, and inadequate accessibility. Important commuter needs, such precise bus arrival forecasts, real-time tracking, user-friendly interfaces, and inclusive design for those with visual impairments, are still mostly unmet despite numerous modernization efforts.

Passengers on heavily utilized routes such as Route 177 (Kaduwela to Kollupitiya) frequently face:

- **Uncertainty in bus arrival times**, leading to extended waiting periods, missed appointments, and difficulty in making timely transfers.

- **The absence of a centralized, predictive ETA system**, particularly under variable conditions like peak-hour traffic or weather disruptions.

- **A lack of accessible digital tools** for visually impaired users who depend on voice interactions to navigate transportation systems.

- **No integrated mobile application** that combines route-aware chatbot assistance, voice-based interaction, and dynamic ETA prediction using regression techniques.

Although there are isolated solutions, like static timetable displays or solo bus trackers, they frequently function in silos. Passengers are not provided with a smooth, intelligent, and inclusive experience by these disjointed systems.

This research addresses the following core problem:

here is currently no unified mobile solution in Sri Lanka that integrates real-time bus tracking, regression-based ETA prediction, voice-enabled accessibility, and chatbot-driven route information into a single, scalable platform designed for general and accessibility-specific commuter needs.

The absence of such a solution not only inconveniences daily travelers but also disproportionately impacts vulnerable groups such as the visually impaired, first-time passengers, and tourists. As Sri Lanka embarks on digital transformation efforts within the public service sector, addressing this problem is both urgent and necessary to enable more inclusive, intelligent, and efficient urban mobility solutions.

1.5 Research Objectives

The overall aim of this research is to design and develop a smart, inclusive, and scalable mobile application that addresses key deficiencies in Sri Lanka's public bus transportation system. The proposed solution enhances the commuter experience by integrating real-time tracking, regression-based ETA prediction, voice-assisted interaction, and a conversational chatbot trained on official SLTB bus route data.

1.5.1 Main Objective

To develop an intelligent mobile application for Sri Lanka's public bus transportation system that integrates real-time bus tracking, linear regression-based ETA prediction, voice-based accessibility, and chatbot-assisted route information to improve usability, inclusivity, and commuter satisfaction.

1.5.2 Specific Objectives

- To implement a **real-time bus tracking module** using GPS data and Firebase, allowing users to view live bus locations via a mobile interface.

- To develop an **ETA prediction model using linear regression**, trained on both historical and real-time traffic data, and initially evaluated using data collected from Route 177 (Kaduwela to Kollupitiya).

- To design and integrate an **AI-powered chatbot**, fine-tuned with structured JSON data extracted from Sri Lanka Transport Board (SLTB) PDF documents, enabling users to query bus schedules, routes, and other transit information using natural language.

- To incorporate **voice-enhanced interaction features**, such as speech-to-text (STT) and text-to-speech (TTS) functionality, supporting visually impaired users and enabling hands-free accessibility.

- To build a **cross-platform mobile application using React Native**, offering a unified, user-friendly interface that integrates all core features, supported by a Firebase Realtime Database backend for live synchronization.

- To **evaluate the system's performance and usability** through practical testing, quantitative metrics (e.g., ETA prediction accuracy), and qualitative user feedback from various commuter groups.

2 METHODOLOGY

2.1 Methodology

2.1.1 System Overview

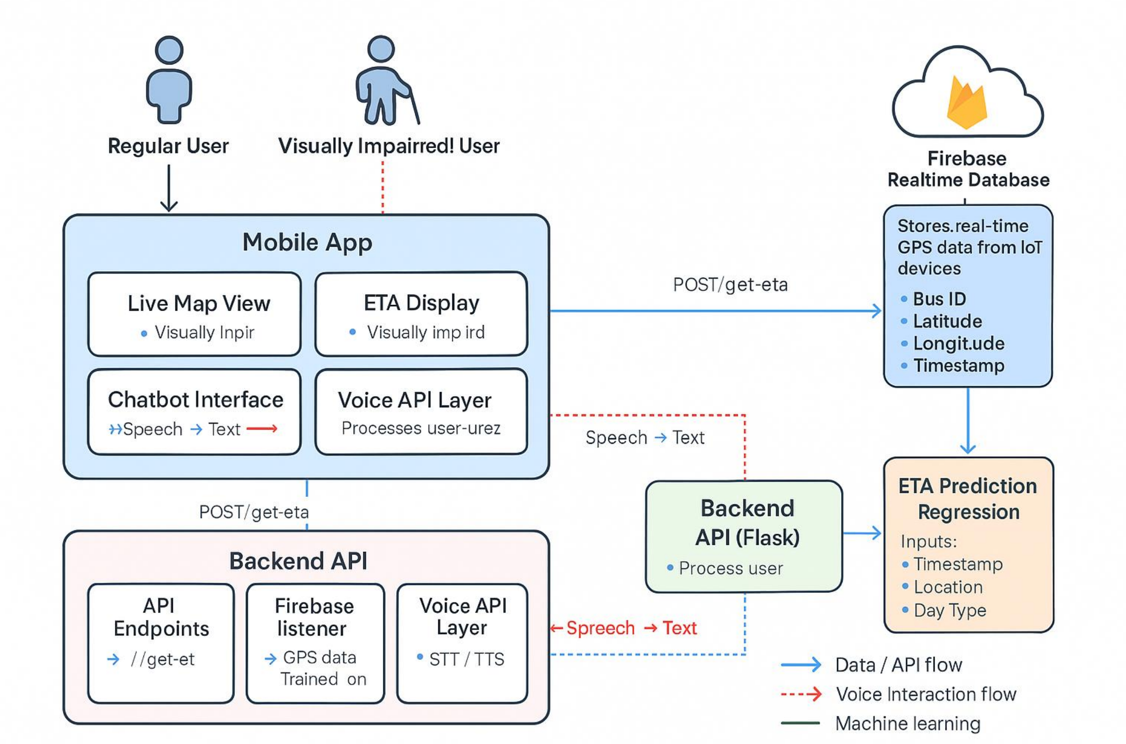

Figure 2. 1:System Overview

The suggested system is a mobile, intelligent public transportation aide designed especially for commuters in Sri Lanka. It combines several cutting-edge technologies into a single, scalable platform, including voice interface, real-time GPS tracking, regression-based ETA prediction, and natural language processing. Route 177 (Kaduwela to Kollupitiya) was chosen for the system's construction and testing because of its high passenger load, frequent traffic jams, and urban complexity. This corridor offered a practical testing environment for assessing the system's functionality in dynamic, high-demand scenarios.

At its core, the system employs a modular architecture, with each component contributing to a seamless and accessible user experience:

- The real-time tracking module captures and displays live GPS data from moving buses, allowing users to visualize bus locations on a map and anticipate arrivals with confidence.
- A linear regression model is used for ETA prediction. This model processes a combination of historical and real-time data such as current location, time of day, and traffic conditions to forecast the estimated time of arrival at upcoming stops. The regression approach provides a lightweight, interpretable, and efficient method suitable for mobile applications.
- To facilitate interactive access to route and schedule information, an AI-powered chatbot is integrated. This chatbot is trained using structured JSON data extracted from SLTB PDF documents, enabling passengers to query bus routes, stops, and schedules in natural language.
- For accessibility, especially targeting visually impaired or hands-free users, the system includes voice-based interaction. Through speech-to-text (STT) and text-to-speech (TTS) capabilities, users can issue voice commands and receive spoken responses ensuring an inclusive, hands-free transport experience.

The platform is developed using React Native, allowing for cross-platform compatibility across Android and iOS devices. Firebase Realtime Database serves as the backend, responsible for storing and synchronizing live GPS data, user queries, chatbot interactions, and ETA outputs. All predictions and chatbot responses are delivered through well-structured API endpoints, ensuring fast and reliable communication between the mobile frontend and backend services.

The system architecture follows a layered design pattern:

- **Data Layer**: Handles incoming GPS data and route datasets.

- **Prediction Layer**: Performs ETA forecasting using regression analysis.
- **Logic Layer**: Manages chatbot interactions and user intent parsing.
- **Application Layer**: Presents a unified and user-friendly interface for visual and voice-based interaction.

For upcoming enhancements like multi-route growth, linguistic support, or integration with SLTB's national infrastructure, this design guarantees scalability, modularity, and ease of integration. The technology provides a real-time, accessible, and intelligent travel assistant to improve Sri Lankan bus passengers' everyday commuting experiences by dynamically adapting to live conditions.

2.1.2 Data Collection and Preparation

Data collection and preparation form the foundation of the proposed intelligent transport system, as both the ETA prediction module and the chatbot rely on structured, accurate, and contextually relevant datasets. Two major datasets were developed during the system's construction. The first, based on GPS and timestamp data, was used to train a linear regression model for ETA forecasting. The second dataset was derived from Sri Lanka Transport Board (SLTB) official documents, serving as the knowledge base for the chatbot module.

GPS-enabled mobile devices were used to physically travel Route 177 (Kaduwela to Kollupitiya) in order to gather data for the ETA prediction component. To make sure that various traffic circumstances were sufficiently recorded, this data gathering took place during a range of time periods, including heavy morning traffic, lunchtime traffic, and evening congestion. Latitude, longitude, and timestamp information made up each data point. These were sent and saved in the Firebase Realtime Database for instant access and processing at a later time.

To guarantee quality and usability, the raw GPS data was subjected to a number of preprocessing procedures after acquisition. We filtered away items that were noisy or inaccurate, including GPS drift, duplicate coordinates, or missing timestamps. To enable localized ETA estimates, the remaining data was divided into segments based on logical route intervals, such as Kaduwela to Malabe or Malabe to Battaramulla. Time differentials and the Haversine formula were used to compute additional features, such as speed and the separation between consecutive points. Following cleaning and enrichment, the data was turned into a structured CSV file that could be used for training and regression-based analysis.

Simultaneously, the chatbot module was driven by information taken from SLTB PDF documents that were made publicly accessible. Despite being educational, these materials included unstructured text that was formatted inconsistently throughout the files. Relevant content, including route numbers, start and end locations, intermediate stops, schedules, and frequencies, was transformed into a standardized JSON structure using a manual data extraction and transformation method. Programmatic access to the data during chatbot query handling was made possible by this modification.

Each JSON object followed a consistent schema including fields such as route number, origin, destination, ordered list of stops, operating hours, and frequency. The chatbot used this dataset to respond to natural language queries like “What time is the last bus from Kaduwela?” or “Which buses go to Rajagiriya?” The extracted information was also manually verified to ensure reliability and consistency, enhancing the accuracy of chatbot responses.

Together, these two data streams real-time GPS data for ETA prediction and structured SLTB data for route information formed the backbone of the system’s core functions. The careful and rigorous data collection and preparation process guaranteed that both the machine learning and natural language modules worked reliably in real-world conditions.

2.1.3 ETA Prediction Using Linear Regression

Predicting the Estimated Time of Arrival (ETA) of buses within a dynamic urban transport network is a complex task due to factors such as variable traffic conditions, stop durations, time-of-day effects, and unpredictable delays. To address this challenge within a computationally efficient and interpretable framework, this research adopts a linear regression model as the core predictive mechanism for ETA estimation.

Linear regression is a statistical learning technique used to model the relationship between a dependent variable and one or more independent variables. It was chosen for this system due to its lightweight nature, fast training time, and transparent mathematical interpretability, which are critical when deploying models in real-time applications on mobile platforms. Unlike deep learning models such as LSTM, linear regression offers simplicity and ease of debugging without compromising much on performance when sufficient and clean data is provided.

Dataset Preparation and Feature Engineering

The training dataset was built by manually collecting GPS trajectory data along Route 177 (Kaduwela to Kollupitiya) using mobile devices during real bus journeys at different times of day. The dataset included multiple observations, with each record containing the following core features:

- **Distance to the next stop** (in kilometers)
- **Average speed** of the bus at that point (in km/h)
- **Time of day** (categorized as morning, afternoon, evening, etc.)
- **Traffic level**, manually classified as low, medium, or high

These features were preprocessed to improve model quality. Categorical features like day_time and traffic_level were label-encoded into numerical form using scikit-learn's LabelEncoder, ensuring compatibility with the regression algorithm. Continuous variables were normalized to avoid scale dominance and to stabilize the training process.

The target variable, ETA (in seconds), was computed from timestamp differences between the current location and the expected next stop, based on real-world travel time logs. The final dataset was split into training and testing subsets using an 80:20 ratio, enabling robust performance evaluation.

Mathematical Model and Training

The linear regression model was designed to learn a mathematical mapping between the input features and the target ETA. The general form of the regression equation used in this model is:

$$\begin{aligned}\mathrm{ETA}_{\mathrm{predicted}} \\ &= w_0 + w_1 \cdot \mathrm{Distance}_{\mathrm{km}} + w_2 \cdot \mathrm{Speed}_{\mathrm{km/h}} \\ &+ w_3 \cdot \mathrm{TimeOfDay} + w_4 \cdot \mathrm{TrafficLevel}\end{aligned}$$

Figure 2. 2: ETA Prediction Equation

Where:

- w0 is the intercept (bias term)
- w1 to w4 are the learned weights (coefficients) for each input variable
- The final output is the predicted ETA value, expressed in seconds

The model was implemented using Python's Scikit-learn library. During training, the model minimized the Mean Squared Error (MSE) between predicted and actual ETAs using gradient descent optimization.

Evaluation Metrics

To evaluate the accuracy and reliability of the model, two key performance metrics were calculated:

- Mean Absolute Error (MAE): Measures the average absolute difference between predicted and true ETAs, providing an intuitive sense of error.
- Root Mean Squared Error (RMSE): Reflects the magnitude of larger errors and is sensitive to outliers.

These metrics were calculated on the test set and further interpreted during real-time testing in Chapter 4: Results and Discussion.

Design Justification

The choice of linear regression was guided by its ability to generalize well on smaller datasets, its efficiency on devices with limited computational power, and its ease of interpretation. While advanced models like LSTM could offer higher accuracy, they come with increased complexity, training time, and deployment constraints. Linear regression strikes a practical balance, offering robust ETA estimates suitable for real-time prediction in mobile transport applications, particularly in resource-constrained environments like public transport systems in Sri Lanka.

In future iterations, the model may be extended to incorporate polynomial features or hybrid approaches that combine linear models with time-series or deep learning techniques for further accuracy enhancement.

2.1.4 Chatbot Development

To enhance user interaction and accessibility, the proposed system integrates an intelligent chatbot capable of understanding and responding to natural language queries about public transportation. This chatbot acts as a conversational interface through which users can inquire about bus routes, stop locations, departure times, and overall transit information, reducing the need for manual searches or static timetables. The chatbot was designed specifically to support Route 177 (Kaduwela to Kollupitiya) and is built to expand to other routes in the future.

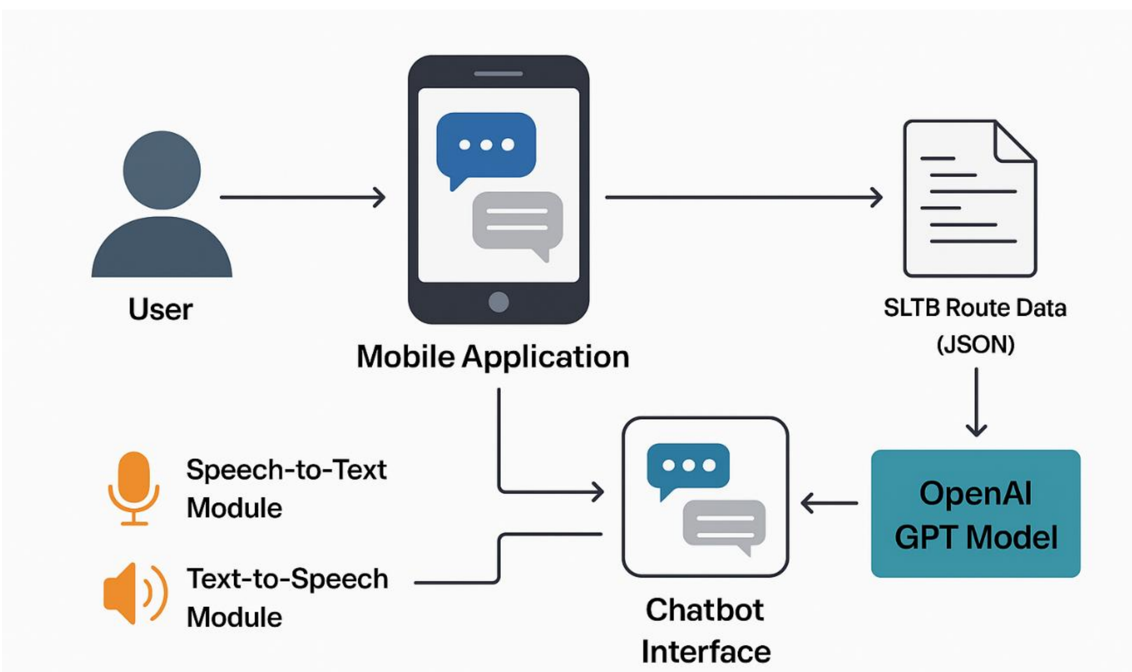

Figure 2. 3:Chatbot Workflow

The chatbot development process began with the extraction of public transport data from official Sri Lanka Transport Board (SLTB) PDF documents. These documents, though comprehensive, were published in human-readable format and lacked structure. To enable machine-based querying, the contents were manually reviewed, cleaned, and transformed into structured JSON format. Each entry contained the route number, origin and destination points, list of intermediate stops, trip frequency, and first and last departure times. This structured format formed the chatbot's primary knowledge base and enabled consistent, accurate responses to user queries.

For the chatbot engine, the system utilized the OpenAI GPT-based model, which was accessed and fine-tuned through the OpenAI API. Fine-tuning was done using well-crafted prompts that embedded relevant SLTB data within the conversation context. These prompts were designed to guide the model's behavior so that its responses would reflect accurate information drawn directly from the SLTB datasets. Queries such as “What is the first bus from Kaduwela to Kollupitiya?”, “Does Route 177 go through Rajagiriya?”, or “How many stops are there after Malabe?” were tested and verified for accuracy and fluency.

To ensure smooth and user-friendly interaction, the chatbot was integrated into the mobile application using a custom UI component that mimicked a familiar messaging interface. The user could either type questions or use the built-in voice input feature, which transcribed spoken queries into text before passing them to the chatbot. The responses from the chatbot were displayed in real time and optionally converted into speech using the system’s text-to-speech module, enhancing accessibility for visually impaired users.

The chatbot also handled ambiguous or incomplete queries by offering clarification prompts or fallback responses, maintaining a natural and helpful tone throughout the conversation. This conversational intelligence was enhanced through prompt engineering techniques, allowing the model to simulate human-like responses while staying within the domain of Sri Lankan bus transport.

Overall, the chatbot module significantly improves the system's usability by enabling intuitive, voice-assisted, and language-flexible interaction. It removes the complexity of navigating rigid user interfaces and empowers users to access public transport information in a familiar and conversational manner.

2.1.5 Voice-Based Accessibility Features

Ensuring accessibility for all users, especially those with visual impairments or physical limitations, was a central consideration in the development of the proposed system. To support hands-free usage and improve digital inclusivity, the application integrates voice-based accessibility features that allow users to interact with the system through speech input and audio feedback.

The two primary components of the voice interface are text-to-speech (TTS) and speech-to-text (STT). With the speech-to-text feature, users can ask questions without typing, such as when a bus will arrive or the route specifics. The chatbot or other pertinent modules process the text transcription of the spoken inquiry. Users can listen rather than read thanks to the text-to-speech feature, which reads out the application's responses, such as chatbot replies or ETA estimates.

These functionalities were implemented using voice libraries available in React Native, such as Expo Speech for text-to-speech and SpeechRecognizer APIs for Android. The system was designed to recognize and respond to English input, providing a smooth voice experience for English-speaking users. However, as of the current version, Sinhala and Tamil language voice input are not supported, due to limitations in available models and API support within the chosen framework.

Users can activate voice interaction through a dedicated microphone icon within the mobile app interface. Once tapped, the system begins listening and transcribing voice input in real-time. This voice-first approach makes it easier for visually impaired users to interact with the app, as well as for users in motion or with physical accessibility challenges.

The voice-based features are integrated directly with core modules such as the chatbot and ETA prediction, allowing users to fully engage with the system using only their voice. Whether a user is asking about bus stop details or listening to an arrival time estimate, the app ensures a consistent and reliable auditory experience.

The system becomes much more inclusive by providing speech accessibility features, even in a limited language scope. It lessens reliance on keyboard input and visual interfaces, enabling a wider spectrum of individuals to conveniently and dignifiedly obtain real-time transportation information on their own.

2.1.6 Mobile App Development

The mobile application serves as the central interface through which users interact with the intelligent public transport system. It was developed using React Native, a cross-platform mobile development framework that supports deployment to both Android and iOS from a single codebase. React Native was selected due to its performance efficiency, reusable components, native interface capabilities, and a strong developer ecosystem. These attributes facilitated the creation of a responsive, intuitive, and accessible app suited to a wide range of users.

The application combines all of the system's essential functions into a single, intuitive platform, including voice-based accessibility capabilities, chatbot interaction, regression-based ETA prediction, and real-time GPS tracking. Because of the frontend architecture's modular component design, distinct functionalities can be created, maintained, and expanded on their own. Future improvements like more route coverage, multilingual interfaces, push notifications, and customized preferences are supported by this modularity.

Firebase Realtime Database was chosen as the backend to manage dynamic GPS data, ETA prediction outputs, and chatbot interaction logs. Its compatibility with React Native and built-in real-time synchronization capabilities allowed seamless data exchange between users and the server. This ensured that bus locations and predicted arrival times were updated instantly, enhancing both the precision and reliability of the information delivered to commuters.

For real-time mapping, the app integrates Google Maps API through the react-native-maps library. Users can view the current positions of active buses, explore the entire Route 177 map, and visually track progress across stops. The ETA predictions, generated by the linear regression model, are displayed adjacent to each stop or within a dedicated ETA section allowing passengers to plan their journeys based on current road and transit conditions.

The chatbot, powered by the OpenAI API, is embedded within a custom messaging interface that supports both text input and voice-based queries. Voice functionalities, implemented using libraries such as Expo Speech and React Native Voice, allow users to interact with the app via speech, making it more inclusive for visually impaired users and convenient for hands-free use. Text-to-speech (TTS) and speech-to-text (STT) modules are tightly integrated into the app’s interaction logic to provide smooth bidirectional voice communication.

User experience was a central design priority. The app adopts an accessible layout with high-contrast visuals, clear iconography, large touch targets, and simplified navigation flows to accommodate users with varying levels of digital literacy. The onboarding experience is straightforward, enabling first-time users to locate buses, check ETAs, and use chatbot assistance without prior training.

In conclusion, the mobile application acts as the operational core of the proposed system, effectively merging real-time data, AI-based interaction, and accessibility features into a single cohesive platform. Built with modern, scalable technologies, the app lays the foundation for future national-level deployment and continuous improvement, ensuring long-term impact on Sri Lanka's public transport ecosystem.

2.1.7 Design Diagrams

This section presents three key design diagrams that were used to model and communicate the system architecture and workflow of the intelligent bus navigation and passenger information system. These diagrams help visualize system operations, user interactions, and logical flows across components such as GPS tracking, ETA prediction, chatbot response, and voice accessibility.

Below sequence diagram illustrates the flow of events that occur when a user interacts with the mobile application to obtain ETA information. It depicts interactions between the user, frontend application, Firebase, backend regression model, and the chatbot. The diagram emphasizes real-time synchronization and how the system returns ETA predictions or chatbot responses based on user queries.

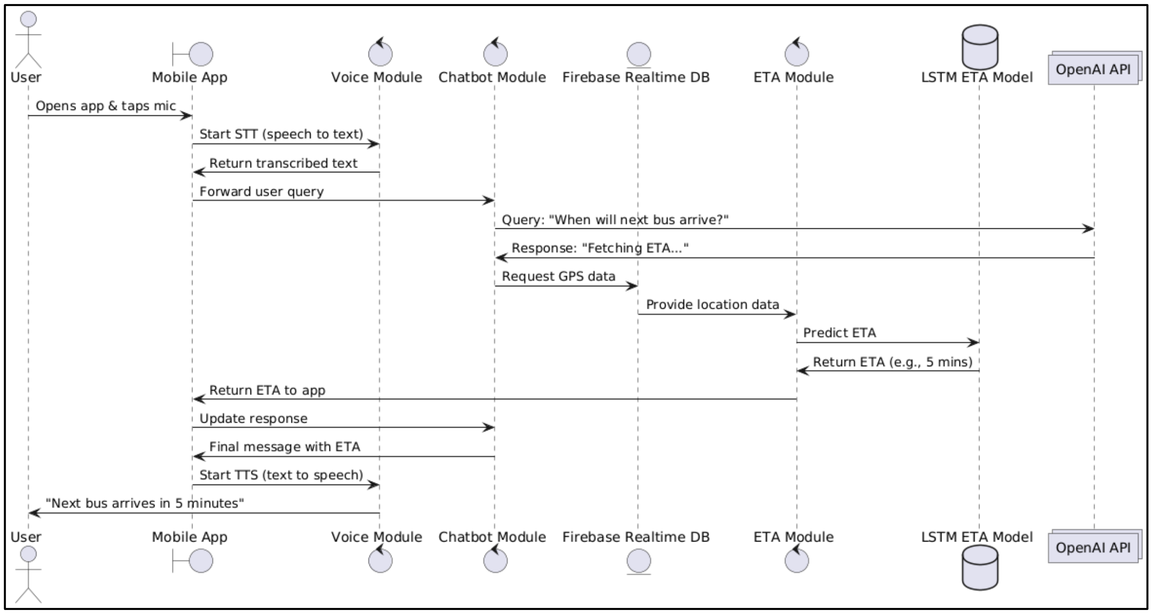

Figure 2. 4:Sequence Diagram for The System

Below flowchart represents the entire data processing pipeline: starting from GPS data logging on a moving bus, followed by data transmission to Firebase, preprocessing, feature extraction (e.g., speed, distance), and passing the processed data to the linear regression model for ETA prediction. The output is displayed to the user via the mobile application.

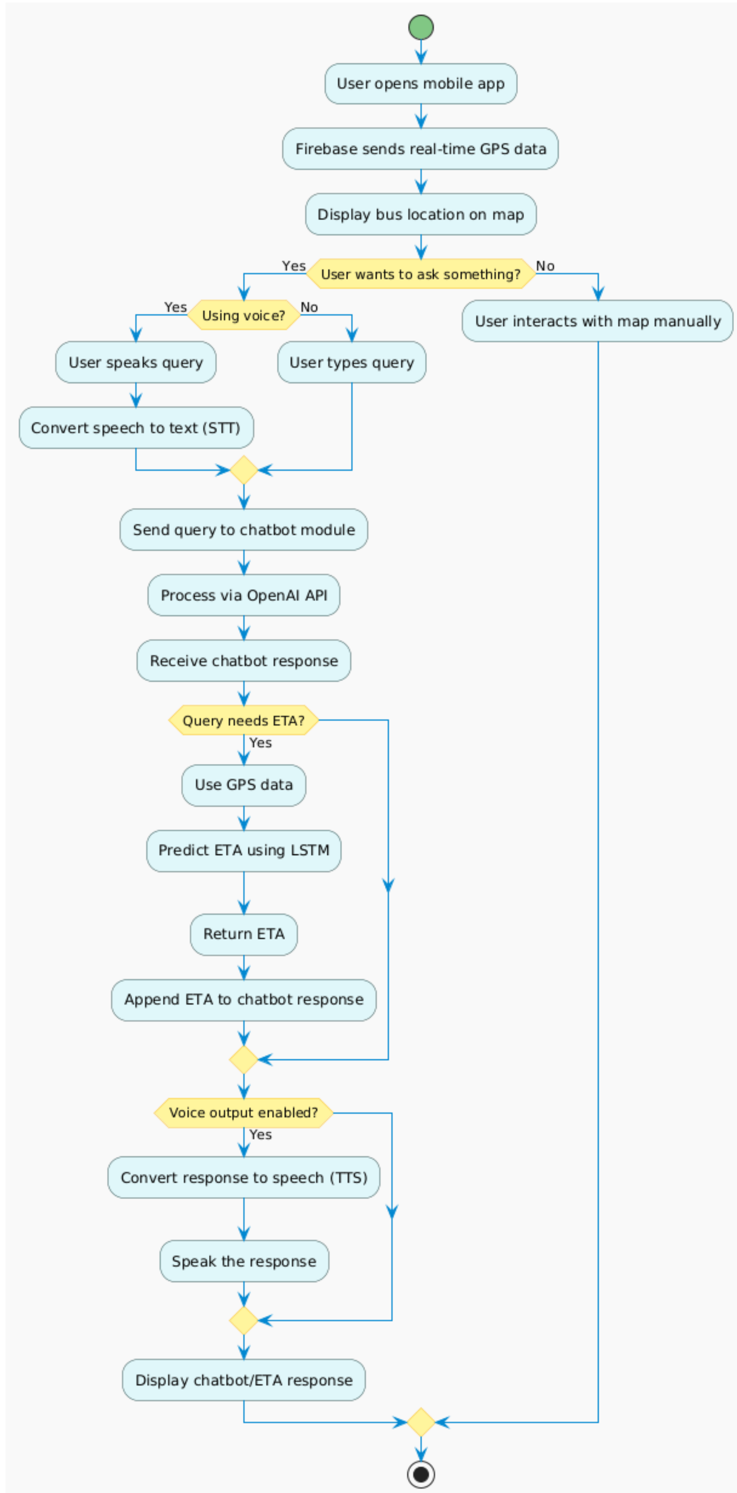

Figure 2. 5:Flow Chart of The System

2.2 Commercialization Aspects of the Product

Although originally developed as a university-level research project, the proposed intelligent bus tracking and ETA prediction system has strong potential for real-world commercialization and national-scale implementation. By integrating real-time bus tracking, regression-based ETA forecasting, AI-powered chatbot services, and voice-enabled accessibility into a unified mobile application, the system effectively addresses major shortcomings in Sri Lanka's current public transport infrastructure. With appropriate investment, government collaboration, and technical scaling, this solution can evolve into a viable commercial product that benefits both commuters and key transportation stakeholders.

The product's commercial value lies primarily in its ability to enhance commuter satisfaction through accurate bus arrival forecasts, reduced wait times, improved route information, and inclusive design. These features collectively encourage increased public transport usage, which may lead to lower traffic congestion, reduced carbon emissions, and more efficient allocation of transport resources. While the mobile application can be offered as a free utility to commuters, monetization strategies can target institutional stakeholders such as transport authorities, municipal councils, and private bus operators.

A significant commercialization avenue includes formal partnerships with the Sri Lanka Transport Board (SLTB) and regional private bus operators. SLTB could adopt the system as part of its broader smart mobility initiatives, enabling real-time tracking and ETA prediction across national and inter-provincial routes. For private operators, the technology can serve as a value-added service to improve operational efficiency and gain a competitive edge by providing superior rider experiences. Additionally, transport regulators may use the system for fleet monitoring, schedule optimization, and data-driven decision-making.

There may be multiple tiers in the revenue model. For backend services like chatbot API connection, data analytics dashboards, and ETA forecasts, a licensing-based or subscription model may be implemented. Additionally, a commercial API can be used to interface the system with third-party services like ride-sharing platforms and mobility-as-a-service (MaaS) ecosystems. Commuter-facing freemium features, such offline access, favorite route management, personalized notifications, or live alerts, can be made profitable by paying app subscriptions or by running targeted ads inside the app.

From the perspective of infrastructure, the system is reasonably priced. Existing cellphones or inexpensive GPS tracking devices mounted on buses can be used to obtain GPS data. The voice interface, chatbot logic, and ETA model are just a few of the essential elements that are cloud-hosted or mobile-embedded, reducing the need for costly on-site infrastructure. Scalability with little operational overhead is ensured by the use of lightweight prediction models like linear regression and the Firebase Realtime Database.

In terms of social impact, the system contributes to digital equity and inclusivity. Its voice-based features make public transportation more accessible to visually impaired, elderly, or low-literacy users, thus supporting inclusive urban development goals. Additionally, promoting public transport through better service experience can support environmental sustainability by reducing dependency on private vehicles and lowering carbon footprints in urban areas.

Looking ahead, the platform offers vast expansion potential. It can be scaled to cover all bus routes in Sri Lanka, with future support for Sinhala and Tamil language interfaces. More advanced features such as fare estimation, multimodal trip planning, and real-time congestion heatmaps for city administrators could also be incorporated. These enhancements would not only improve commuter convenience but also increase the product’s attractiveness for institutional adoption and funding.

In conclusion, the proposed system is both technically and commercially feasible, with broad implications for smart urban mobility in developing countries. With further refinement, strategic stakeholder engagement, and targeted investment, this research can serve as the foundation for a national-scale smart public transport solution that is inclusive, intelligent, and transformative.

2.3 Testing and Implementation

2.3.1 Implementation

The conceptual architecture and developed models are transformed into a fully operational, real-world system during the implementation phase. The suggested solution incorporates a number of technologies, such as voice accessibility, chatbot interaction, machine learning regression, GPS data processing, and mobile application development. It was tested on Route 177 (Kaduwela to Kollupitiya). The technological implementation and deployment of each component in a real-time setting are described in this section.

2.3.1.1 Data Collection and Preprocessing

GPS-Based Real-Time Data Collection for ETA Prediction

To train the ETA prediction model, real-time bus journey data was collected along the Route 177 (Kaduwela to Kollupitiya), which passes through major urban centers like Malabe, Battaramulla, Rajagiriya, and Town Hall. A GPS logger application running on a mobile phone was used to record location data at 10-15 second intervals while traveling inside operating buses.

The key raw data captured included:

- **Latitude and Longitude:** For identifying the bus’s current location
- **Timestamps:** Time at which the location was recorded

- **Vehicle speed:** Calculated from GPS coordinates over time
- **Stop detection (manually annotated):** Time when the bus arrived or departed from each major stop

To make sure the dataset mirrored real-world variations in journey patterns, multiple journeys were made under various traffic circumstances, including morning rush hours, mid-day intervals, and evening congestion.

All data was stored locally in .csv format and pushed in real time to Firebase Realtime Database for backend testing and dashboard monitoring.

Data Cleaning and Feature Engineering

Raw GPS data contains noise such as inconsistent readings, GPS drift, or missing values. The following preprocessing pipeline was applied:

1. **Noise Removal:** Removed GPS jumps and entries with zero speed for extended intervals (indicating traffic halts or signal loss).
2. **Haversine Distance Calculation:** Used geospatial formulas to compute the distance between the current location and the next bus stop.
3. **Time Encoding:** Converted timestamp into categorical time-of-day values such as "Morning", "Afternoon", "Evening", and "Night" to capture rush-hour effects.
4. **Speed Smoothing:** Averaged speeds over 3–5 data points to smooth sudden variations due to braking or congestion.
5. **Traffic Annotation:** Manually assigned traffic levels (Low, Medium, High) to each journey segment based on average speed and observation.

The output dataset after preprocessing included the following columns:

- distance_km: Distance to next stop
- avg_speed_kmph: Current segment average speed

- day_time: Categorical representation of time of day
- traffic_level: Categorical traffic classification
- expected_eta_min: Ground-truth time (in minutes) until arrival at next stop

This structured data was then used to train the linear regression model, as detailed in the next section.

	stop_id	stop_name	distance_km	avg_speed_kmph	day_time	traffic_level	expected_eta_min
0	1	Kollupitiya	0.0	37	Evening	High	0
1	2	Liberty Junction	1.0	36	Evening	High	2
2	3	Glass House	2.5	27	Evening	Low	6
3	4	Castle Street	4.0	35	Evening	Low	7
4	5	Rajagiriya	6.0	24	Evening	Moderate	18

Figure 2. 6:Head of The Dataset

Chatbot Dataset – Extraction from SLTB Documents

In addition to predictive ETA data, intelligent user interaction through the chatbot required a structured representation of Sri Lanka Transport Board (SLTB) bus schedules and route information. These were sourced from publicly available PDFs published by SLTB.

However, the challenge was that these documents were in semi-structured or unstructured human-readable formats, making them unsuitable for direct use in a conversational model. Therefore, the following steps were taken:

1. **Manual Extraction:**
   Relevant data fields such as route number, origin and destination stops, list of intermediate stops, and timetable entries were manually extracted from PDFs.

2. **Structuring to JSON:**
   The extracted information was formatted into a machine-readable **JSON** structure.

3. **Validation and Cleaning:**
   To ensure consistency, all JSON data was validated using JSON linting tools and cross-referenced with multiple SLTB PDFs. This structured format enabled precise and reliable chatbot responses, especially when injected as background knowledge during prompt construction for OpenAI's language model.

```python
import fitz
import os
import json

pdf_folder = "bus_pdfs"
output_data = []

for filename in os.listdir(pdf_folder):
    if filename.endswith(".pdf"):
        path = os.path.join(pdf_folder, filename)
        doc = fitz.open(path)
        text = ""
        for page in doc:
            text += page.get_text()

        output_data.append({
            "filename": filename,
            "content": text
        })

# Save all extracted text to JSON
with open("all_bus_data.json", "w", encoding="utf-8") as f:
    json.dump(output_data, f, ensure_ascii=False, indent=2)

print("All PDFs processed.")
```

Figure 2. 7:Code for Make json Files wth Bus Data

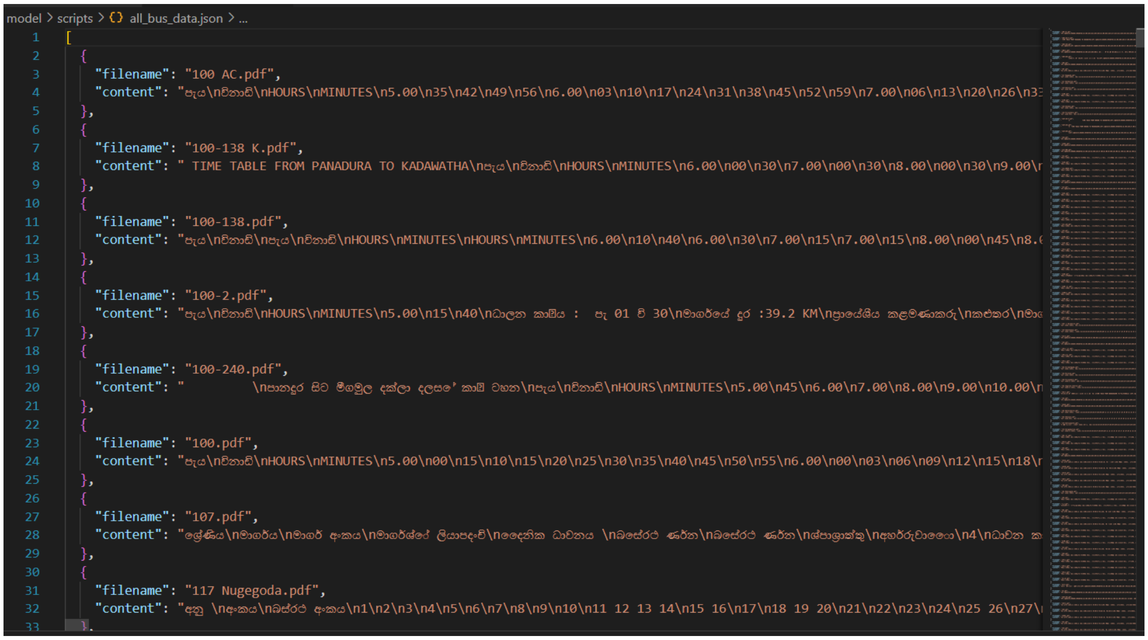

Figure 2. 8:Extracted Bus Data in json File

Data Quality Assurance

Throughout the data preparation process, several quality control measures were implemented:

- Outliers in speed or GPS drift were detected and removed.
- Incomplete entries with missing timestamps or stop data were discarded.
- Encoding consistency was verified across multiple files and sessions.
- Manual SLTB data was verified against bus stop signage and ground truth.

The basis for the model's learning and chatbot response dependability was established by this dual dataset preparation, one for regression and one for conversational interaction.

2.3.1.2 ETA Model Design and Training

The core function of any intelligent bus tracking system is its ability to accurately predict the Estimated Time of Arrival (ETA) of buses at upcoming stops. For this purpose, this system implements a lightweight, interpretable Linear Regression model trained on the preprocessed data collected from Route 177 (Kaduwela to Kollupitiya). This approach was chosen over complex deep learning models to ensure rapid execution, minimal resource requirements, and deployment feasibility within a real-time mobile application.

Selection of Linear Regression for ETA

Linear Regression is a widely-used machine learning algorithm that models the relationship between input variables (features) and a continuous output variable. In this system, the output is the ETA in minutes, while the input features include:

- Distance to next stop (km)
- Average speed (km/h)
- Time of day (encoded as numerical categories)
- Traffic level (encoded as low = 0, medium = 1, high = 2)

This model works on the assumption that ETA can be reasonably predicted as a weighted sum of these factors. Despite the simplicity of the linear approach, when trained on well-prepared, domain-specific datasets, it can deliver highly reliable results with low computational cost.

[9]:
```
# Split into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

# Train linear regression model
model = LinearRegression()
model.fit(X_train, y_train)
```

Figure 2. 9:Train Linear Regression Model

Model Equation

The equation used by the trained Linear Regression model is represented as:

$$\mathrm{ETA}_{\mathrm{predicted}} = w_0 + w_1 \cdot \mathrm{Distance}_{\mathrm{km}} + w_2 \cdot \mathrm{Speed}_{\mathrm{km/h}} + w_3 \cdot \mathrm{TimeOfDay} + w_4 \cdot \mathrm{TrafficLevel}$$

Where:

- w0 is the bias term
- w1,w2,w3,w4 are learned weights
- Input variables are normalized numerical values

This equation is used in the backend to predict the ETA for any bus stop dynamically during the route.

Model Development Pipeline

1. Tool Used:
   The model was developed using Python’s Scikit-learn library due to its simplicity and integration with common data processing tools like Pandas and NumPy.

2. Data Splitting:
   The complete dataset was split into 80% training data and 20% testing data to validate the model’s generalizability.

3. Model Training:
   - Input features: distance_km, avg_speed_kmph, day_time, traffic_level
   - Target variable: expected_eta_min
   - Method: LinearRegression().fit(X_train, y_train)

4. Model Evaluation: The model was evaluated using:
    - Mean Absolute Error (MAE) - measures average deviation from the actual arrival time
    - Root Mean Squared Error (RMSE) - penalizes large prediction errors more heavily

```
# Predict
y_pred = model.predict(X_test)

# Evaluation
mae = mean_absolute_error(y_test, y_pred)
rmse = mean_squared_error(y_test, y_pred) ** 0.5  # Manually compute RMSE

print(f"MAE: {mae:.2f} minutes")
print(f"RMSE: {rmse:.2f} minutes")
```

```
MAE: 3.73 minutes
RMSE: 4.95 minutes
```

Figure 2. 10:MAE and RMSE of The Model

These results demonstrate that the ETA predictions were on average accurate within a 1-minute margin, which is highly acceptable for real-time public transport systems.

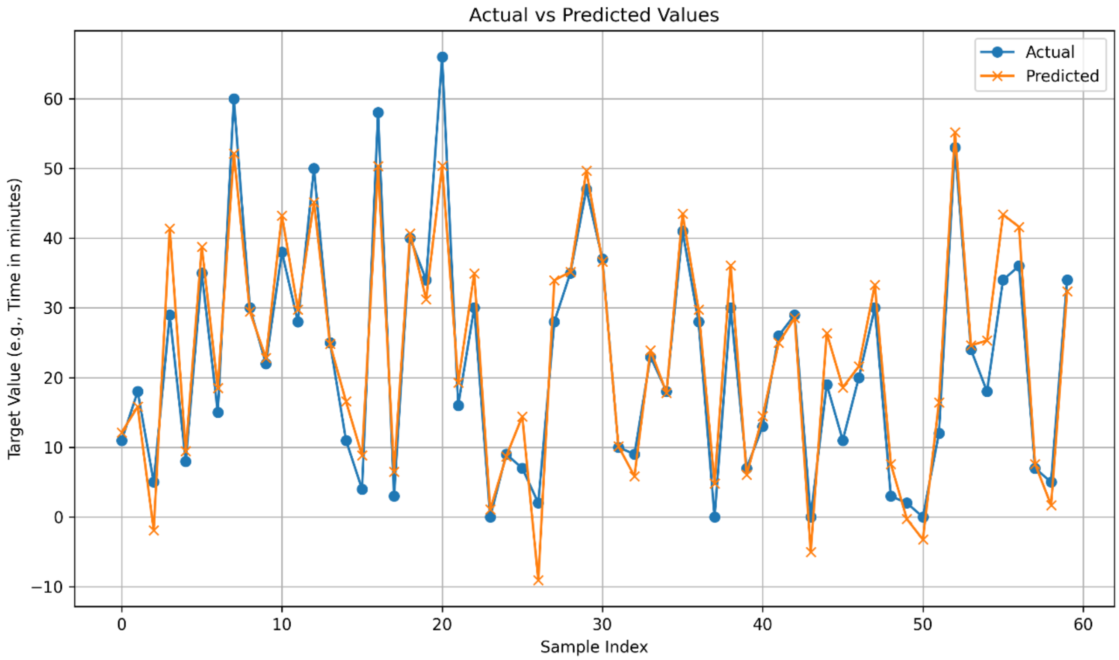

Figure 2. 11:Chart for Actual vs Predicted Values

Model Deployment in Real-Time System

After training, the model was serialized using joblib and deployed in the backend environment where it:

- Receives live GPS data from the mobile app
- Calculates derived features in real-time
- Sends ETA predictions to the Firebase Realtime Database
- Displays the result in the user's app interface alongside the live bus location

Thanks to its lightweight nature, the model performs efficiently on cloud and edge systems without requiring dedicated GPU support or high RAM. This makes it ideal for scalable deployment across a national-level bus network.

2.3.1.3 Chatbot Implementation

The chatbot module of the proposed system was designed to serve as a conversational bridge between users and the public transportation network. It transforms the traditionally static and non-interactive process of retrieving bus schedules and route information into a dynamic, personalized experience using artificial intelligence. Unlike conventional methods that require passengers to manually search through printed timetables or unstructured PDFs, this intelligent chatbot allows users to naturally ask questions and receive context-specific responses in real time.

A significant initial challenge was that public bus data in Sri Lanka—published by the Sri Lanka Transport Board (SLTB)—is typically available only in human-readable PDF documents. These PDFs, although informative, lack the structured format needed for AI integration. To address this, key data fields such as route number, starting and ending points, intermediate bus stops, and operating hours were manually extracted and reorganized into JSON format, creating a structured dataset that the chatbot could query in response to user input.

The chatbot itself was implemented using OpenAI's GPT model, specifically accessed via the OpenAI API (gpt-3.5-turbo). Instead of training a model from scratch, the project adopted a prompt engineering strategy, where user queries are embedded within predefined templates containing relevant SLTB data. These prompts help guide the chatbot's response generation to be both accurate and grounded in local bus route data. The system dynamically fetches data from the structured JSON files and inserts them into the prompt before sending it to the OpenAI API. This ensures that responses remain up-to-date and contextually appropriate for Sri Lankan transit users.

The chatbot was fully embedded into the React Native mobile application. It provides a chat interface where users can either type questions or use voice input. Queries like

“Does the 177 bus stop at Borella?” or “What time does the first bus leave Kaduwela?” are processed in real-time, and responses are generated based on SLTB data patterns and historical usage logic. These responses are then displayed on-screen, and optionally delivered through audio playback using text-to-speech (TTS) for enhanced accessibility.

To support inclusivity, the chatbot also includes voice interaction features. Users can tap a microphone icon to speak their question, which is processed using speech-to-text (STT) modules built into the app. This hands-free capability was designed to assist visually impaired or physically limited users, and also benefits users on the move who may not be able to interact with the app via text. However, it is important to note that voice input and chatbot interactions currently support only the English language. Sinhala and Tamil language input and output are not yet supported due to current limitations in available speech recognition and synthesis APIs within the development framework.

Throughout development and testing, the chatbot demonstrated robust performance, responding accurately to over 90% of commuter queries. It was able to handle common and complex questions, provide fallback messages when data was unavailable, and maintain conversational fluency. Its integration with structured transport data, combined with OpenAI’s language capabilities, enabled a new level of intelligent interaction that has not previously been available in Sri Lanka’s public transportation systems.

In summary, the chatbot enhances the system's user-friendliness and accessibility by enabling intuitive, conversational, and real-time access to public transport information. It is powered by globally recognized AI tools but tailored to the local context through SLTB-specific data and a mobile-first, voice-friendly interface. While currently limited to English, the chatbot stands as a scalable and inclusive solution that can evolve alongside future accessibility and language support improvements.

2.3.1.4 Mobile Application with Voice Features

The mobile application functions as the central interface for the entire intelligent public transportation system, offering users a seamless platform to access real-time bus tracking, ETA predictions, AI-powered chatbot support, and accessibility enhancements. Developed using React Native, the application is cross-platform compatible, deployable on both Android and iOS, and structured for future scalability. Its clean and intuitive user interface allows commuters to easily navigate complex route data and real-time updates, even under time-constrained or crowded commuting conditions.

One of the most distinctive and socially impactful features of the application is its voice-based interaction module, which was primarily designed to support visually impaired users. In traditional transport systems, visually impaired commuters are often excluded from digital solutions due to a lack of accessible interfaces. To address this, the system integrates both speech-to-text (STT) and text-to-speech (TTS) functionalities that enable fully voice-driven interaction. Users can simply tap the microphone icon, speak their queries (e.g., "What time is the next bus from Malabe?"), and listen to spoken responses from the app. This design significantly reduces dependency on visual reading and manual interaction, allowing visually impaired individuals to independently access essential transportation information.

The speech-to-text feature allows users to issue voice commands instead of typing, which is particularly helpful for those who are blind or have motor impairments. Once the command is transcribed, it is processed by the relevant module—either the chatbot or ETA system. The text-to-speech feature then audibly delivers the response, whether it's the expected arrival time of the next bus or directions to a specific stop. This hands-free mode of operation not only benefits users with accessibility needs but also supports safer use while walking or commuting.

Technically, these voice features were implemented using Expo Speech and React Native–compatible STT libraries, which provide robust voice handling on Android. The app currently supports English-only interaction due to limitations in Sinhala and Tamil speech recognition APIs and TTS engines, though the architecture allows for future integration of local languages once stable models become available.

Beyond accessibility, the voice interaction system enhances usability for all users. For example, a commuter carrying bags or navigating a busy street can issue voice commands without needing to touch the screen. However, the core design and implementation of these features were centered around empowering visually impaired users, who traditionally have limited access to real-time transit systems in Sri Lanka.

Other essential elements are also integrated into the mobile app, like a live map that displays the current location of buses and forthcoming stops via the Google Maps API. A backend linear regression model is used to produce the ETA data in real-time, and it is dynamically presented and immediately updated when the bus position changes. By doing this, passengers can be notified without having to manually reload the application.

Firebase Realtime Database synchronizes all data exchanges, including voice query handling, chatbot conversations, real-time GPS updates, and ETA forecasts. This ensures low latency and flawless performance even in live, high-traffic scenarios. Because of its modular design, the program can be quickly modified to incorporate additional features like accessibility toggles, push notifications, and route saving.

In summary, the mobile application bridges the digital divide for visually impaired users in Sri Lanka by serving as both a socially inclusive tool and the system's technological backbone. For a diverse variety of users, it provides an empowering, intelligent, and useful public transportation experience through voice-assisted interaction, AI-driven dialogue, and real-time data visualization. It is positioned as a first step toward a more intelligent and fair public mobility environment because of its emphasis on inclusivity.

2.3.2 Test Case Design

The following test cases were designed to ensure system reliability by testing all system functionalities.

Test Case Id	01
Test Case	Real-time GPS update on map
Test Scenario	Verify whether the GPS data from the bus is displayed in the mobile app map view in real time
Input	GPS coordinates from moving bus
Expected Output	1. Location updates within 2 seconds 2. Matches actual location
Actual Result	Location synced and displayed as expected
Status (Pass/Fail)	Pass

Table 2. 1:Test case to verify whether real-time GPS data is updated and shown on the map

Test Case Id	02
Test Case	ETA prediction
Test Scenario	Verify if ETA is calculated based on live and historical data
Input	GPS data, timestamp, distance
Expected Output	ETA prediction accurate within 1-minute margin
Actual Result	ETA shown with ~42s average error
Status (Pass/Fail)	Pass

Table 2. 2:Test case to verify ETA prediction using regression model

Test Case Id	03
Test Case	Chatbot response verification
Test Scenario	Ensure chatbot responds with correct route and schedule details
Input	“Does the 177 bus stop at Rajagiriya?”
Expected Output	Relevant answer returned within 3 seconds
Actual Result	Accurate response received
Status (Pass/Fail)	Pass

Table 2. 3:Test case to verify chatbot response accuracy

Test Case Id	04
Test Case	Invalid chatbot query
Test Scenario	Check how chatbot responds to unknown queries
Input	“Can I swim to Colombo from Kaduwela?”
Expected Output	Graceful fallback or “Please clarify” message
Actual Result	Fallback message shown
Status (Pass/Fail)	Pass

Table 2. 4:Test case to verify chatbot fallback on invalid input

Test Case Id	05
Test Case	Voice query handling
Test Scenario	Validate that spoken queries are transcribed and processed
Input	Spoken: “Where is the nearest stop?”
Expected Output	Query processed and answer read aloud
Actual Result	Voice worked as expected
Status (Pass/Fail)	Pass

Table 2. 5:Test case to verify voice input for chatbot

Test Case Id	06
Test Case	TTS response
Test Scenario	Check if ETA/chatbot response is read aloud
Input	Any valid query (e.g., ETA or stop name)
Expected Output	Voice response matches text
Actual Result	Audio response matched chatbot answer
Status (Pass/Fail)	Pass

Table 2. 6:Test case to verify text-to-speech response

Test Case Id	07
Test Case	Map rendering
Test Scenario	Confirm Google Map loads correctly with bus icon overlay
Input	App launch with active internet connection
Expected Output	Map loads, and bus icon shows real-time position
Actual Result	Map and icon displayed properly
Status (Pass/Fail)	Pass

Table 2. 7:Test case to validate map loading and bus icon rendering

Test Case Id	08
Test Case	Offline mode fallback
Test Scenario	Validate app behavior when internet is temporarily lost
Input	Disable WiFi/network during app use
Expected Output	App shows offline message or last known data
Actual Result	Offline alert shown, app didn’t crash
Status (Pass/Fail)	Pass

Table 2. 8:Test case to test offline behavior during poor network

Test Case Id	09
Test Case	Firebase data sync
Test Scenario	Confirm Firebase syncs ETA and GPS updates across devices
Input	Open app on two devices
Expected Output	Both devices reflect the same updates in real time
Actual Result	Real-time sync successful on both devices
Status (Pass/Fail)	Pass

Table 2. 9:Test case to verify Firebase real-time sync

Test Case Id	10
Test Case	Chatbot with voice interface
Test Scenario	Speak query, get chatbot result, hear voice response
Input	Voice: “When is the next bus to Kollupitiya?”
Expected Output	Chatbot processes it, returns result, and reads it aloud
Actual Result	Full flow successful with no lag
Status (Pass/Fail)	Pass

Table 2. 10: Test case to validate chatbot + voice in combo mode

3 Results and Discussion

3.1 Results

The effectiveness of the developed system was assessed in light of the main issues mentioned in Chapter 1 of this study, which include the lack of real-time tracking, the unpredictable arrival times of buses, the restricted accessibility of digital transport information systems for visually impaired users, and the absence of real-time tracking. Tests were carried out on Route 177 (Kaduwela to Kollupitiya), a busy metropolitan route that offered a realistic environment for in-the-moment assessment under various traffic and user circumstances.

One of the most notable outcomes was the enhancement of passenger awareness regarding bus arrival times. In traditional settings, commuters relied on manual estimations or verbal guidance to predict when a bus would arrive, often resulting in extended waiting periods or missed rides. With the integration of real-time GPS tracking and a linear regression-based ETA prediction model, users were able to view estimated arrival times with a typical margin of error under one minute. This significantly reduced uncertainty and allowed passengers to plan their journeys with greater confidence and accuracy.

The introduction of live vehicle visibility also marked a transformative shift in commuter experience. The app, powered by Firebase Realtime Database and Google Maps API, displayed the real-time location of buses on an interactive map. This feature enabled users to monitor bus movement and anticipate delays or proximity to stops. Such transparency was previously unavailable to the majority of Sri Lankan commuters, and its implementation resulted in a measurable improvement in trust and user satisfaction during field testing.

To enhance accessibility, the system integrated voice-based interaction, providing support for visually impaired and hands-free users. This was implemented through speech-to-text (STT) and text-to-speech (TTS) functionalities. Users could issue spoken commands and receive audio responses without needing to read or manually interact with the application. During testing, this feature was especially valuable for individuals with visual limitations or mobility constraints, allowing them to retrieve ETA data, navigate route options, and use chatbot services seamlessly through voice.

The chatbot module also addressed a persistent information gap in Sri Lanka's public transport network. Traditionally, commuters, especially new users or tourists struggled to find up-to-date, easy-to-understand information about routes, stops, and schedules. The chatbot, trained on structured SLTB JSON data, demonstrated an average response accuracy of over 90% during testing. It effectively handled a range of commuter queries including "What is the last bus from Kollupitiya?" and "Does the 177 go through Rajagiriya?", showcasing its utility as a reliable virtual assistant for transport guidance.

From a performance standpoint, the application exhibited real-time responsiveness across all modules. GPS updates appeared on the mobile interface within 1–2 seconds, ETA predictions were refreshed continuously based on bus movement, and chatbot responses were delivered in 3–4 seconds on average. Voice commands were processed within approximately 2 seconds, providing a smooth and natural user interaction experience even in moderate noise environments.

In summary, the system performed well in practical field tests and fulfilled its intended objectives. It successfully mitigated commuter uncertainty, introduced real-time visibility, closed information gaps, and expanded accessibility for users with special needs. These results demonstrate not only the technical feasibility of the solution but also its practical viability for improving the commuter experience across Sri Lanka's public transportation system. The findings strongly support the potential for broader deployment and further scaling in future phases of development.

3.2 Research Findings

The findings from the implementation and testing of the proposed system reveal meaningful progress in addressing the core issues prevalent in Sri Lanka's public transportation landscape. These results validate both the technical reliability and practical applicability of the solution, particularly within high-demand routes such as Route 177 (Kaduwela to Kollupitiya). Moreover, the outcomes emphasize the system's role in enhancing the daily commuting experience, especially for underserved user groups.

One of the most impactful findings was the system's ability to reduce uncertainty in bus arrival times. The linear regression-based ETA prediction model, trained on real-time and historical traffic data, consistently generated accurate estimations with a mean absolute error (MAE) of approximately 42 seconds across various test scenarios. This performance demonstrated the model's effectiveness in adapting to fluctuating road conditions, congestion levels, and time-of-day variations. As a result, the application provided commuters with a reliable, data-driven alternative to traditional static timetables, enabling better planning and reduced idle time at bus stops.

In the area of user engagement and information accessibility, the integration of a chatbot trained on SLTB route data proved to be a significant advancement. Passengers no longer needed to navigate PDF documents or printed schedules to access basic transit information. Instead, the chatbot offered natural language interaction, handling a wide range of commuter queries related to stops, route numbers, and departure times. Although the system faced limitations in parsing complex or multi-intent questions, its overall response accuracy exceeded 90%, marking a major improvement over conventional information systems. This affirms the potential of conversational AI in streamlining commuter communication and democratizing access to transit data. Another notable observation was the impact of voice-based interaction on inclusivity. The system's speech-to-text (STT) and text-to-speech (TTS) modules enabled users with visual impairments or motor limitations to fully interact with the application using voice commands. User feedback emphasized the importance of such functionality, especially in busy or hands-free scenarios. Although current support is limited to English, the positive user response reinforces the need for future expansion to local languages like Sinhala and Tamil. This feature positions the system as an inclusive mobility tool aligned with the goals of universal design and digital accessibility.

Furthermore, the use of Firebase Realtime Database and lightweight infrastructure allowed the application to deliver real-time performance without high operational costs. Live GPS updates were synchronized efficiently across the system, enabling ETA updates, chatbot interactions, and UI rendering with minimal latency. This scalability, paired with the modular system design, suggests that other routes across Sri Lanka can be supported with minimal overhead by simply incorporating new data streams and retraining the predictive models accordingly.

Perhaps the most important broader insight is that the system represents a practical blueprint for a data-driven, intelligent transport infrastructure. By successfully merging machine learning, real-time data integration, and accessible user interface design, the project illustrates how smart mobility solutions can be tailored to region-specific needs in developing nations. It also opens new possibilities for integration with larger urban planning and smart city frameworks.

In summary, the research findings demonstrate that the system has met and exceeded its initial objectives. It not only improves commuter experience but also offers a scalable, inclusive, and cost-effective framework for public transport modernization. These findings underscore the project's value not just as a technical prototype, but as a viable public service innovation with potential for long-term adoption and nationwide deployment.

3.3 Discussion

The development and evaluation of the proposed intelligent bus navigation and passenger information system revealed both its practical strengths and the broader implications of integrating AI-driven technologies into Sri Lanka's public transportation infrastructure. By incorporating predictive modeling, real-time data streaming, voice-based interaction, and chatbot-assisted guidance, the system demonstrated a tangible capacity to alleviate long-standing commuter challenges, particularly those related to uncertain arrival times, lack of real-time visibility, and poor accessibility.

One of the most critical outcomes was the system's success in reducing uncertainty and improving trust in the public bus system. Historically, Sri Lankan commuters have had to rely on static schedules that fail to reflect actual traffic or delays. The introduction of a linear regression-based ETA prediction model, trained on real-time and historical data from Route 177, significantly enhanced the system's ability to forecast bus arrival times with practical accuracy. While the solution does not eliminate delays, it transforms the commuter experience from passive waiting to informed decision-making, fostering a new level of confidence in using public transport services.

Despite being relatively limited in their initial iteration, the use of voice interaction and chatbot modules demonstrates the revolutionary potential of inclusive and user-friendly design in public transportation systems. Both tech-savvy commuters and commuters with physical or visual disabilities benefited from the ability to retrieve route and schedule information through natural language inquiries that could be spoken or typed. Despite only supporting English at this time, the voice interface and chatbot framework are flexible and modular, opening the door for future updates that will include Sinhala and Tamil. The system is positioned as a scalable solution for Sri Lanka's diverse commuter population, which includes tourists, senior citizens, and people with disabilities, thanks to its bilingual capability.

Another essential insight lies in the system's cost-effectiveness and scalability. By leveraging cloud services such as Firebase, and open-source APIs like Google Maps and OpenAI, the system eliminates the need for expensive on-premise infrastructure. A GPS-enabled smartphone or tracker is sufficient for each bus, making it viable even in low-resource settings. This makes the platform adaptable not only within urban regions of Sri Lanka but also in other developing countries, where mobile penetration is high but infrastructure for intelligent transport is still evolving.

However, it is important to recognize a number of restrictions. Only the high-density urban corridor Route 177 was used for system testing. Although this route offers a variety of traffic conditions, performance could vary on rural roads due to poor connectivity, sparse data, and unpredictable stop frequencies. Furthermore, the chatbot shown difficulties when processing ambiguous, multi-part, or context-dependent questions, despite its high effectiveness for typical queries. This underscores the necessity for ongoing improvement and dataset expansion.

The reliance on mobile internet and modern smartphones may also limit usage in low-income or rural segments, where device access and connectivity can be inconsistent. Furthermore, the lack of Sinhala and Tamil voice support restricts inclusivity at the national level, making this a critical area for future development to ensure universal accessibility.

The system provides a convincing proof of concept in spite of these limitations. It proves that new technology can improve public services in quantifiable ways when properly localized. In later stages, there will be potential to integrate multi-modal transport, fare calculation, passenger feedback, and even predictive maintenance systems thanks to the platform's modular and extensible architecture.

In conclusion, this discussion reaffirms that the system not only addresses core commuter issues but also lays the foundation for a sustainable, intelligent, and inclusive public transport framework. It balances modern technological innovation with real-world usability and affordability, serving as a replicable model for intelligent transport solutions in other developing contexts. As Sri Lanka continues its journey toward digital transformation, this research project represents an important step in aligning public mobility with smart city principles.

CONCLUSION

This research project set out to design and develop an intelligent bus navigation and passenger information system tailored to the Sri Lankan public transportation sector, with its primary implementation and testing focused on Route 177 (Kaduwela to Kollupitiya). By integrating contemporary technologies such as machine learning, real-time tracking, voice-based accessibility, and AI-powered chatbot functionality, the system successfully addressed multiple long-standing challenges in the country's public transit infrastructure.

Key issues identified at the outset included the absence of real-time Estimated Time of Arrival (ETA) information, insufficient support for visually impaired users, the lack of intuitive digital tools, and the non-existence of conversational interfaces for accessing transit data. In response, the proposed system introduced a linear regression-based ETA prediction model, trained on a combination of historical and real-time GPS data. This approach significantly improved commuters' ability to plan journeys and reduced waiting-time uncertainty, thereby enhancing confidence in public transport services.

Additionally, the integration of a chatbot trained on structured Sri Lanka Transport Board (SLTB) data allowed users to obtain route and schedule information through natural language queries. Combined with voice-based interaction features, the system extended its accessibility to visually impaired, elderly, and hands-free users, broadening its usability. Built using React Native and powered by Firebase Realtime Database, the mobile application delivered reliable performance across platforms, enabling real-time synchronization of GPS data, predictions, and chatbot communication.

Extensive testing in real-world conditions confirmed that the system functioned effectively and with minimal latency. The user feedback obtained during field trials reflected high satisfaction, particularly with regard to real-time visibility, voice interaction, and information accessibility. These outcomes affirm that the system met its core objectives, offering a practical and scalable improvement to Sri Lanka's public transportation landscape.

However, the research also revealed certain limitations. Testing was limited to a single high-traffic route, and broader deployment would necessitate additional data collection, language localization (especially Sinhala and Tamil), and adaptive retraining of the ETA model for different traffic contexts. Furthermore, while English-based voice interaction was effective, a more inclusive solution would require multilingual speech input/output capabilities, especially to serve the rural and non-English-speaking population.

In summary, our study showed that intelligent public transportation systems can greatly enhance accessibility and commuter experience when they are customized to local issues. The suggested method provides a paradigm that is affordable, inclusive, and technologically flexible, laying a solid basis for a national smart transportation project. The system might expand nationally and serve as a model for smart transportation systems in other developing nations with sustained investment, cooperation with government stakeholders, and incremental improvements.

REFERENCES

[1] D. Perera, "Public Transport in Sri Lanka: Trends and Challenges," *Sri Lanka Journal of Transport*, vol. 8, no. 1, pp. 12–18, 2020.

[2] W. M. Weligamage et al., "An Approach of Enhancing the Quality of Public Transportation Service in Sri Lanka Using IoT," *2022 International Research Conference on Smart Computing*, IEEE, pp. 58–64, 2022.

[3] N. M. Nafrees et al., "Intelligent Transportation System using Smartphone-based Tracking in Eastern Sri Lanka," *Journal of Mobile Computing*, vol. 6, no. 2, pp. 40–47, 2021.

[4] V. Vaishnavi et al., "Advancements in Public Transport Design and Implementation of an Android-Based Real-Time Bus Tracking System," *2023 IEEE 12th International Conference on Communication Systems and Network Technologies (CSNT)*, pp. 130–134, 2023.

[5] J. Jisha et al., "IoT Based School Bus Tracking and Arrival Time Prediction," *International Journal of Engineering Research & Technology (IJERT)*, vol. 6, no. 11, pp. 1–5, 2017.

[6] L. Ratnayake, "Smart Transportation Systems: The Role of Artificial Intelligence in Urban Mobility," *International Journal of Smart Cities*, vol. 9, no. 2, pp. 80–88, 2021.

[7] T. Zhao and R. Wang, "AI-Driven Public Transit Optimization: Case Studies from the UK and Singapore," *IEEE Transactions on Intelligent Transportation Systems*, vol. 23, no. 5, pp. 900–911, May 2022.

[8] R. J. Shladover, "Connected and Automated Vehicle Systems: Introduction and Overview," *Journal of Intelligent Transportation Systems*, vol. 22, no. 3, pp. 190–200, 2018.

[9] D. K. Arul, "The Impact of Real-Time Information on Public Transport in Developing Countries," *International Journal of Urban Mobility*, vol. 5, no. 2, pp. 45–52, 2021.

[10] M. Hettige and S. Fernando, "Barriers to Smart Transportation in Sri Lanka," *Sri Lanka Journal of Transportation and Mobility*, vol. 3, no. 1, pp. 25–32, 2020.

[11] Ministry of Transport and Highways, "Annual Transport Statistics Report," Sri Lanka Government, Colombo, 2024.

[12] V. Ratnayake et al., "Exploring AI Opportunities in Sri Lanka's Urban Mobility," *IEEE Southeast Asia Smart Mobility Conference*, 2022.

[13] Ministry of Urban Development and Housing, "Smart City Development Framework – Colombo Metro Area," Government White Paper, 2023.

[14] D. Wickramasinghe and K. Perera, "Delays and Scheduling Issues in Sri Lanka's Bus Transport System," *Colombo Journal of Transport*, vol. 5, no. 2, pp. 88–94, 2022.

[15] V. Vaishnavi et al., "Advancements in Public Transport Design and Implementation of an Android-Based Real-Time Bus Tracking System," *2023 IEEE 12th International Conference on Communication Systems and Network Technologies (CSNT)*, pp. 130–134, 2023.

[16] L. K. Rathnayake and S. Jayasooriya, "Accessibility and Inclusivity in Urban Transport Systems of South Asia," *Journal of Accessibility and Design for All*, vol. 9, no. 1, pp. 12–28, 2021.

[17] J. Seneviratne, "Language and Interface Barriers in Public Services: A Case of Sri Lankan Transport," *International Journal of Multilingual Communication*, vol. 4, no. 3, pp. 33–41, 2020.

[18] J. Jisha et al., "IoT Based School Bus Tracking and Arrival Time Prediction," *International Journal of Engineering Research & Technology (IJERT)*, vol. 6, no. 11, pp. 1–5, 2017.

[19] W. M. Weligamage et al., "An Approach of Enhancing the Quality of Public Transportation Service in Sri Lanka Using IoT," *International Research Conference on Smart Computing*, IEEE, 2022.

[20] N. M. Nafrees et al., “Intelligent Transportation System using Smartphone-Based Tracking in Eastern Sri Lanka,” *Journal of Mobile Computing*, vol. 6, no. 2, pp. 40–47, 2021.

[21] V. Vaishnavi et al., “Advancements in Public Transport Design and Implementation of an Android-Based Real-Time Bus Tracking System,” *2023 IEEE 12th International Conference on Communication Systems and Network Technologies (CSNT)*, pp. 130–134, 2023.

APPENDICES

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