Smart Mobility on Campus: A Real-Time GPS Bus Tracking System With Cloud Integration

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DOI: https://dx.doi.org/10.47772/IJRISS.2025.90900003

Received: 22 August 2025; Accepted: 28 August 2025; Published: 26 September 2025

ABSTRACT

The increasing reliance on real-time data has underscored the need for intelligent and scalable systems to improve transportation efficiency, particularly in closed environments such as university campuses. Traditional approaches, including printed schedules and static route information, often lead to uncertainty, overcrowding, and inefficient bus utilization. To address these limitations, this study presents the development of *My Bus Tracker (MBT)*, a mobile-based application designed to enhance campus transit services. The system integrates Global Positioning System (GPS) tracking, route visualization, Google Maps API, and Firebase services to deliver live bus locations, estimated arrival times, and push notifications. Role-based access allows administrators to manage routes and bus data, while users benefit from a cross-platform interface developed with Flutter. Implemented using Agile methodology, the system was refined through iterative design, testing, and feedback. Evaluation results indicate that MBT improves user satisfaction, enhances bus utilization, and increases overall transportation efficiency within the campus environment. By emphasizing automation, usability, and real-time updates, MBT offers a practical and cost-effective solution for modernizing campus transportation. Its primary contribution lies in delivering a functional prototype that can be further enhanced with predictive arrival features and integration with broader public transport networks, thereby supporting the advancement of scalable smart mobility platforms.

Keywords: Bus tracking, GPS, Mobile application, Public transportation, Real-time system, My Bus Tracker

INTRODUCTION

Public transportation remains an essential pillar of sustainable urban mobility, offering accessible, cost-effective alternatives to private vehicles and easing environmental burdens. However, irregular bus arrival times and schedule uncertainties continue to undermine user confidence, leading to inefficiencies, increased wait times, and decreased reliance on public transit services [1].

To mitigate these issues, real-time tracking technologies, especially GPS-integrated systems which have been increasingly adopted. These systems enable dynamic location monitoring and reliable Estimated Time of Arrival (ETA) updates, empowering commuters to better plan their journeys and reducing perceived wait times [2]. Empirical studies indicate that real-time information delivery significantly improves user experience and transit efficiency ([1],[2]).

Recent developments in the research landscape further underscore the effectiveness of such systems. GPS and IoT-based tracking systems, when paired with mobile apps and smart bus stop displays, can markedly enhance public transportation transparency and service quality, resulting in notable reductions in passenger wait times and heightened satisfaction [3]. Similarly, an AI-driven prediction model using neural networks tailored for IoT-enabled public buses was introduced and tested across 151 bus routes in Boston, achieving remarkable accuracy in predicting real-time departure deviations within approximately 80 seconds, which can significantly boost schedule reliability [4].

Despite these advances, many existing systems remain tailored to large-scale urban deployments, leaving niche transit environments, such as university campuses or institutional fleets underserved. These contexts demand tailored solutions that balance scalability, cost-efficiency, and user-centric design.

In response, the My Bus Tracker (MBT) mobile application was proposed as a dedicated solution to provide real-time bus tracking and accurate ETA updates within closed or localized transit environments. Prioritizing usability and system robustness, the project aims to enhance commuter trust, reduce waiting times, and improve overall operational efficiency. By addressing current gaps in localized services, the MBT application overcomes limitations of existing models while offering a modular framework adaptable to diverse smart mobility scenarios.

Related Works

The development of real-time bus tracking systems has been approached from both commercial and academic perspectives. Popular consumer applications such as Google Maps Transit and Moovit have played a significant role in transforming commuter navigation. Google Maps Transit provides comprehensive route planning, estimated travel times, and static bus schedules for large-scale metropolitan networks. However, its functionality is limited when applied to localized or private transportation environments such as campus shuttles, where real-time customization and flexibility are essential [6]. Similarly, Moovit has gained global popularity by offering live arrival times and real-time updates through a combination of GPS integration and crowd-sourced data. While effective for urban mass transit, it lacks the tailored features necessary for controlled systems, making it less suitable for small-scale implementations [7].

Beyond these commercial applications, several academic studies have proposed specialized frameworks to overcome the shortcomings of generic platforms. For example, a GPS/GPRS-based bus tracking system was developed to transmit live location updates to users, successfully reducing passenger waiting times and improving service transparency [8].

The evolution of tracking technologies has also extended toward IoT-based systems. An IoT-enabled smart transport framework using Raspberry Pi and GPS modules was introduced to enhance real-time monitoring in smart city applications, highlighting the scalability of IoT devices in creating low-cost yet effective solutions for public transportation [9]. More recently, a web-based GPS bus monitoring platform, Smart Transit, combined cloud-based data processing with predictive modelling to demonstrate how web technologies and real-time GPS data can be integrated into a scalable monitoring framework, particularly useful for medium- to large-scale deployments [10].

Table 1 Login modules

References	Features	Strengths	Limitations
Google Maps Transit [6]	Route planning, schedules, estimated travel times.	Widely used, integrates with global transit data.	Not tailored for private/campus buses; limited real-time precision.
Moovit [7]	Real-time arrival, crowd-sourced updates, route planning.	Strong global coverage, user-friendly.	Dependent on crowd data; unsuitable for localized systems.
Gayathri et al. (2018) [8]	GPS/GPRS-based live tracking.	Reduces waiting time, increases transparency.	Requires continuous data transmission; limited scalability.
Vakula & Raviteja (2018) [9]	IoT with Raspberry Pi, GPS modules.	Low-cost, scalable IoT approach.	More suited for smart city integration than campus buses.
Prabha et al. (2025) [10]	GPS + cloud-based predictive modelling.	Scalable, web-based monitoring, predictive analytics.	Focused on city-level smart transit; requires higher infrastructure.
My Bus Tracker (Proposed)	GPS tracking, Firebase cloud storage, mobile app interface.	Tailored for university shuttles; real-time updates; cost-effective and scalable.	Limited to campus environment; requires stable internet and device adoption.

Overall, these studies highlight the diversity of approaches to real-time bus monitoring, from global commercial applications to academic prototypes and IoT-driven systems. However, most existing solutions either target large urban environments or focus on broad smart city applications, with limited emphasis on localized transportation needs. This underscores the necessity for systems like MBT mobile apps, which is specifically designed to serve campus communities by integrating real-time GPS tracking, cloud databases, and user-friendly interfaces into a scalable and cost-effective platform.

METHODOLOGY

This project adopts the Agile methodology as its development framework. Agile was selected due to its iterative nature, which allows continuous improvement, user feedback integration, and flexibility in adapting to changes throughout the project lifecycle. The methodology was implemented through four main stages: planning, system design, development, and evaluation, with iterative cycles carried out in each phase.

A. Planning

In the planning phase, the project objectives were clearly defined, emphasizing the development of a reliable real-time bus tracking application tailored for campus use. Stakeholders, including students and staff, were consulted to identify key issues such as unpredictable bus arrival times and long waiting periods. In line with Agile principles of collaboration, user stories were collected and prioritized as backlog items. A feasibility study was also conducted to assess available resources, project timelines, and the suitability of technologies such as GPS, Firebase, and Android Studio.

B. System Design

System design followed an incremental approach, where features were broken down into smaller deliverables to be implemented in sprints.

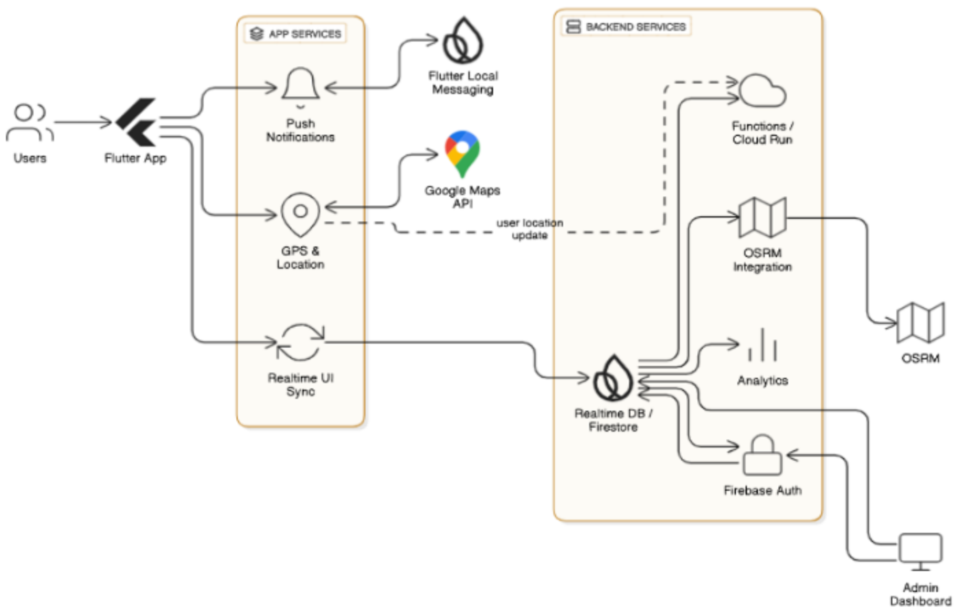

Fig. 1 Architecture Design My Bus Tracker

The architecture of the MBT mobile apps system, as illustrated in Fig. 1, follows a client–server model that integrates GPS-enabled devices, a cloud database, and a mobile application interface. At the core of the system are the buses equipped with GPS-enabled smartphones, which continuously capture the geographical coordinates of each moving vehicle. These coordinates are transmitted in real time to a Firebase cloud database, where data is stored and synchronized efficiently.

The cloud server acts as the central hub, processing the incoming location data and making it readily available for client-side access. Users interact with the system through the mobile application, which retrieves data

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue IX September 2025

directly from Firebase. The application is designed to present bus positions on an interactive map interface, ensuring that students and staff can easily track vehicle movement and estimate arrival times.

To ensure accuracy and responsiveness, the system relies on real-time synchronization between the GPS modules, the Firebase database, and the application front-end. Whenever the bus location updates, the new coordinates are instantly reflected on the user's device. The design also emphasizes scalability, as additional buses or routes can be incorporated seamlessly without significant modifications to the overall structure.

In summary, the architecture is structured to maintain continuous data flow from buses to the database and then to the mobile application. This design ensures real-time updates, enhances reliability, and provides a practical solution to address uncertainty in campus transportation.

C. Security Architecture

The system uses Firebase Authentication with Google Sign-In to ensure that only authorized users can access the application, supported by role-based access for public users, drivers, and administrators. Data management is handled by Cloud Firestore, which provides built-in security features, including encrypted communication during data transfer and encrypted storage within the database service. While these protections are part of the Firebase infrastructure rather than custom implementation in the prototype, they ensure that authentication and data protection requirements are met.

D. Development

The development of MBT mobile apps was carried out using an Agile sprint-based approach, where features were built, tested, and refined incrementally. The implementation involved three core components: the mobile application, the cloud database, and the GPS tracking integration.

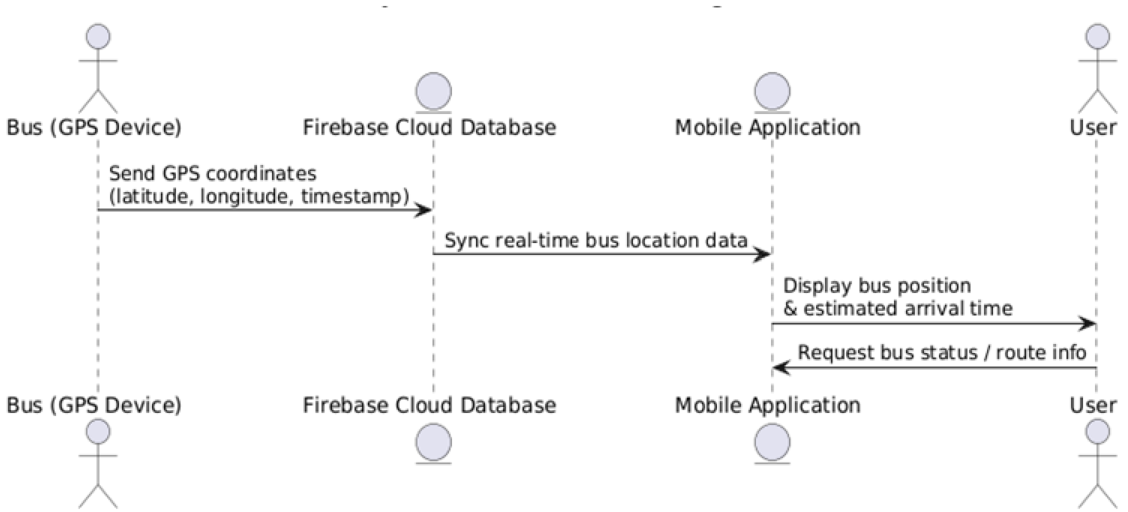

Fig. 2 Workflow Diagram MBT apps

The workflow of MBT mobile apps begins with the bus-mounted GPS device, which continuously captures location data in the form of latitude, longitude, and timestamp values. This data is transmitted directly to the Firebase cloud database, which acts as the central repository for all bus location updates. Firebase was selected because of its ability to handle real-time synchronization and ensure that data changes are instantly reflected across connected clients.

Once the information is stored in Firebase, the mobile application retrieves the latest location updates through integrated APIs. The app processes this data and displays it to end-users in an interactive and user-friendly format, typically through a map interface that highlights the current bus position and estimated arrival times. Finally, the user interacts with the system through the mobile application, which provides clear and accurate information without requiring manual updates or requests.

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This architecture ensures a one-way, streamlined flow of information from the bus GPS device to the user interface for minimizing latency and enhancing reliability. By leveraging cloud synchronization, the system guarantees that any change in the bus location is reflected almost instantly in the mobile app, thereby improving the overall efficiency and user satisfaction in campus transportation.

E. Evaluation

The evaluation of MBT mobile apps was carried out using black-box testing, which focuses on verifying the system's outputs against expected results without examining the internal code. This method was chosen because it aligns with the end-user perspective, ensuring that the application meets functional requirements as specified in the design phase.

Functional tests were conducted by providing different input scenarios, such as varying bus locations and routes, to confirm that the mobile application consistently displayed the correct real-time position and estimated arrival times. The synchronization between the GPS device, Firebase cloud, and mobile application was tested by observing whether updates in bus location were accurately reflected for the user within acceptable time intervals.

Table 2 Black-box test cases for My Bus Tracker (MBS) Apps

ID	Input Condition	Expected Output	Actual Output	Result
TC-01	GPS device sends valid coordinates (lat, long)	Location stored in Firebase and synced to app in real time	Location displayed correctly on app within 2–3 seconds	Pass
TC-02	GPS device loses signal	Last known bus location displayed with status "No Update" until signal restored	App displayed last location, updated automatically when signal resumed	Pass
TC-03	Multiple buses sending data simultaneously	Each bus location correctly mapped and displayed with unique identifiers	All bus locations shown accurately with correct IDs	Pass
TC-04	User requests bus location via mobile app	Application retrieves latest coordinates from Firebase and displays on map	Correct bus location shown without error	Pass
TC-05	Firebase temporarily offline	Application unable to fetch new data, should show warning message	App displayed error notification and resumed updates once Firebase restored	Pass
TC-06	User navigates through app menus	Interface responds within 2 seconds without crashing	All menus loaded smoothly	Pass

All six test cases passed successfully, confirming that the MBT mobile apps performed reliably across its core modules. These results indicate that the system is functionally stable and ready for usability testing in future evaluations.

RESULT

The MBT mobile apps was successfully developed and deployed, demonstrating its ability to provide real-time bus tracking for campus transportation. The results of the system are presented in this section, supported by screenshots that illustrate its main functionalities.

A. Authentication Interface

The authentication interface of the MBT mobile application ensures that only authorized users can gain access to the system. It consists of two main components: user registration module and login module.

1) Login: The login page, as shown in Fig. 3, requires users to enter their registered email address and password. The system also provides an alternative option to sign in using a Gmail account, offering faster access, improved security, and greater convenience for users.

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Fig. 3 Login Interface

2) Register: The register page, as shown in Fig. 4, requires users to complete all mandatory fields, including personal information, contact details, and account security credentials such as password.

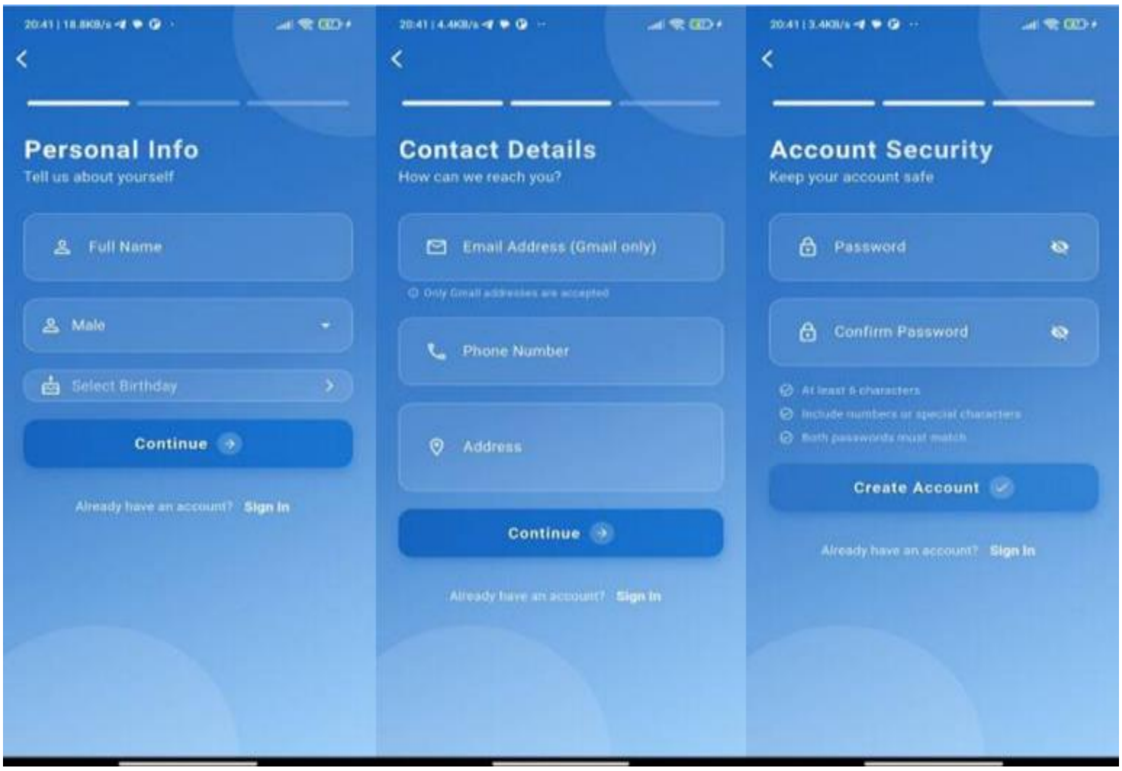

Fig. 4 Register Account User Interface

3)Forget password: The forgot password page, as shown in Fig. 5, requires users to enter their registered and valid email address to proceed. Once verified, the system sends a reset link to the user's email inbox, allowing them to securely reset their password.

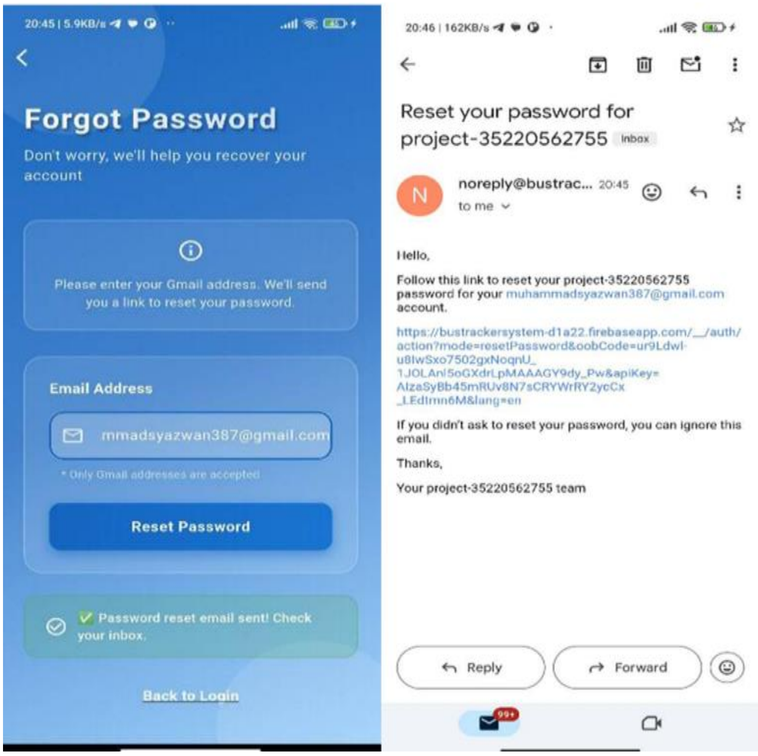

Fig. 5 Forget Password Interface

B. Users (Passenger) Interface Design

The passenger interface forms the core component of MBT mobile apps, as it directly supports students and staff in accessing real-time transportation information. The design emphasizes simplicity, clarity, and responsiveness, ensuring that users can quickly obtain bus location data without unnecessary complexity.

1) Home page and bus route schedule: The user's main page of MBT apps, as shown in Fig. 6, displays the map along with a bottom navigation bar that provides access to the Route, Information, and Profile pages. The Route Schedule page presents all available bus route schedules.

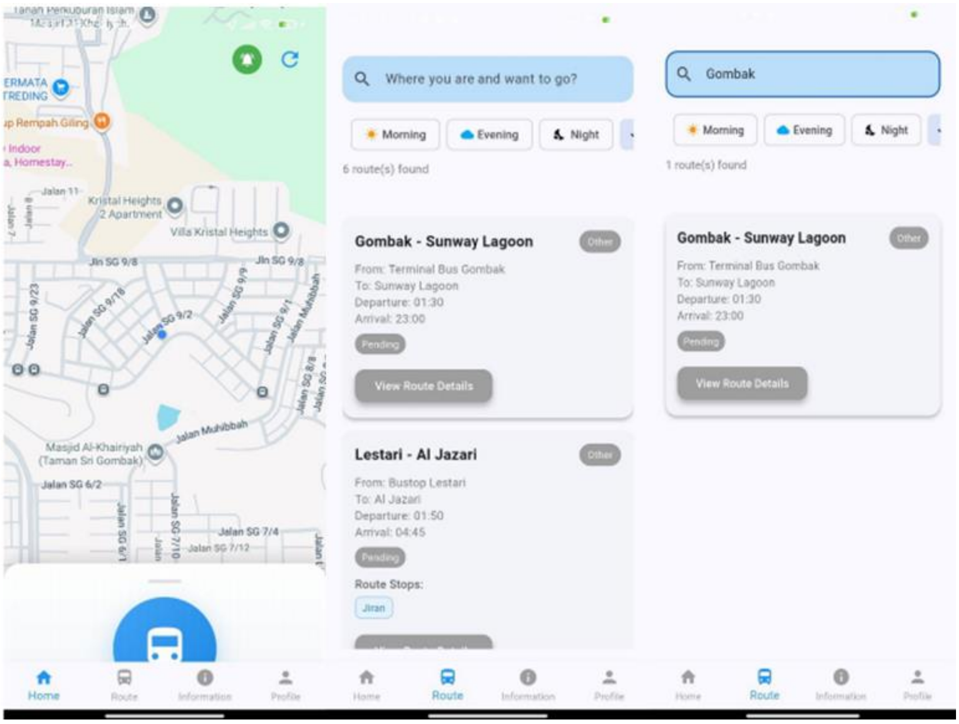

Fig. 6 Homepage and Bus Route Schedule Interface

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2)Real-Time Bus Tracker: The real-time bus tracker interface, as shown in Fig. 7, allows users to select a bus route schedule, after which the route and driver information are displayed together with the bus location and directional polyline on the map.

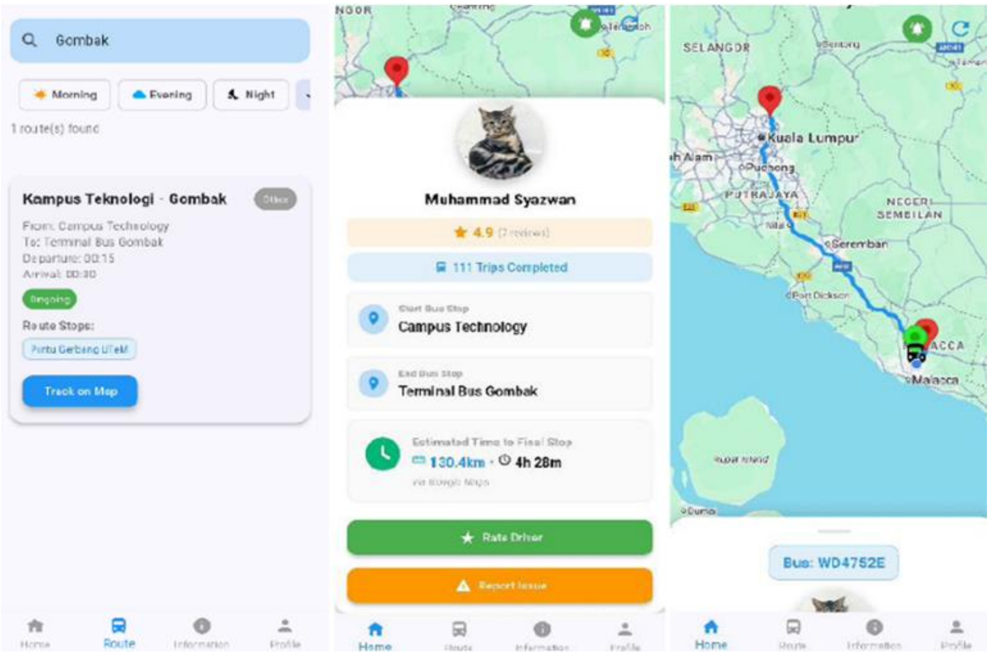

Fig. 7 Real-Time Bus Tracker Interface

3)Rate Driver Performance and Complaint Report: The rating page, as shown in Fig. 8, prompts users to provide feedback immediately after completing a bus trip by giving a star rating and leaving additional comments, which helps capture the passenger's travel experience in real time. The complaint report page allows users to select an issue category, such as driver manner, and provide detailed descriptions regarding the driver's attitude, communication, or bus condition. This dual feedback mechanism empowers passengers to voice their experiences, enables administrators to monitor driver performance more effectively, and ensures that recurring issues are identified and addressed promptly, thereby improving overall service quality and passenger satisfaction.

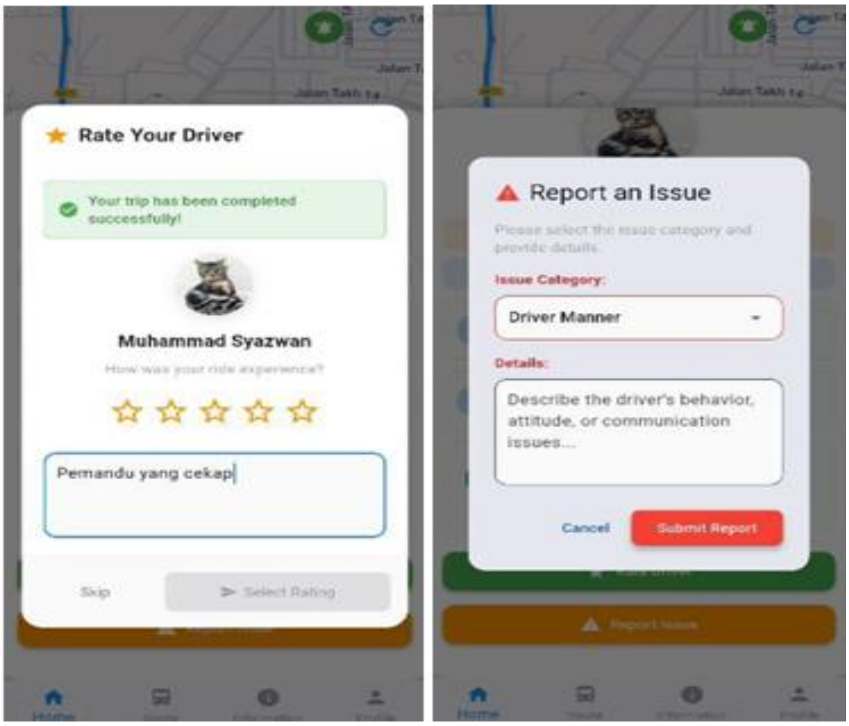

Fig. 8 Rate and Complaint Report Interface

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4)Real-Time Notification: The real-time bus notification feature of the MBT mobile application triggers alerts when the driver's GPS location is detected near or at a bus stop. Notifications include "Waypoint Reached," "Bus Departed," and "Bus Arrived," which keep users updated on bus movements, as shown in Fig. 9.

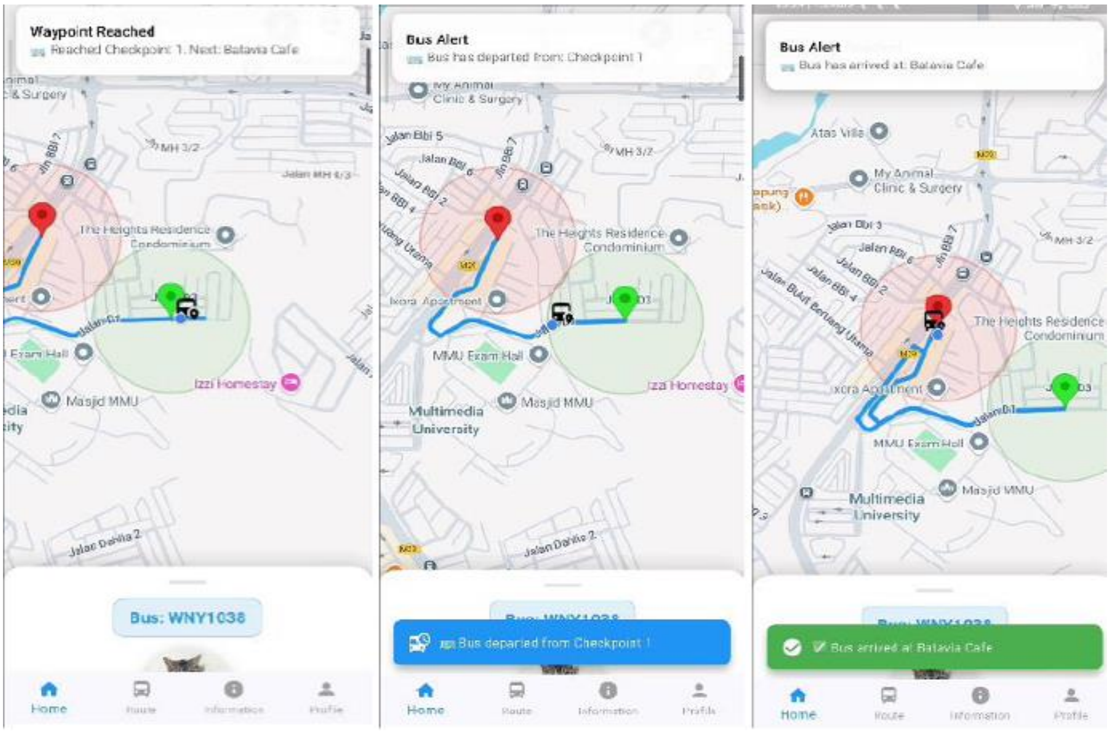

Fig. 9 Real-Time Notification Interface

5)Notifications: The notifications page, as shown in Fig. 10, displays both past and present information related to bus alerts and updates, allowing users to stay informed about bus arrivals, checkpoints, and route progress.

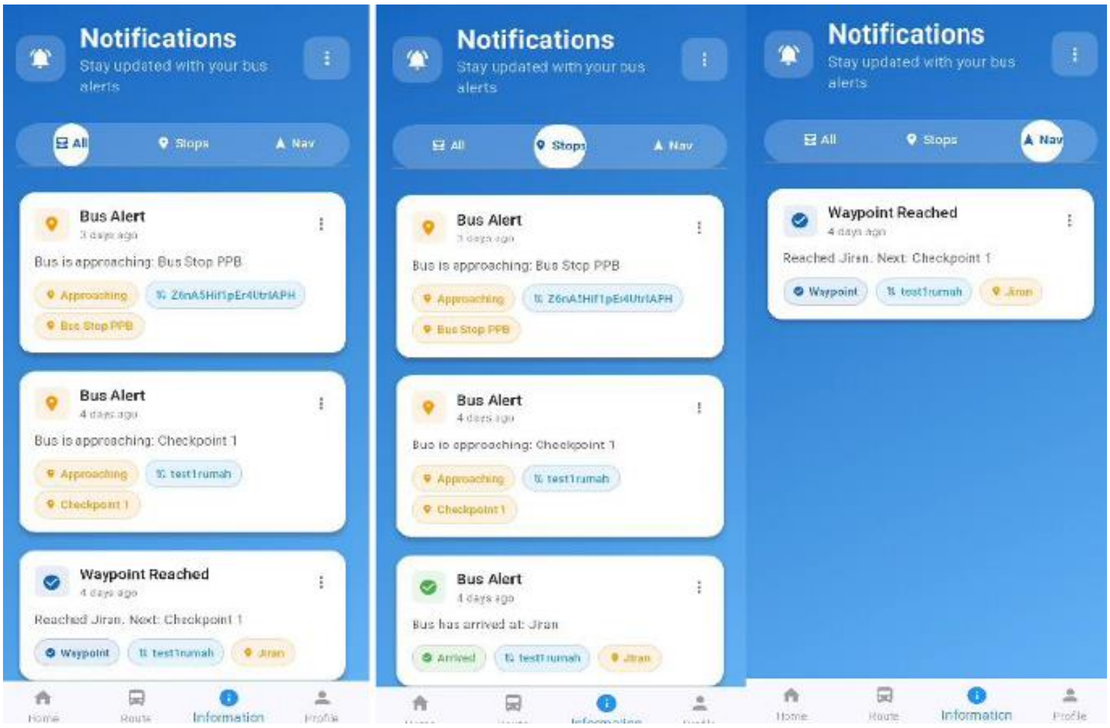

Fig. 10 Information Page Interface

6)User Profile: The profile page, as shown in Fig. 11, displays the user's personal and contact information, which can be updated directly within the application. The system validates the entered data, and once confirmed, a success message is displayed.

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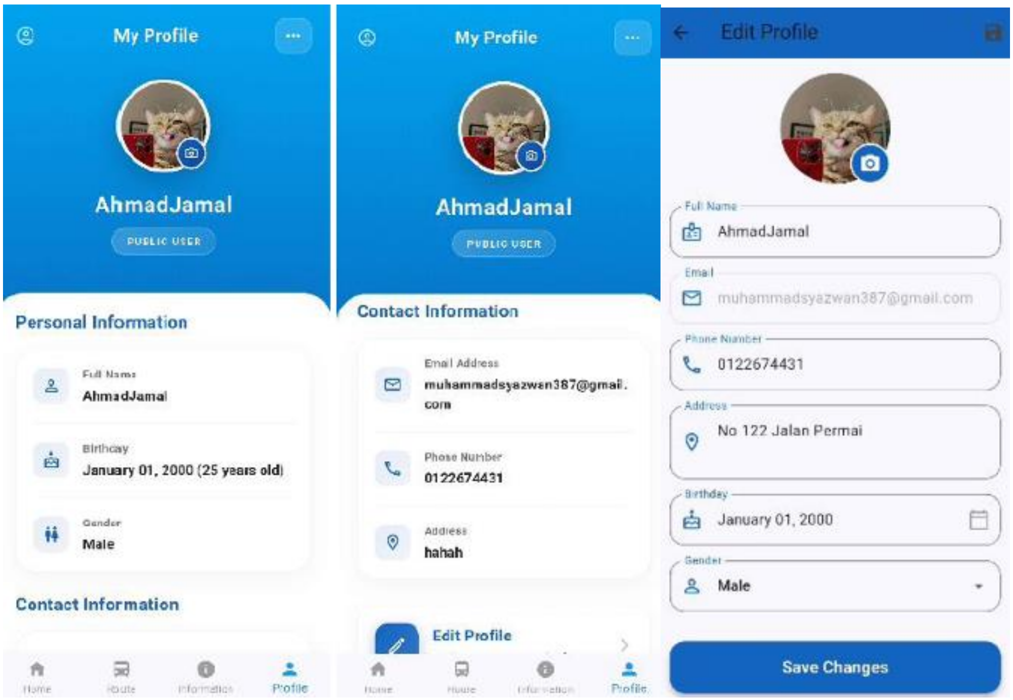

Fig. 11 User Profile Interface

C. Users (Driver) Interface Design

The driver interface of the MBT mobile application was developed to allow bus operators to seamlessly share real-time location data with the system. As drivers use the application while managing vehicle operations, the design emphasizes simplicity, minimal interaction, and reliability. The following section provides an explanation of the MBT interfaces specific to users with the driver role

1) Driver Main page and Profile: The driver's main screen displays upcoming or current bus shifts along with trip details, helping drivers to manage their schedules more effectively. It also provides quick access to navigation and bus status updates, ensuring smoother trip execution. Meanwhile, the Profile page presents personal and contact information, including email, phone number, and address, and allows drivers to update their details when necessary. These features support both operational efficiency and data accuracy, as shown in Fig. 12.

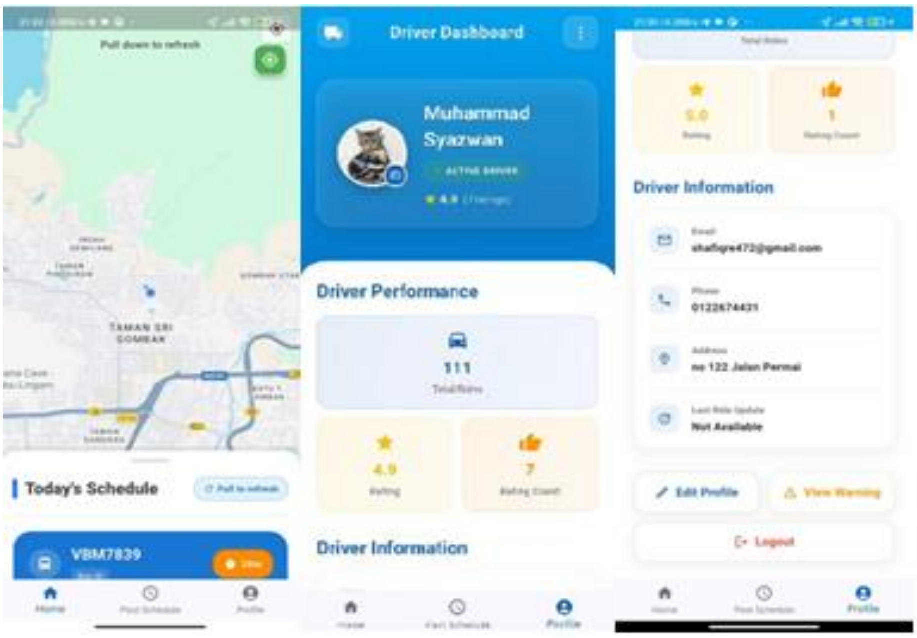

Fig. 12 Driver Main page and Profile Interface

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2) Start Bus Trip Schedule: The interface for starting a bus shift, as shown in Fig. 13, displays the driver's assigned schedule and provides a confirmation option before initiating the trip. Once started, the navigation view presents a directional polyline on the map, while the driver's GPS location is simultaneously visible on the user page.

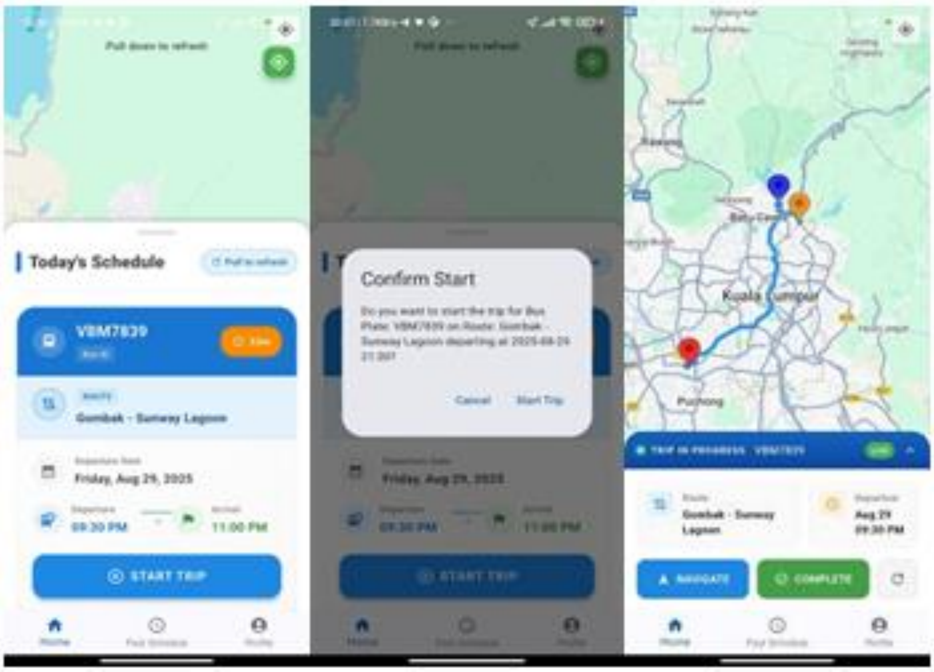

Fig. 13 Start Bus Trip Schedule Interface

3) Driver Warning & Reports: The Driver Warning page, as shown in Fig. 14, displays driver's behaviour alerts and customer complaint reports, each categorized by severity levels such as high, medium, or low.

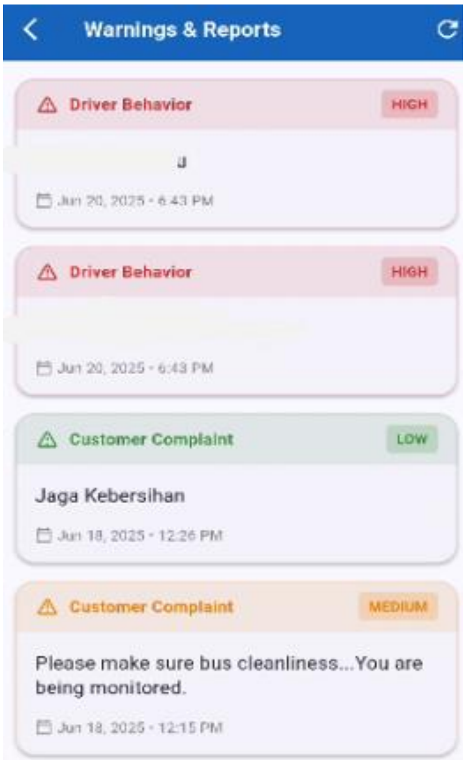

Fig. 14 Driver Warning Interface

4) Past Bus Schedule and Edit Driver Profile: The Past Schedule page displays all completed bus shifts for the driver, while the Edit Profile page allows the driver to insert and update personal, contact, and driving information. The application validates the entered data, and if the information is correct, a success message is displayed, as shown in Fig. 15.

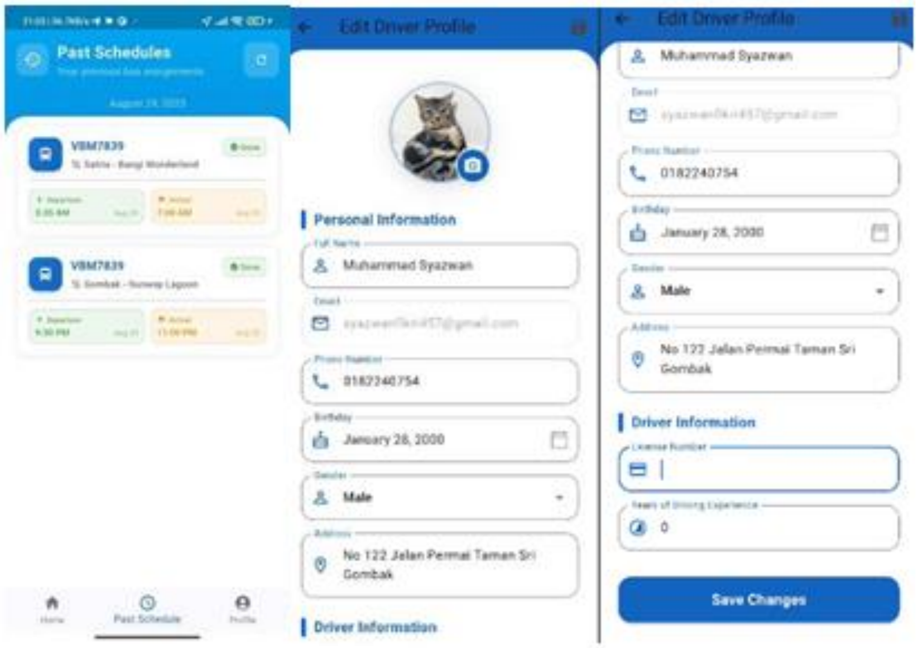

Fig. 15 Past Schedule and Edit Driver Profile Interface

D. Admin Interface Design

The administrator interface in the My Bus Tracker system provides management and monitoring capabilities to oversee the entire transportation system. Unlike passenger and driver interfaces, which focus on real-time usage, the admin interface emphasizes control, oversight, and system maintenance. Therefore, a web-based platform for administrators were also developed.

1) Bus Tracking: The Admin Main Dashboard as shown in Fig. 16 allows the administrator to monitor bus locations and movements. Access to the dashboard requires login with a valid email and password, after which the system authenticates the credentials and grants access. The dashboard displays real-time information on the total number of buses, drivers, and active bus schedules.

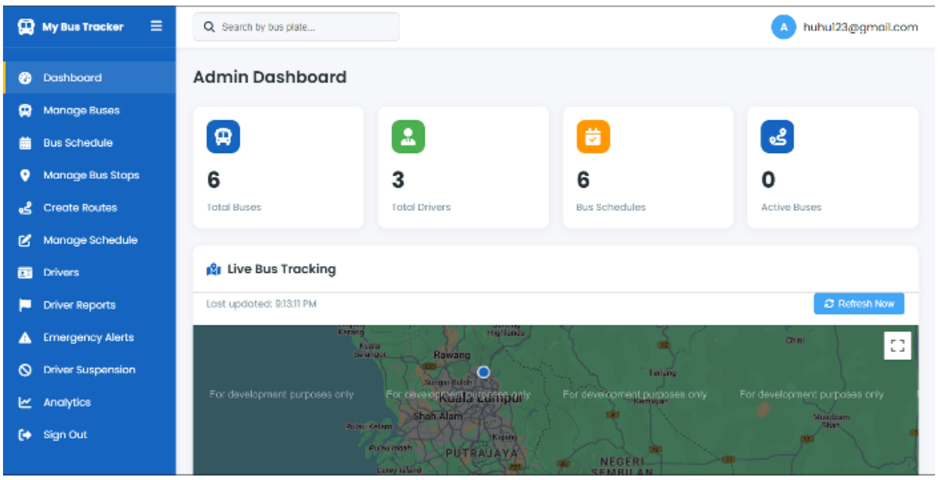

Fig. 16 Admin Main Dashboard Interface

2) Bus Management: The Bus Management page as shown in Fig. 17 allows administrator to view all buses with their respective statuses. This page helps the administrator to identify buses that require maintenance (when mileage exceeds 3000 km) and provides functions to add or edit bus information.

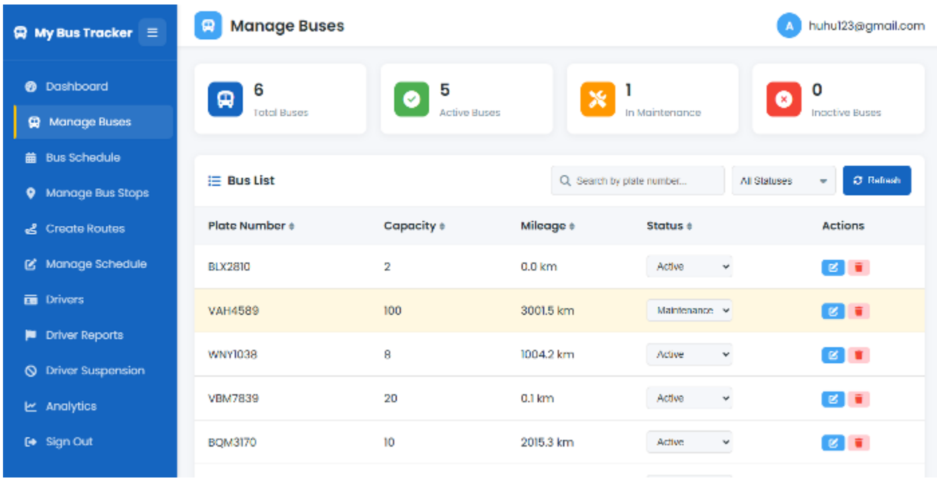

Fig. 17 Admin Bus Management Interface

3) Bus Schedule Management: The Schedule Management page, as shown in Fig. 18, allows the administrator to create new bus schedules by assigning routes, dates, and buses to drivers. The administrator can also edit or delete existing schedules.

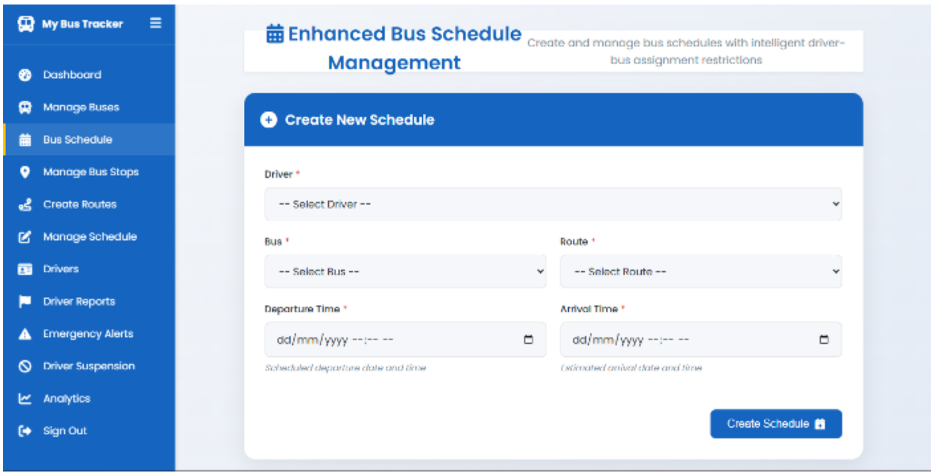

Fig. 18 Bus Schedule Interface

4) Bus Stop Management: The Bus Stop Management page, as shown in Fig. 19, allows the administrator to create a new bus stop by searching its location on the map. Once selected, the system automatically displays the bus stop information, including the address and coordinates, after which the administrator can confirm and add the bus stop to the database to ensure accurate route planning and real-time tracking integration.

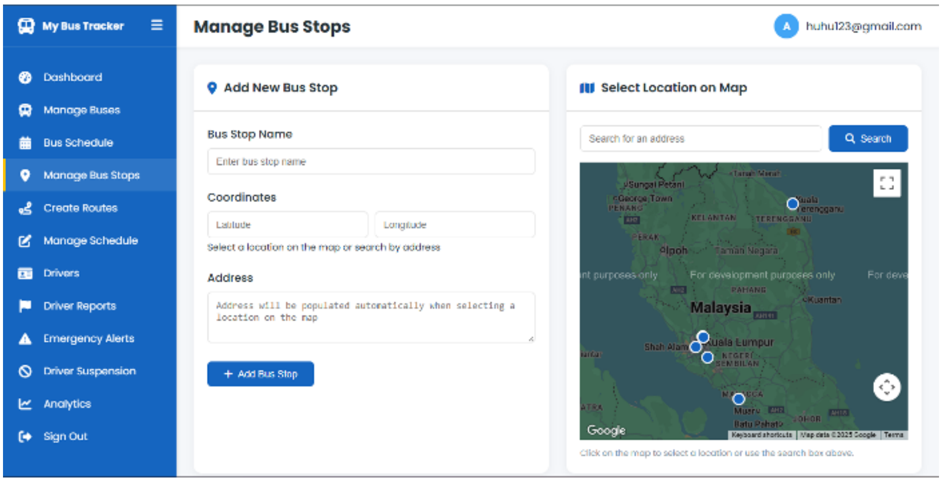

Fig. 19 Bus Stop Management Interface

5) Route Management: The Route Management page as shown in Fig. 20, allows administrator to create new bus route by combining the Starting Point, Sequence Point and Finished Point to make one bus route.

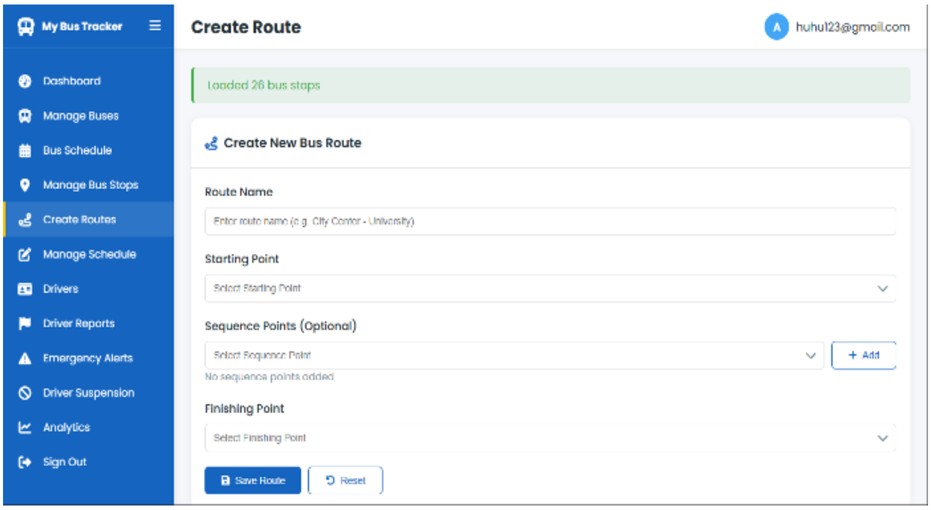

Fig. 20 Route Management Interface

6)Driver Management: The Driver Management page, as shown in Fig. 2, allows the administrator to view registered drivers, add new drivers, and manage driver records to maintain data accuracy and support efficient operations.

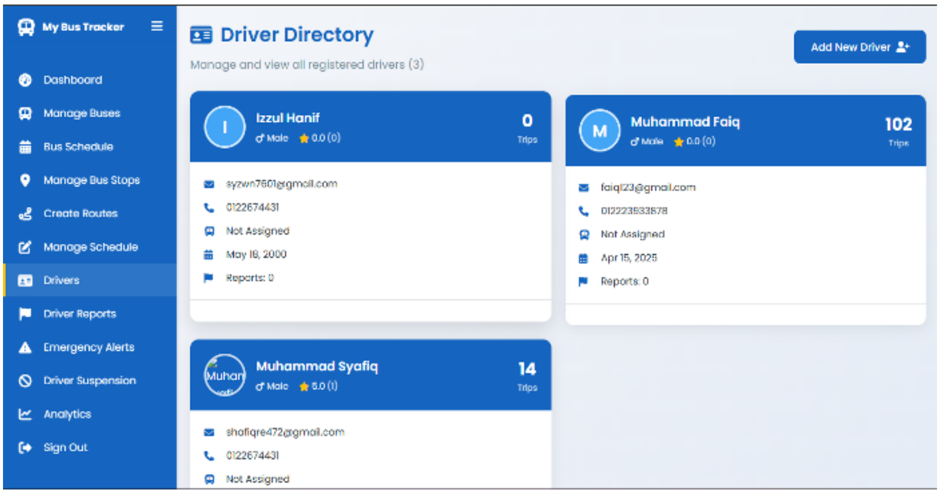

Fig. 21 Driver Management Interface

7) Driver Complaint Report: The Manage Driver Complaint Report page, as shown in Fig. 22, allows the administrator to view and manage complaints submitted against drivers. Each report is reviewed to verify its validity, and if confirmed, the administrator can issue a warning letter and send a notification to the respective driver.

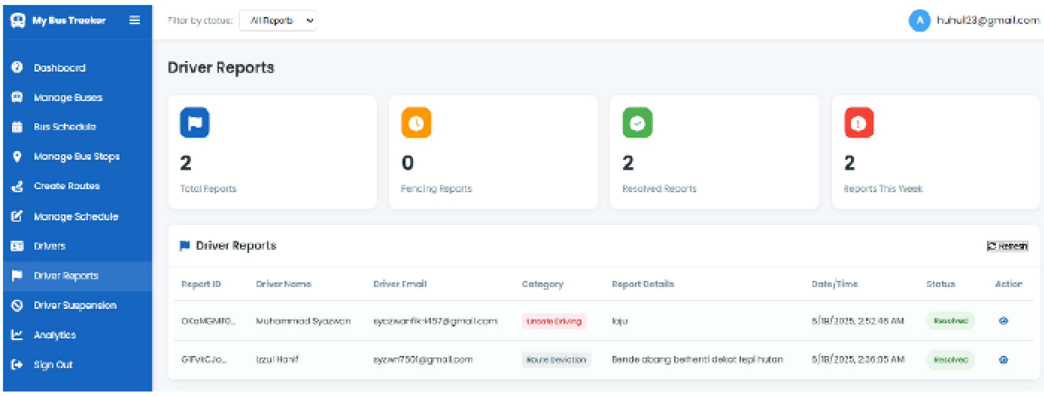

Fig. 22 Driver Report Management

8) Driver Warning Management: The Manage Driver Suspension page, as shown in Fig. 23, allows the administrator to view all drivers who have accumulated 5 warning reports. From this page, the administrator can suspend a driver's account, preventing them from operating for seven days. After the suspension period, the account is automatically reactivated.

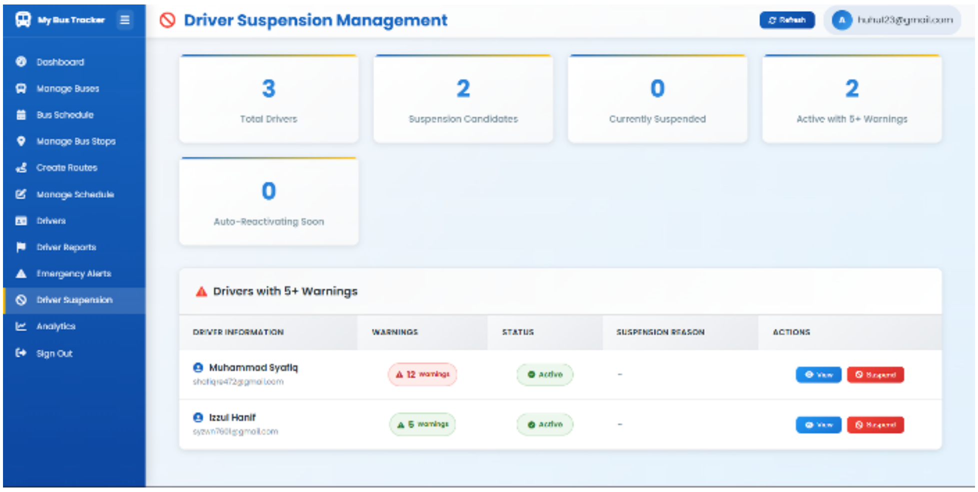

Fig. 23 Driver Warning Management

9) Analytic Report: Fig. 24 shows the Analytics Report Page where admin can view and analyse the user route usage.

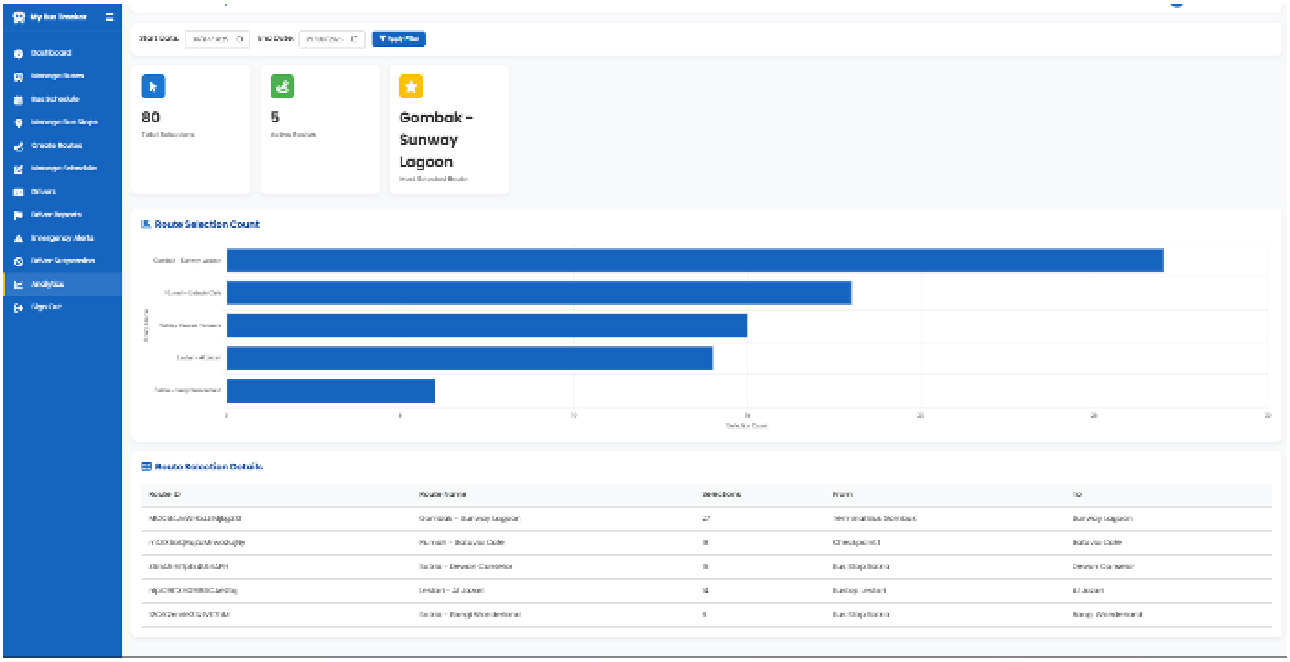

Fig. 24 Analytic Report Interface

CONCLUSIONS

The development of the My Bus Tracker (MBT) application system has effectively addressed the issue of uncertainty in campus transportation by providing a reliable and user-friendly real-time bus tracking solution. By integrating GPS-enabled devices with Firebase as a cloud database, the system ensures accurate synchronization of bus location data and instant updates to the mobile application. This integration enables passengers to track buses in real time, thereby reducing waiting times and increasing confidence in the service. The implementation of authentication, along with passenger, driver, and administrator interfaces, further demonstrates the system's versatility in supporting multiple user roles while maintaining both security and usability.

Evaluation results confirmed that the system meets its intended functional requirements and performs effectively across diverse test cases. Black-box testing validated its accuracy, stability, and ease of use, while user feedback highlighted improved reliability and reduced delays. Overall, the MBT application provides a scalable and practical solution for campus transportation management, and with future enhancements such as predictive arrival times or integration with broader public transport systems, it has the potential to evolve into a more advanced smart mobility platform.

Future Works

This study has demonstrated the feasibility of a campus-based real-time bus tracking system, though it remains at the prototype stage. At present, performance evaluation is limited to validating non-functional requirements, such as real-time updates within a few seconds, system availability, and scalability by design. Future work will conduct more comprehensive testing on latency, server response times, and long-term reliability under real-world conditions. A quantitative comparison with existing solutions like Google Maps Transit will also be pursued, focusing on ETA accuracy, update frequency, and scalability.

In terms of security, the current prototype already implements Firebase Authentication with Google Sign-In, role-based access control, and the built-in protection features of Cloud Firestore. Future work will build on this foundation by introducing multi-factor authentication, stronger encryption mechanisms, and advanced monitoring to further strengthen user data protection and system reliability.

In summary, these future enhancements will improve performance, security, and scalability, positioning My Bus Tracker as a comprehensive intelligent transportation solution.

ACKNOWLEDGEMENT

The authors would like to express gratitude to Centre of Advanced Communication Technology (C-ACT), Fakulti Teknologi Maklumat dan Komunikasi (FTMK), Universiti Teknikal Malaysia Melaka (UTeM) for their invaluable support and resources provided throughout this research.

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ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue IX September 2025

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