Safe Driver: AI powered Real Time Driver Monitoring and Accident Prevention System

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Document Revisions

Date	Version	Description	Author
04/06/2026	V1	Final Report	T.P. Denagamage
07/06/2026	V1.1	Reviewed Version	P.S. Ekanayake D.S. Sandeepa R.U. Gonalagoda K.J.L. Perera

Table 1 : Document version history

Declaration

We hereby declare that this final report is our original work and does not include, without proper acknowledgment, any material previously published or submitted for a degree or diploma at any other university or institution of higher learning. To the best of our knowledge and belief, it does not contain any material written or published by another person except where such acknowledgement is made within the text.

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I have reviewed the final report and confirm that it adheres to the provided final report outline. I hereby approve the report for submission.

Signature of the supervisor: .... Date: 08.06.2026

Dr. D.D.M. Ranasinghe

Acknowledgement

We would like to express our sincere gratitude to our project supervisor, Dr. D.D.M. Ranasinghe, for her valuable guidance, encouragement, and continuous support throughout the development of the SafeDriver: AI-Powered Real-Time Driver Monitoring and Accident Prevention System.

We also thank the faculty members and staff of the university for providing the necessary resources and knowledge that contributed to the success of this project.

Our heartfelt appreciation goes to our teammates for their dedication, collaboration, and commitment during all phases of the project. Their teamwork and perseverance were essential in overcoming challenges and achieving project objectives.

Finally, we would like to thank our families and friends for their patience, encouragement, and unwavering support throughout this journey.

CodeCrafters Team

June 2026

Executive Summary

Road traffic accidents remain a leading cause of death and injury in Sri Lanka, with over 2,000 fatalities reported annually. Public bus operations are disproportionately represented in these statistics, with driver fatigue, mobile phone use, and inattentiveness identified by the National Transport Commission as primary contributing factors. Despite this, Sri Lanka's bus fleet has operated without any proactive, automated driver monitoring capability — relying instead on reactive post-accident reporting and manual inspections that consistently fail to prevent incidents before they occur.

The SafeDriver Solution

SafeDriver is a fully implemented, AI-powered hybrid edge-cloud platform that continuously monitors bus driver behaviour in real time and intervenes before unsafe situations escalate into accidents. The system deploys a Raspberry Pi 4-based embedded unit fitted with a NoIR infrared camera and GPS module inside the bus cabin. Using OpenCV, MediaPipe, TensorFlow Lite, and YOLO running locally on the device, SafeDriver detects drowsiness through Eye Aspect Ratio and PERCLOS calculations, yawning via Mouth Aspect Ratio analysis, head-turn distraction, mobile phone use, and cigarette smoking — all at 29–31 frames per second with sub-100 millisecond local alert latency.

System Architecture and Key Components

Component	Delivered Capability
Embedded Monitor	Real-time detection of drowsiness, yawning, head-turn distraction, mobile phone use, and smoking on Raspberry Pi 4 at 29–31 FPS using MediaPipe, TensorFlow Lite, and YOLO.
Alert Escalation	Four-level graduated response: immediate on-device buzzer and voice warning escalating to Firebase cloud push notifications and NTC authority SMS for persistent unsafe behaviour.
Authority Dashboard	NextJS web application with live fleet map, real-time alert management (Active / Acknowledged / Resolved), driver profiles, route monitoring, feedback analytics, and hazard zone mapping across Sri Lanka.

Component	Delivered Capability
Passenger Mobile App	Flutter cross-platform app (Android & iOS) with live bus safety status, driver and bus feedback, reward points, emergency SOS with contact confirmation, and multilingual support in English, Sinhala, and Tamil.
Cloud Backend	Firebase Firestore (10-entity normalized schema), Cloud Functions, Authentication, and Cloud Messaging with offline alert buffering for intermittent rural connectivity.

Table 2:System Architecture and Key Components

Outcomes and Achievements

- All core driver behaviour detection algorithms — drowsiness, yawning, head-turn, phone use, and smoking — implemented and validated with confidence scores consistently above 0.77 in testing.
- End-to-end alert pipeline from on-device detection to authority dashboard notification confirmed operational with latency under 5 seconds over standard connectivity.
- Authority web dashboard deployed with live Firestore integration, showing real fleet data including driver records, bus assignments, alert histories, and passenger feedback.
- Passenger mobile application delivered in three languages with feedback submission, reward points, emergency SOS, real-time bus safety status, and QR-based bus identification.
- Comprehensive test suite prepared covering 10 functional and 8 non-functional test cases across performance, security, reliability, and usability dimensions.
- Total per-vehicle hardware cost of approximately LKR 75,000 — substantially below imported commercial alternatives — making nationwide fleet deployment economically viable.

Significance and Impact

SafeDriver is the first driver monitoring solution purpose-built for Sri Lanka's right-hand-drive public bus fleet, with multilingual interfaces, tropical climate hardware selection, and integration with NTC regulatory reporting requirements. By shifting from reactive accident investigation to proactive real-time intervention, the system has the potential to meaningfully reduce the human and economic cost of bus-related road accidents across the country. The modular, open-source-based architecture ensures the platform can scale cost-effectively across the national fleet and adapt to future regulatory and operational requirements

1.Introduction

1.1 Background

Road safety is a complex global challenge, particularly acute in developing countries where infrastructure, enforcement, and awareness may be inadequate. In Sri Lanka, over 2,000 road fatalities are reported annually, with bus accidents accounting for a significant proportion. According to the National Transport Commission (NTC), the leading causes include driver fatigue, mobile phone use while driving, and general inattentiveness to road conditions.

Traditional safety measures in Sri Lanka rely heavily on reactive processes: accident reports, manual inspections, and driver self-reporting. These approaches fail to provide real-time interventions, which have been proven critical in reducing accident risk. Advancements in computer vision, machine learning, and embedded systems now offer new possibilities. Systems using cameras and AI to monitor drivers have demonstrated effectiveness in detecting early warning signs such as prolonged eye closure (PERCLOS), yawning, and head pose changes indicative of drowsiness. Moreover, integrating driver monitoring systems with GPS data and cloud infrastructure enables hazard mapping and timely alerts, fundamentally improving accident prevention and emergency response.

1.2 Problem Statement

Sri Lanka's public transport system currently lacks a proactive and continuous monitoring mechanism for the safety of drivers and passengers while on the move. Key challenges identified include:

- Absence of real-time detection of driver fatigue and distraction, leading to unaddressed risky behavior during operation.
- Delayed accident prevention — warnings or interventions typically occur post-incident rather than proactively.
- Limited communication pathways between drivers, transport authorities, and passengers regarding live safety status.
- Lack of scalable, cost-effective AI-enabled monitoring solutions tailored to local conditions including right-hand-drive vehicles, tropical climates, and multilingual requirements.
- High per-vehicle costs of imported commercial systems that are unsustainable at national scale.

1.3 Project Aim

The SafeDriver system aims to revolutionize public transport safety in Sri Lanka by providing a comprehensive, AI-driven monitoring solution that bridges the gap between reactive accident reporting and proactive safety intervention. The system serves as a technological backbone for modernizing Sri Lanka's public transport infrastructure while ensuring scalability and cost-effectiveness through locally developed, open-source-based hardware and software.

1.4 1.4 Objectives

- Detect drowsiness using Eye Aspect Ratio (EAR), blink frequency, head pose and yawning detection.
- Identify distractions (mobile phone usage) via CNN models.
- Implement a multi level alert system (buzzer, voice, authority notifications).
- Integrate GPS based hazard mapping for accident prone zones.
- Develop a passenger transparency mobile application.
- Generate automated compliance reports for authorities.

1.5 Project Scope

SafeDriver is a modular, scalable driver-monitoring system targeting Sri Lankan public bus fleets. The system continuously analyses driver behavior to detect drowsiness and distraction and escalates alerts to drivers, authorities, and passengers via a hybrid edge-cloud architecture. The solution encompasses four integrated tiers: (1) an embedded device on Raspberry Pi 4 performing real-time AI inference, (2) an edge analytics layer processing detections locally, (3) a Firebase cloud services layer for data persistence and communications, and (4) user-facing web and mobile applications for authorities and passengers.

Summary of Chapter 1

Chapter 1 restates the project background, problem statement, aim, objectives, and scope to frame SafeDriver as a proactive AI-based solution for improving bus safety in Sri Lanka. It explains that current public transport safety practices are largely reactive and do not provide real-time intervention for drowsiness or distraction, which creates a serious accident risk. The chapter also establishes the project's intended outcomes, including drowsiness detection, distraction identification, multi-level alerts, GPS-based hazard mapping, a passenger transparency app, and automated compliance reporting.

2. Literature Review

2.1 Driver Monitoring Approaches

The literature on driver monitoring systems identifies four main technical approaches: image-based methods using facial features, biological-signal-based methods (EEG, ECG), vehicle-based measures (steering and lane behavior), and hybrid combinations of these. Each approach presents distinct trade-offs between accuracy, implementation cost, and practical deployability in real-world transport contexts.

Image-based deep learning models such as 3D CNNs and CNN-LSTM networks have achieved over 90% accuracy for drowsiness detection in controlled environments. Specialized architectures can detect mobile-phone usage and other distractions with accuracy above 95%. These results demonstrate that computer vision and deep learning provide a strong technical foundation for real-time detection of risky driver behaviors. However, most published benchmarks are obtained under ideal laboratory conditions with controlled lighting and standardized camera positioning, limiting their direct generalizability to field deployments.

Biological signal approaches using EEG and ECG offer high physiological accuracy but require physical sensors attached to the driver, making them impractical for public transport deployment where drivers change frequently. Vehicle-based approaches monitoring steering behavior and lane deviation are non-intrusive but suffer from elevated false-positive rates due to legitimate driving maneuvers and variable road conditions.

2.2 Deep Learning Techniques for Drowsiness and Distraction Detection

The PERCLOS (Percentage of Eye Closure) metric has been established as a highly reliable indicator of driver drowsiness, measuring the proportion of time the eyes are more than 80% closed over a rolling temporal window. Srivastava et al. (2024) demonstrated a lightweight real-time PERCLOS implementation capable of operating on embedded hardware with minimal latency. Complementary research by Rahman et al. (2023) showed that combining EAR with head pose estimation using 3D landmark tracking significantly improved detection accuracy under varying lighting conditions, including the low-light scenarios common in early morning bus operations.

For distraction detection, Jin et al. (2020) developed a deep-learning scheme achieving high accuracy for cell-phone use detection, while Vaegae et al. (2022) presented an efficient distracted driver detection system with accuracy exceeding 95% across multiple distraction categories. These architectures, when converted to TensorFlow Lite quantized models, retain sufficient accuracy levels for deployment on Raspberry Pi 4 hardware within the required inference time budget.

Yawning detection as a supplementary fatigue indicator uses Mouth Aspect Ratio (MAR) calculations analogous to EAR. Soukupova and Cech (2016) established the foundational facial landmark approach underpinning modern real-time blink and yawn detection. MediaPipe's 468-point face mesh has since become the dominant framework for extracting these landmarks efficiently on mobile and embedded platforms.

2.3 Commercial Driver Monitoring Solutions and Their Limitations

Commercial driver monitoring products from international vendors such as Mobileye, Seeing Machines, and SmartDrive demonstrate that integrated camera-based systems with multi-level alerts and cloud connectivity are technically mature. However, these solutions are designed primarily for left-hand-drive vehicles, temperate climates, and high-income markets. Key limitations for Sri Lankan deployment include: limited support for Sinhala and Tamil languages; incomplete environmental specifications for high-humidity tropical conditions; and per-vehicle licensing costs economically unsustainable for Sri Lanka's predominantly small-scale, privately operated bus fleets.

The Sri Lankan government's 2025 rapid deployment initiative for AI-powered driver monitoring confirmed the national policy priority but relied on imported commercial systems with limited localization. Studies and government reports highlight additional constraints: intermittent rural connectivity, right-hand-drive vehicle configurations, and significant economic pressure on transport operators. These factors collectively create a strong case for a locally developed, cost-optimized solution.

2.4 GPS and Hazard Mapping in Transport Safety

Amin et al. (2025) demonstrated SafeTrax, an IoT-based smart collision prediction and alert system that correlates GPS location data with historical accident hotspots to generate context-sensitive driver alerts. Their work showed that combining real-time vehicle position with a dynamic risk map significantly reduces response time for safety-critical events. This geofencing approach, adapted to Sri Lanka's road network, forms the conceptual basis of SafeDriver's GPS hazard mapping module.

Cloud-based analytics platforms built on Firebase Real-time Database provide infrastructure for aggregating location and behavioral data across a fleet, enabling pattern recognition for recurring hazard zones and temporal risk analysis as demonstrated by Khalil et al. (2025). Firebase's offline persistence capabilities are particularly relevant for the intermittent connectivity environments encountered on rural Sri Lankan routes.

2.5 Research Gaps and Justification for SafeDriver

From this review, several critical research gaps and practical challenges emerge that justify the SafeDriver project:

- Lack of driver monitoring solutions specifically optimized for right-hand-drive bus configurations.
- Insufficient environmental hardening specifications for tropical climates with high humidity and direct sunlight.
- Limited multilingual and culturally adapted user interfaces in Sinhala and Tamil.
- High-cost barriers preventing large-scale deployment across developing-country bus fleets.
- Absence of integrated passenger transparency mechanisms in existing commercial systems.

SafeDriver addresses these gaps through: locally developed Raspberry Pi-based hardware reducing per-vehicle costs to approximately LKR 75,000; TensorFlow Lite models optimized for edge deployment eliminating dependency on continuous network connectivity; offline-capable GPS hazard mapping with periodic cloud synchronization; multilingual interfaces for drivers, passengers, and authorities; and right-hand-drive camera positioning calibrated for Sri Lankan bus configurations.

Summary of Chapter 2

Chapter 2 reviews existing driver monitoring methods, deep-learning techniques for drowsiness and distraction detection, commercial systems, and GPS-based safety approaches. It shows that computer vision and lightweight edge AI are suitable for real-time monitoring, but many existing solutions are limited by laboratory conditions, high cost, poor localization, and lack of support for Sri Lankan transport needs. The chapter concludes by identifying the research gaps that justify SafeDriver, especially right-hand-drive support, multilingual usability, tropical-environment suitability, and passenger transparency features.

3. Methodology and Proposed Solution

3.1 Development Methodology

The project follows an iterative, Agile-inspired methodology aligned with the university's progress-report milestones and CMMI-oriented process requirements. Work began with stakeholder consultations, problem analysis, and a comprehensive literature review, synthesized into a Software Requirements Specification (SRS) containing functional, non-functional, and pilot-success criteria.

Tasks are managed using GitHub Projects and Trello boards, ensuring requirements, design changes, and implementation work are tracked and reviewed systematically. Regular team and supervisor meetings are documented through CMMI-compliant minutes capturing decisions, risks, and action items. The development lifecycle progressed through the following phases:

- Phase 1 - Requirements and Literature Review (Weeks 1–4): Stakeholder meetings, SRS definition, literature survey.
- Phase 2 - System Architecture and Design (Weeks 5–8): UML diagrams, four-tier architecture, high-level component design.
- Phase 3 - Detailed Design and Prototyping (Weeks 9–14): Database design (ER and Firestore), GUI prototypes using Figma, test plan preparation.
- Phase 4 - Implementation (Weeks 15–24): Parallel development of monitoring system (Python), authority dashboard (NextJS), and passenger app (Flutter).
- Phase 5 - Testing and Calibration (Weeks 25–30): Unit, integration, system, and acceptance testing with threshold tuning.
- Phase 6 - Pilot Deployment and Evaluation (Weeks 31–36): Real-world bus testing, final documentation, and report preparation.

3.2 System Architecture Overview

SafeDriver employs a distributed four-tier architecture combining edge computing for real-time processing with cloud integration for data analytics and communication. This hybrid approach ensures minimal latency for safety-critical functions while enabling comprehensive fleet-wide monitoring and reporting.

3.2.1 Tier 1 - Embedded Edge Device

Built on Raspberry Pi 4 with a NoIR camera module (for infrared night vision), GPS module, audio buzzer, and local SSD storage. The device runs Python with OpenCV, MediaPipe, TensorFlow Lite, and YOLO, processing all video locally for zero-latency safety decisions without network dependency.

3.2.2 Tier 2 - Edge Analytics

The computer vision pipeline processes facial landmarks via MediaPipe, computes EAR/MAR metrics, estimates 3D head pose, and classifies distractions via TensorFlow Lite CNNs. Behavioral events exceeding configured thresholds are structured as alert objects with timestamps, GPS coordinates, and driver identifiers for cloud transmission.

3.2.3 Tier 3 - Cloud Backend (Firebase)

Firebase Firestore stores structured operational data for drivers, vehicles, routes, alerts, feedback, and configuration. Firebase Authentication provides role-based access control. Cloud Functions handle serverless processing and report generation. Cloud Messaging dispatches push notifications to the dashboard and passenger app.

3.2.4 Tier 4 - User Applications

A NextJS-based web authority dashboard serves fleet operators and transport regulators. A Flutter-based cross-platform passenger mobile application serves passengers on Android and iOS. Both communicate exclusively with the Firebase backend using authenticated REST APIs and real-time Firestore listeners.

3.3 Multi-Level Alert Escalation System

The alert escalation system implements a four-level graduated response protocol:

- Level 1 (0–5 seconds): Immediate local audio buzzer and text-to-speech voice warning to the driver.
- Level 2 (5–15 seconds): Increased alert intensity with repeated voice warnings and visual indicators.
- Level 3 (15+ seconds): Automated push notifications and SMS to National Transport Commission authority dashboard.

- Level 4 (severe/emergency): GPS location sharing with emergency services for critical incidents.

Smart threshold management allows dynamic sensitivity adjustment based on time of day, route risk level, and driver-specific behavioral baselines. Thresholds are stored in the Firestore configs collection and can be updated remotely by system administrators.

3.4 Technology Stack

Layer / Module	**Technology / Tool**	**Purpose**
Hardware	Raspberry Pi 4, Pi Camera 2 NoIR, GPS, Buzzer	Embedded processing and sensing
Computer Vision	OpenCV, MediaPipe (468-pt face mesh)	Face/eye tracking and head pose estimation
Deep Learning	TensorFlow Lite, YOLO	Drowsiness and distraction detection on edge
Backend & Cloud	Firebase Firestore, Cloud Functions, Cloud Messaging, Authentication	Real-time data and communications
Web Dashboard	NextJS, React, TypeScript	Authority fleet management interface
Mobile Application	Flutter (Dart)	Cross-platform passenger application
Languages	Python, TypeScript, Dart	System integration, web, and mobile dev
Project Management	GitHub Projects	Task tracking and version control

Table 3:Technology Stack

Summary of Chapter 3

Chapter 3 explains the development methodology and the overall SafeDriver solution design. It describes an iterative, Agile-inspired process aligned with the project milestones, from requirements and architecture through prototyping, implementation, testing, and pilot deployment. The chapter also presents the four-tier architecture, multi-level alert escalation strategy, and technology stack that combine Raspberry Pi edge processing, Firebase cloud services, a web dashboard, and mobile applications.

4. UML Diagrams

4.1 Use Case Diagram

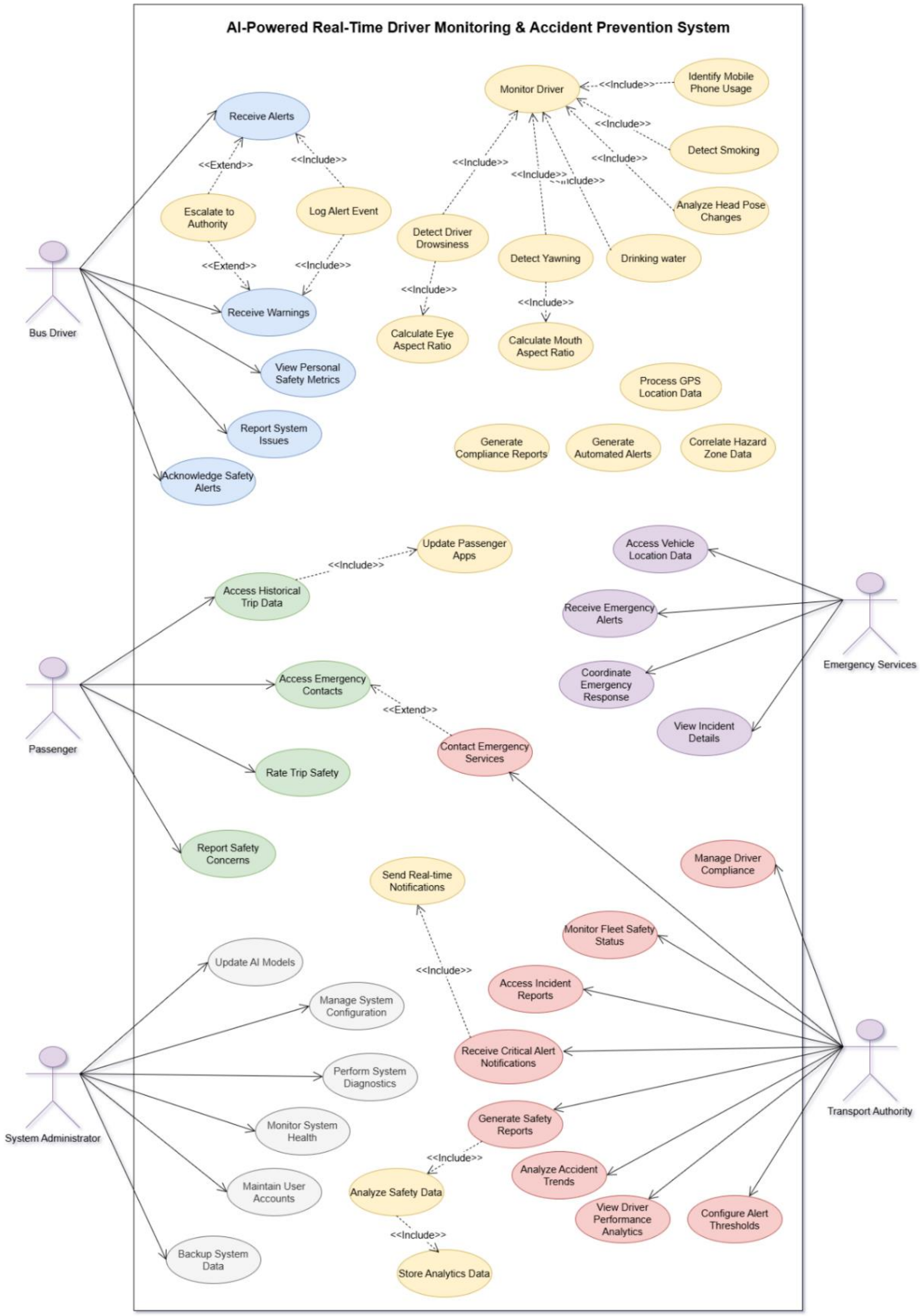


Figure 1 - Use case diagram

4.2 System Architecture Diagram

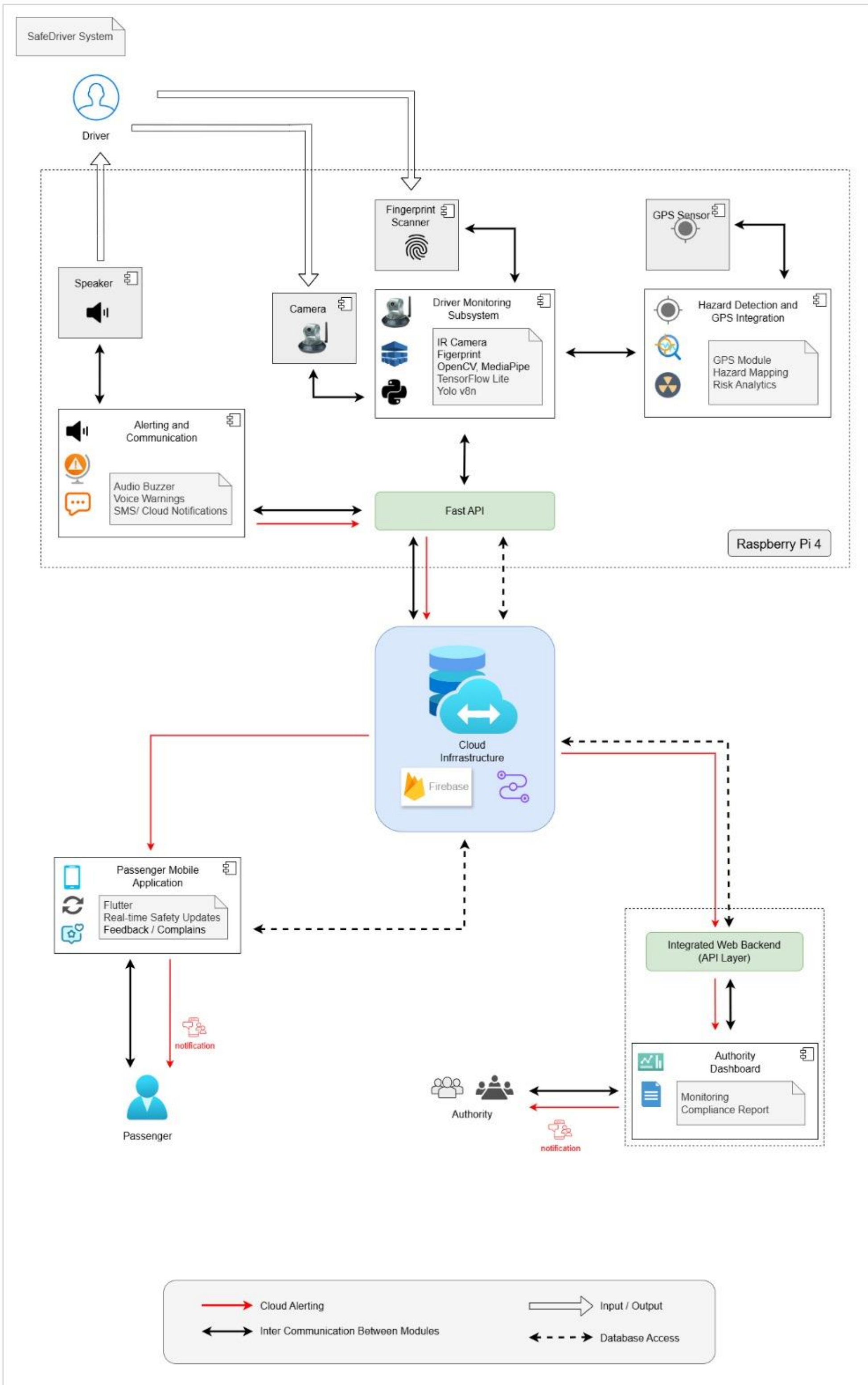


Figure 2 - System architecture diagram

4.3Class Diagram

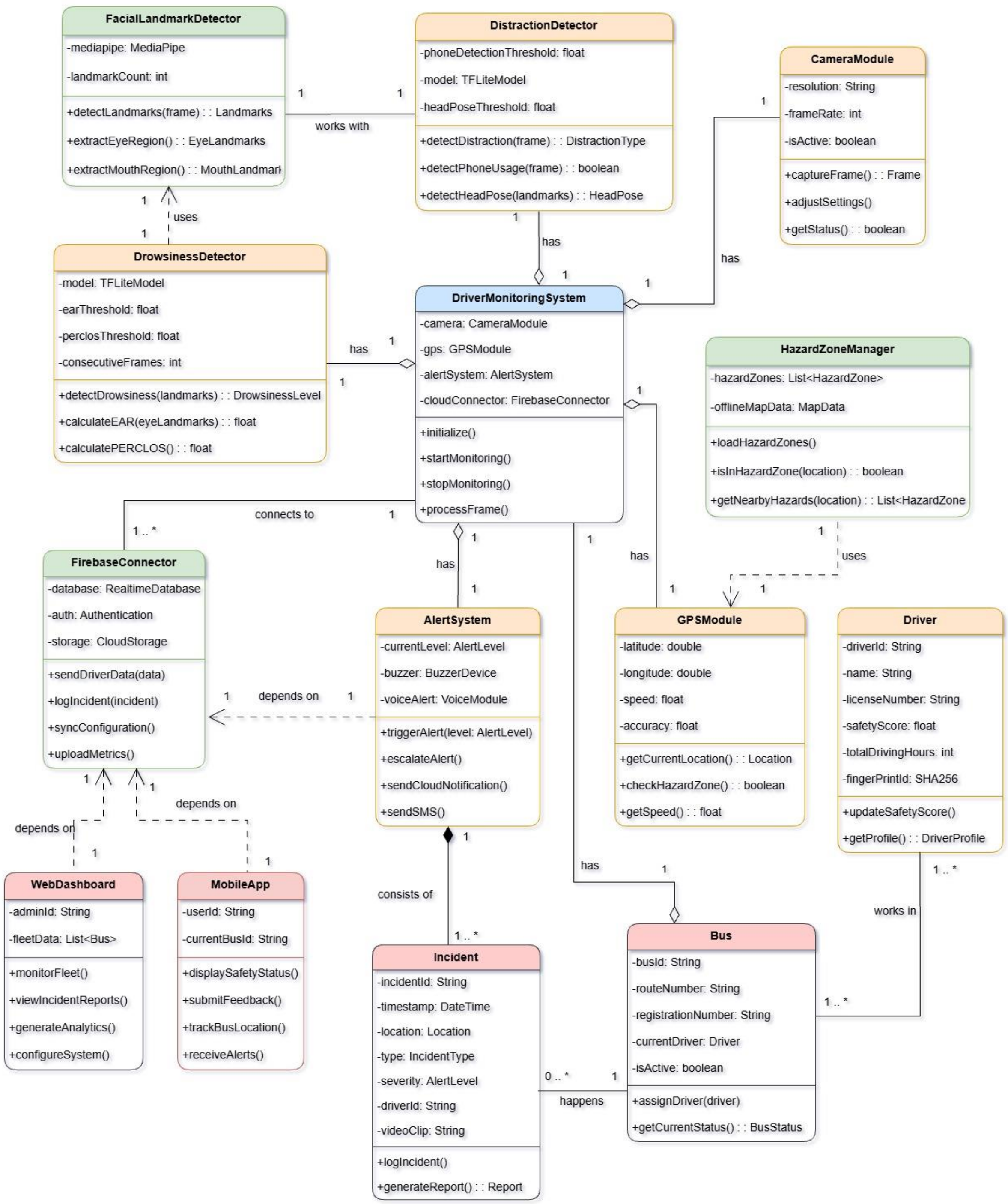


Figure 3 - Class Diagram

4.4 Sequence Diagram

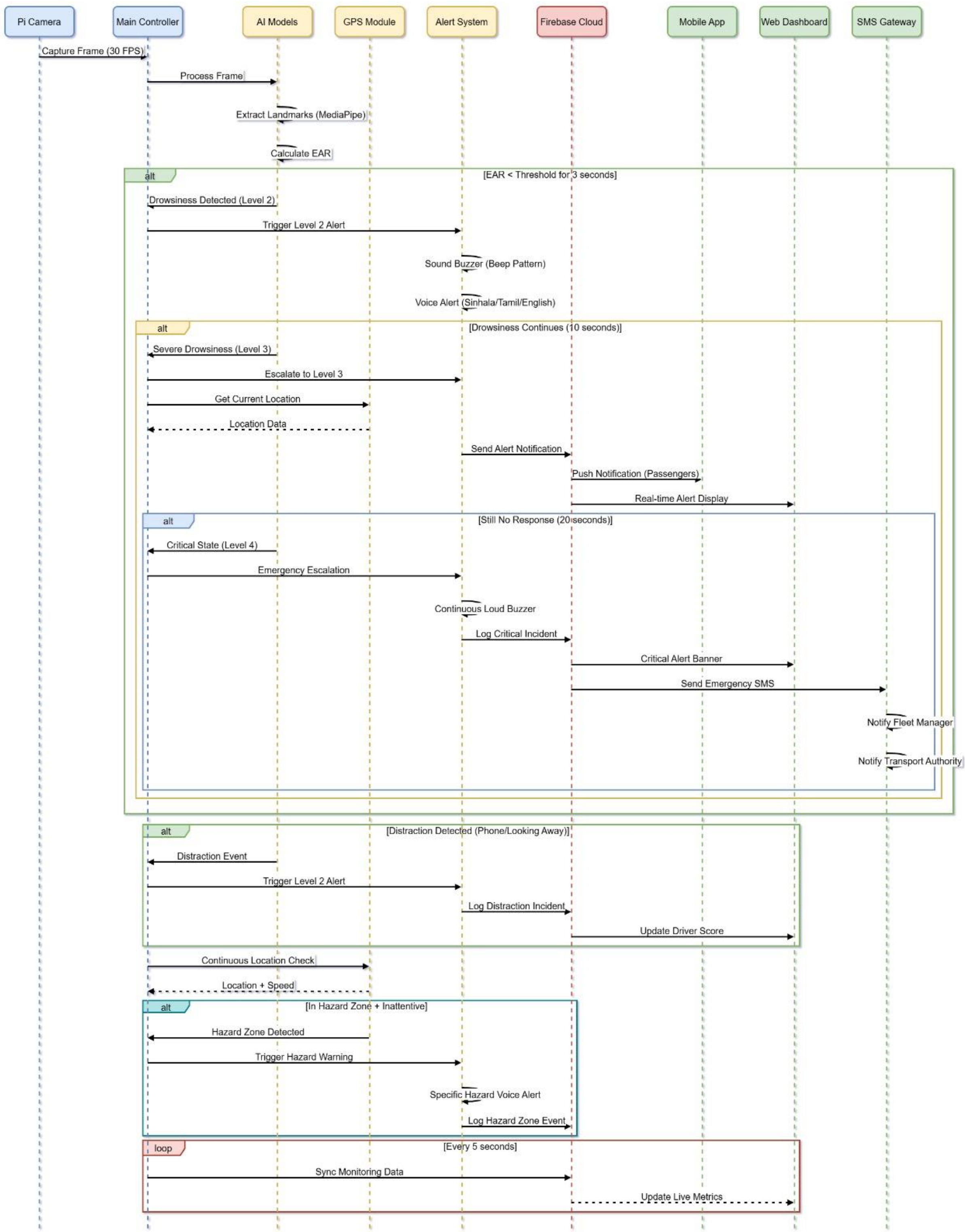


Figure 4 - Sequence Diagram

4.5 Activity Diagram

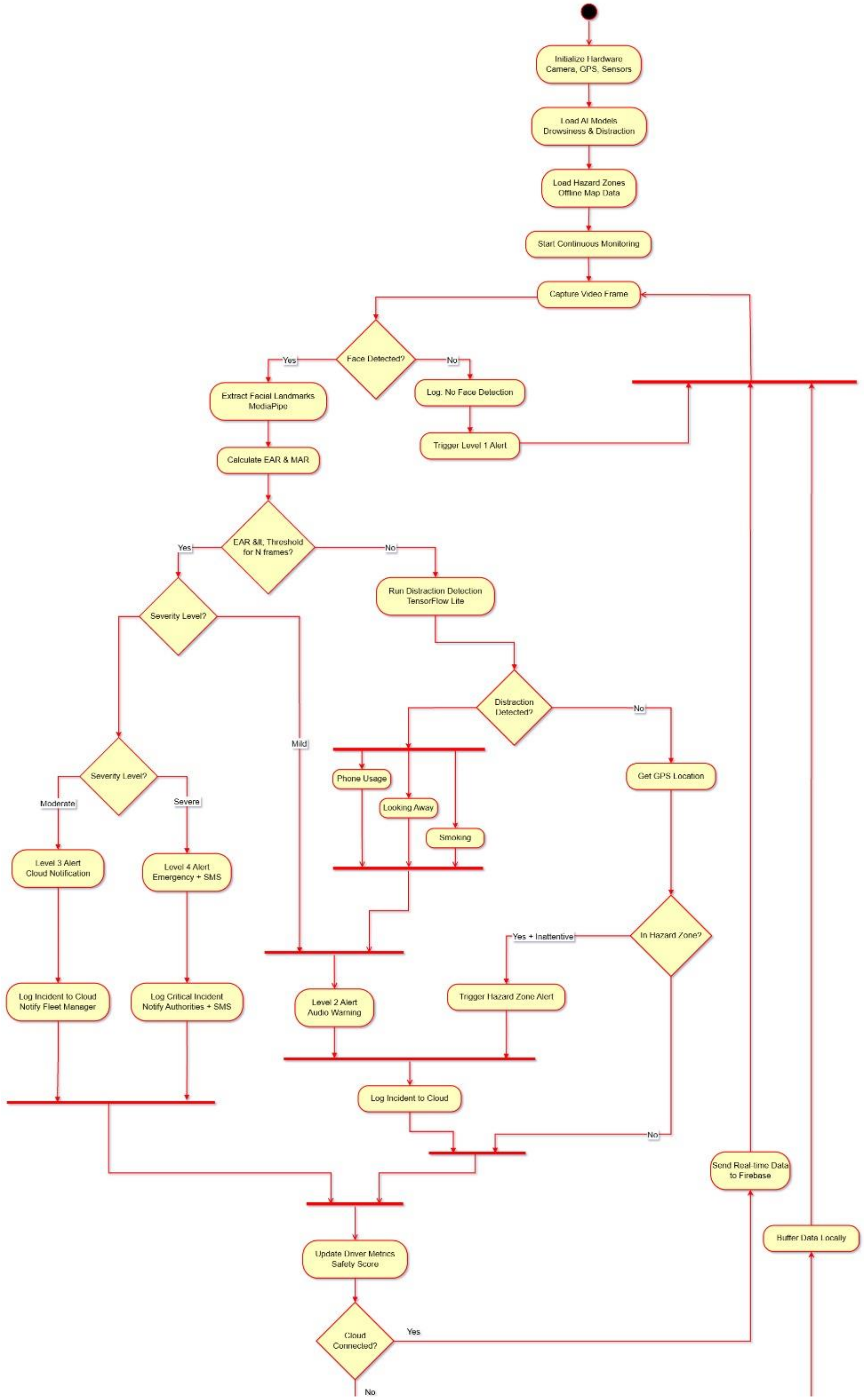


Figure 5 - Activity Diagram

4.6Raspberry Model Diagram

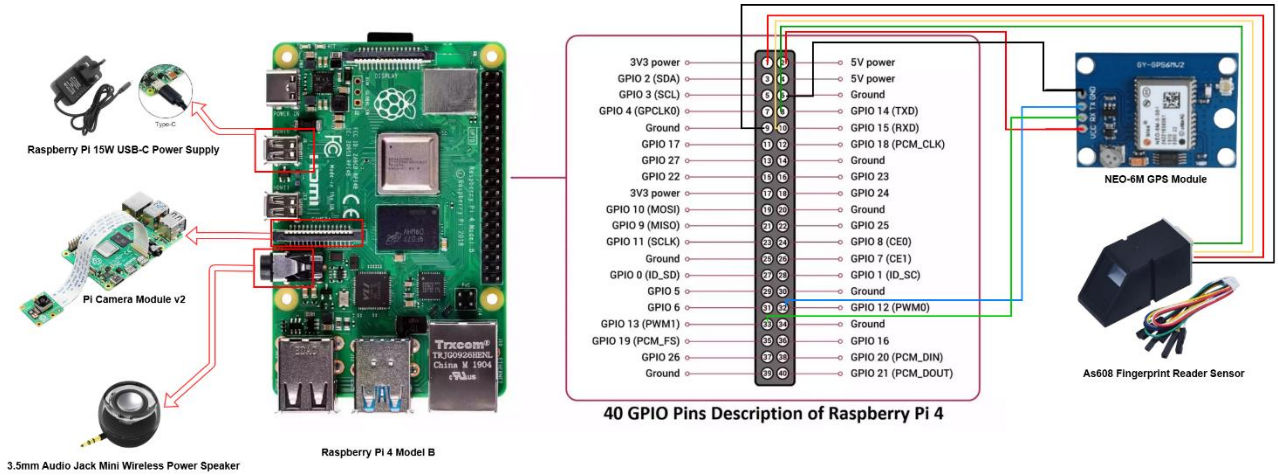


Figure 6 - Raspberry Model Diagram

Summary of Chapter 4

Chapter 4 presents the UML diagrams used to model the SafeDriver system at a structural and behavioral level. It includes the use case, architecture, class, sequence, activity, and Raspberry Pi model diagrams, which together define how the system components interact and how the monitoring workflow is executed. This chapter provides the blueprint for implementation by translating the project requirements into clear system models.

5. Database Design

5.1 Overview

The SafeDriver backend uses Cloud Firestore as its primary operational database, complemented by Firebase Authentication for identity management and Cloud Storage for media attachments. To maintain rigorous data modeling, the team first designed a normalized relational ER model and then mapped it to Firestore collections, preserving all key entities and relationships while optimizing for Firestore access patterns.

5.2 Core Data Entities

Entity	Description
VEHICLES	Buses equipped with SafeDriver devices; stores registration, device binding, GPS telemetry, safety score, and status.
DRIVERS	Registered bus drivers with biometric profiles, license numbers, experience, safety scores, and alert counts.
ROUTES	Public transport routes with start/end points, distance, estimated time, active vehicles, and performance KPIs.
USERS	Authentication profiles with global role assignments (driver, passenger, admin, authority).
PASSENGER_DETAILS	Passenger profiles with preferences, favourite buses/routes, device tokens, and verification status.
FEEDBACK	Structured passenger feedback linked to driver and bus; includes ratings, comments, images, GPS location, and public flag.
ALERTS	Real-time unsafe behaviour events with type, severity tag, GPS coordinates, timestamp, and device/driver/vehicle IDs.
POINT_TRANSACTIONS	Immutable reward point audit trail with delta, new balance, reason, and timestamp.

Entity	Description
DEVICES	Embedded device records with MAC/device ID, driver and vehicle assignment, last active time, and health status.
CONFIGS	System-wide AI model configuration including detection thresholds and alert sensitivity parameters.

Table 4:Core Data Entities

5.3 Key Entity Relationships

- ROUTES ↔ VEHICLES via routeId — each route can have multiple active vehicles.
- DRIVERS ↔ VEHICLES via driverId — a driver is assigned to one vehicle per shift.
- USERS ↔ PASSENGER_DETAILS via userId — one profile per user.
- USERS ↔ FEEDBACK and POINT_TRANSACTIONS via userId.
- VEHICLES ↔ FEEDBACK and ALERTS via busNumber.
- DRIVERS ↔ ALERTS via driverId — enables per-driver incident pattern analysis.
- DEVICES ↔ ALERTS via deviceId — alerts partitioned by date for efficient time-range queries.
- VEHICLES ↔ DEVICES via busNumber — each vehicle has exactly one registered device.

5.4 Firebase Firestore Physical Data Model

The Firestore physical model maps relational entities to collections optimized for the access patterns of the SafeDriver application:

- vehicles/{busNumberPlate} — vehicle fields and runtime telemetry.
- drivers/{driverId} — driver profiles with biometric and safety attributes.
- routes/{routeId} — route data including performance KPIs and stop arrays.
- devices/{deviceId} — device records with driver and vehicle assignments.
- alerts/{deviceId}/{date}/{alertId} — alerts partitioned by date for efficient time-range queries.
- feedback/{feedbackId} — feedback linked to user, bus, and driver.
- passenger_details/{uid} — passenger profile with preferences and favorites.

- point_transactions/{transactionId} — immutable reward point audit trail.
- configs/model_configurations — system-wide AI configuration parameters.

Summary of Chapter 5

Chapter 5 describes the database design used to support SafeDriver's cloud backend. It outlines the core entities such as vehicles, drivers, routes, users, feedback, alerts, devices, configs, and point transactions, along with their relationships and Firestore mappings. The chapter shows how the logical data model was normalized first and then adapted into a Firestore physical structure optimized for real-time queries and mobile access.

6. GUI Detailed Design and Prototypes

Design Principles and Tools

The graphical user interface design follows the principles of clarity, safety-critical visualization, and multilingual usability described in the PR2 non-functional requirements. Figma was used as the main tool for wireframing and interactive prototyping, ensuring consistent style and reusable components across the embedded UI, authority dashboard, and passenger mobile application.

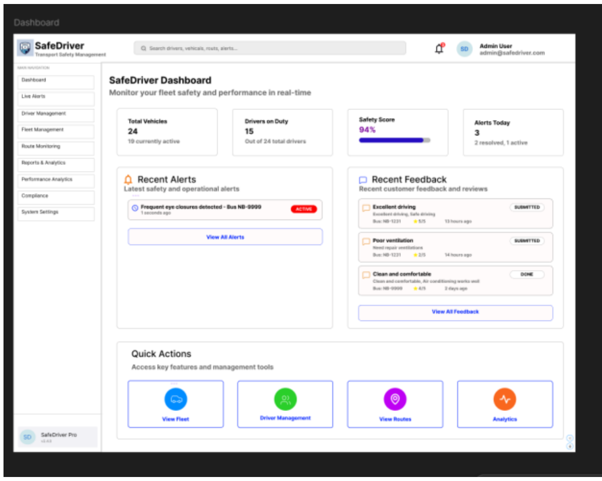
6.1 Authority Dashboard Screens

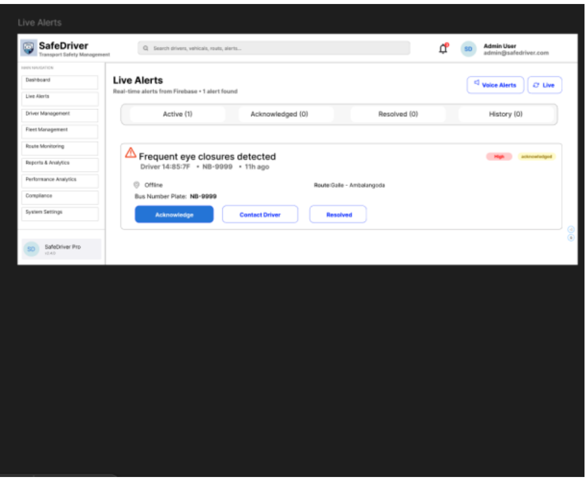
The web-based dashboard for fleet operators and transport authorities includes:

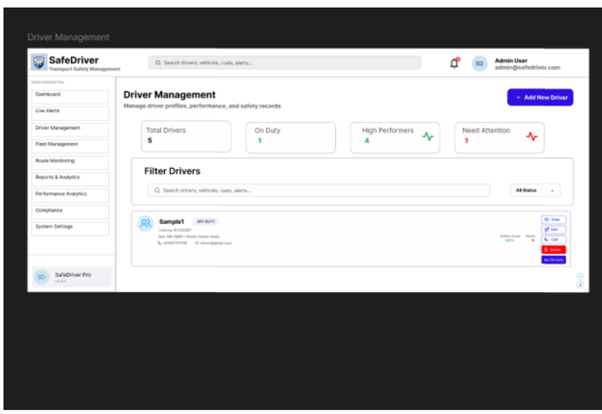
- **Login & access control** screens integrated with Firebase Authentication and role-based routing.
- A **Fleet Overview** homepage with map visualization of active buses, color-coded by safety status and route.
- **Driver Management** views for listing drivers, viewing safety scores, and checking biometric registration status.
- **Live Alert** pages with filterable tables by route, driver, alert type, and time range.
- **Route Monitoring** pages with charts for incidents per route, on time performance.
- **Configuration** views for managing alert thresholds, hazard zones, and notification recipients.

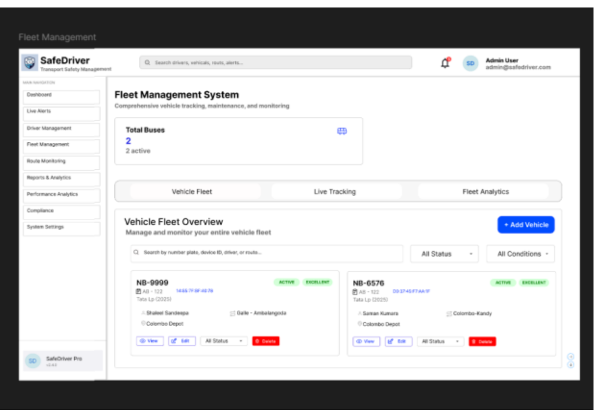
Figma Link:

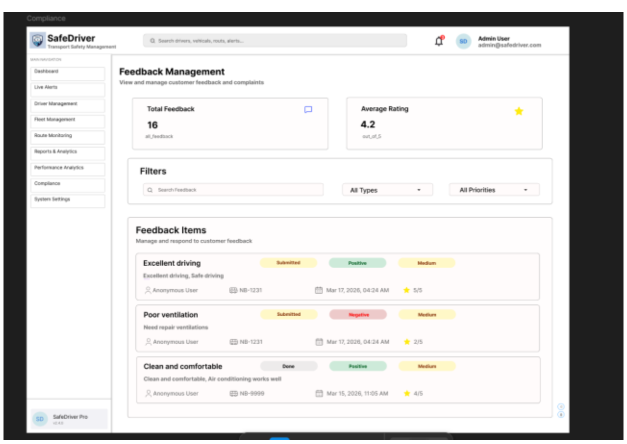
https://www.figma.com/design/ib3qEk3sChFRF4fi3UuQZ0/Untitled?node-id=0-1&t=rHqVNtVk0vdxBwrj-1


Dashboard
SafeDriver
SafeDriver Dashboard
Monitor your fleet safety and performance in real-time
Total Vehicles
24
Drivers on Duty
15
Safety Score
94%
Alerts Today
3
Recent Alerts
Recent Feedback
View All Alerts
View All Feedback
Quick Actions
Access key features and management tools
View Fleet
Driver Management
View Routes
Analytics


Live Alerts
SafeDriver
Live Alerts
Voice Alerts
Live
Active (1)
Acknowledged (0)
Resolved (0)
History (0)
Frequent eye closures detected
Acknowledge
Contact Driver
Resolved


Driver Management
SafeDriver
Driver Management
+ Add New Driver
Total Drivers
5
On Duty
1
High Performers
4
Need Attention
1
Filter Drivers
Sample1

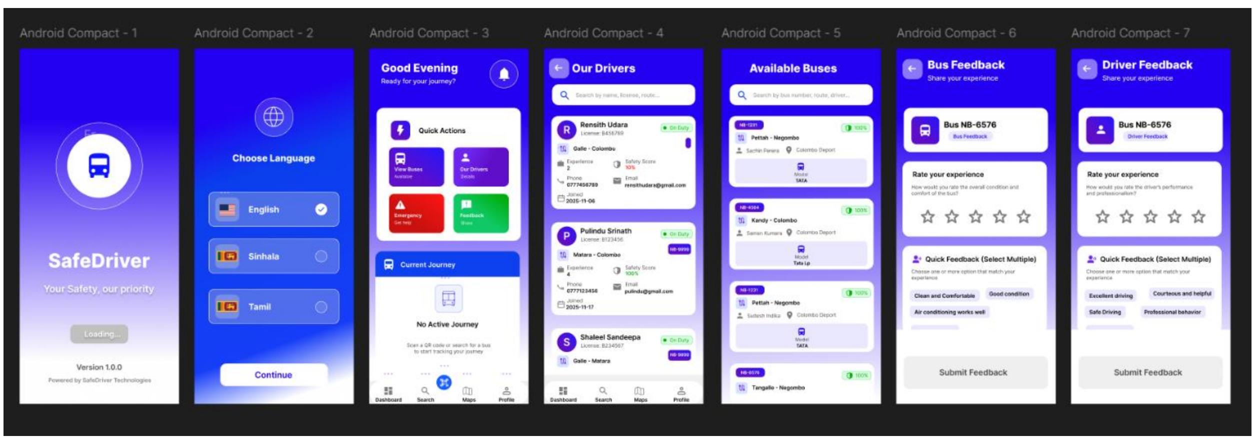

Fleet Management
SafeDriver
Fleet Management System
Total Buses
2
2 active
Vehicle Fleet
Live Tracking
Fleet Analytics
Vehicle Fleet Overview
+ Add Vehicle
NB-9999
NB-6576


Compliance
SafeDriver
Feedback Management
Total Feedback
16
Average Rating
4.2
Filters
Feedback Items
Excellent driving
Poor ventilation
Clean and comfortable

6.2 Passenger Mobile Application Screens

The passenger app, designed using Flutter and guided by PR2 requirements, includes:

- Registration and login screens using email/OTP and storing profiles in passenger details.
- A **Home** screen that displays current route information, driver safety status, and last alert summaries for the selected bus.
- A **Feedback** form allowing passengers to submit comments, select categories, attach images, and optionally remain anonymous.
- A **Points Wallet** showing current points and a list of point transactions with reasons and timestamps.
- **Favorites** management for saving commonly used buses and routes for quick access.



Figma Link: https://www.figma.com/design/X6BaOAPspOH2MycPN4qtFp/Untitled?node-id=7-23&t=krzd1UM5u4BTbwxn-1

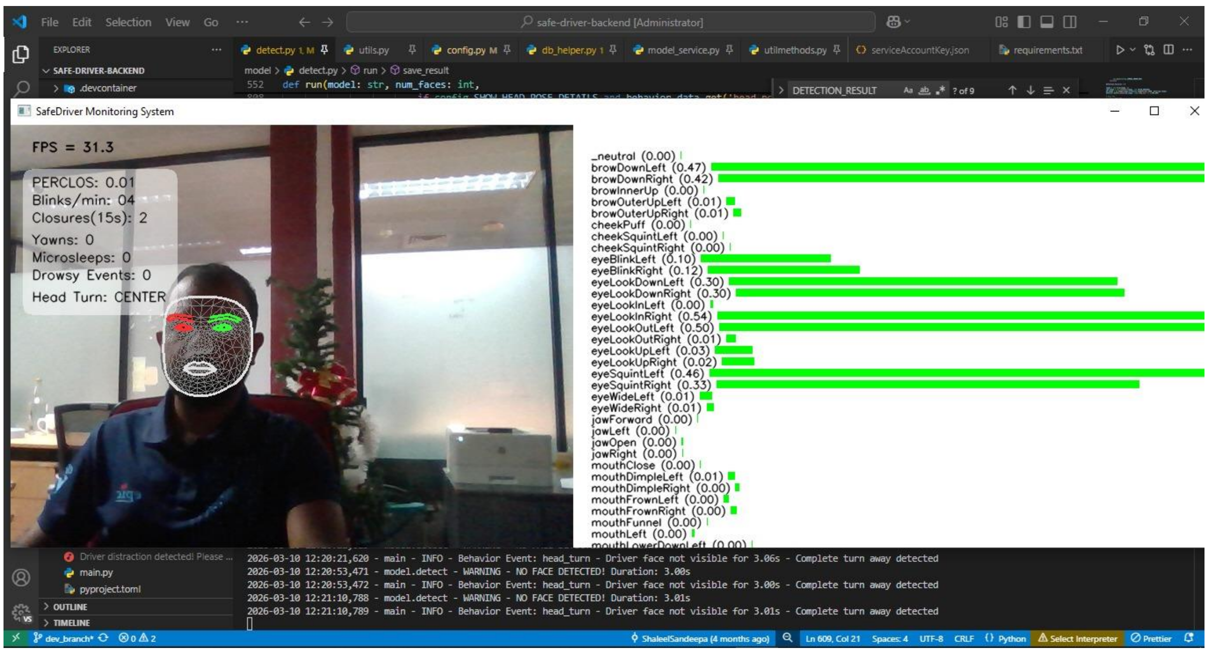
Summary of Chapter 6

Chapter 6 focuses on the GUI detailed design and prototypes for the authority dashboard and passenger mobile application. It explains the design principles used, including clarity, safety-critical visualization, and multilingual usability, and shows how Figma was used to develop the wireframes and interactive mockups. The chapter also defines the main screens for dashboards, alerts, route monitoring, feedback, rewards, and emergency support to ensure the system is easy to use for all user groups.

7. Implementation

7.1 Embedded Monitoring System

The core of SafeDriver is a Raspberry Pi 4-based embedded monitoring unit running a Python application integrating multiple AI-powered detection modules. The system achieves real-time performance at 29–31 frames per second with sub-100ms local alert latency.



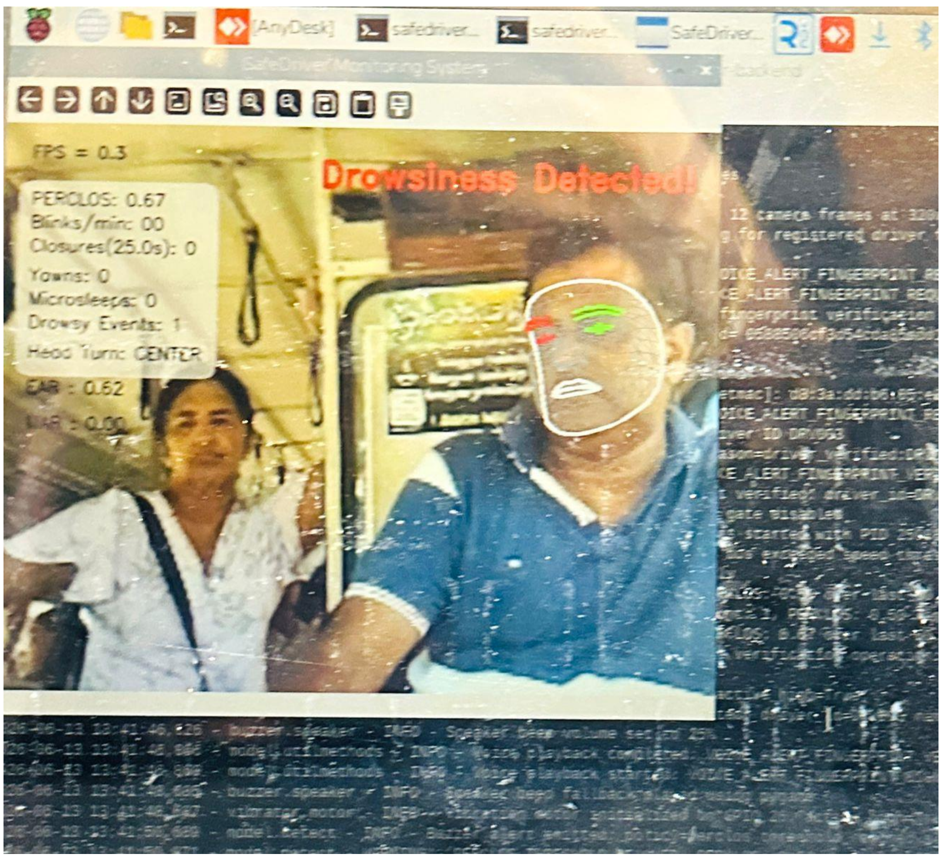
7.1.1 Drowsiness Detection Pipeline

The drowsiness detection pipeline uses MediaPipe's 468-point face mesh to extract per-frame facial landmarks. Eye Aspect Ratio (EAR) is calculated from six landmark coordinates around each eye. A rolling 15-second closure event counter tracks microsleep episodes, and a Mouth Aspect Ratio (MAR) detector identifies yawning events. The PERCLOS metric is computed over a configurable rolling window with the following operational thresholds:

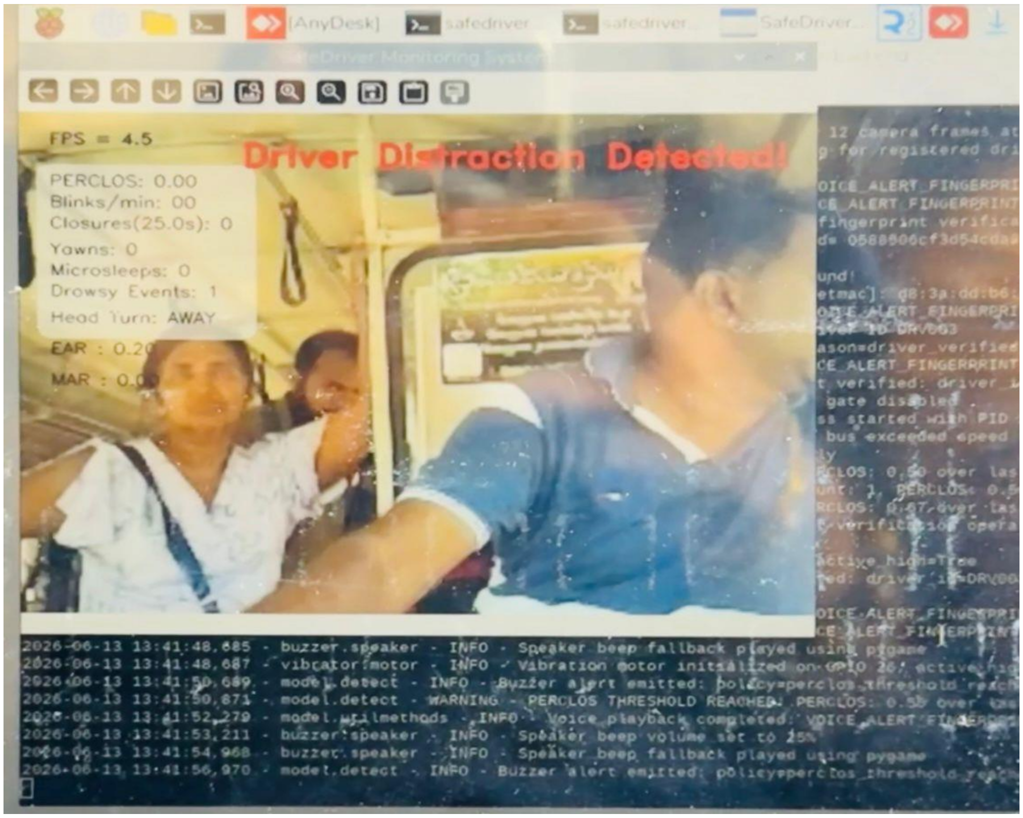
- EAR threshold: 0.25 (below this value = eye closed).
- Eye closure duration before alert trigger: 3.0 seconds.
- Yawn count fatigue threshold: 3 yawns within any 5-minute window.

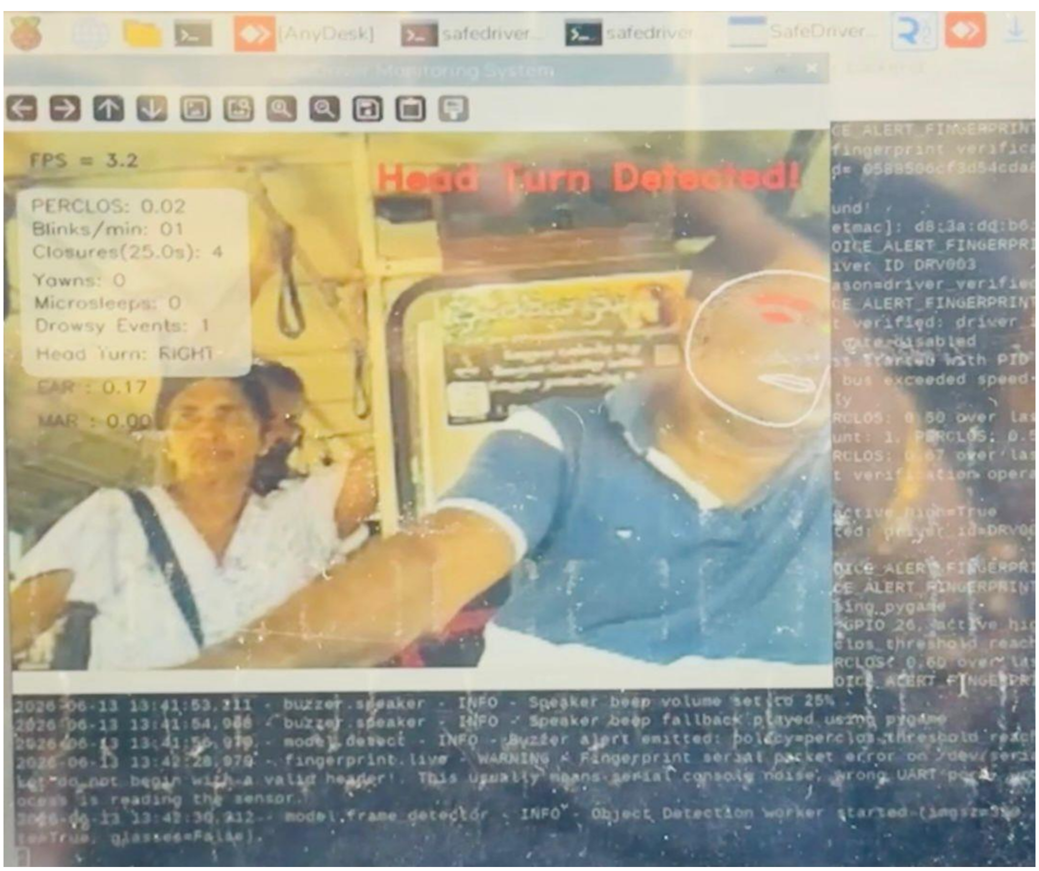
Development testing confirmed successful detection of yawning events (Yawning Detected overlay with drowsy event count incrementing), head-absent events (driver face not visible for 3 seconds triggering complete turn-away alert), and normal baseline monitoring at 31.3 FPS with PERCLOS 0.01.

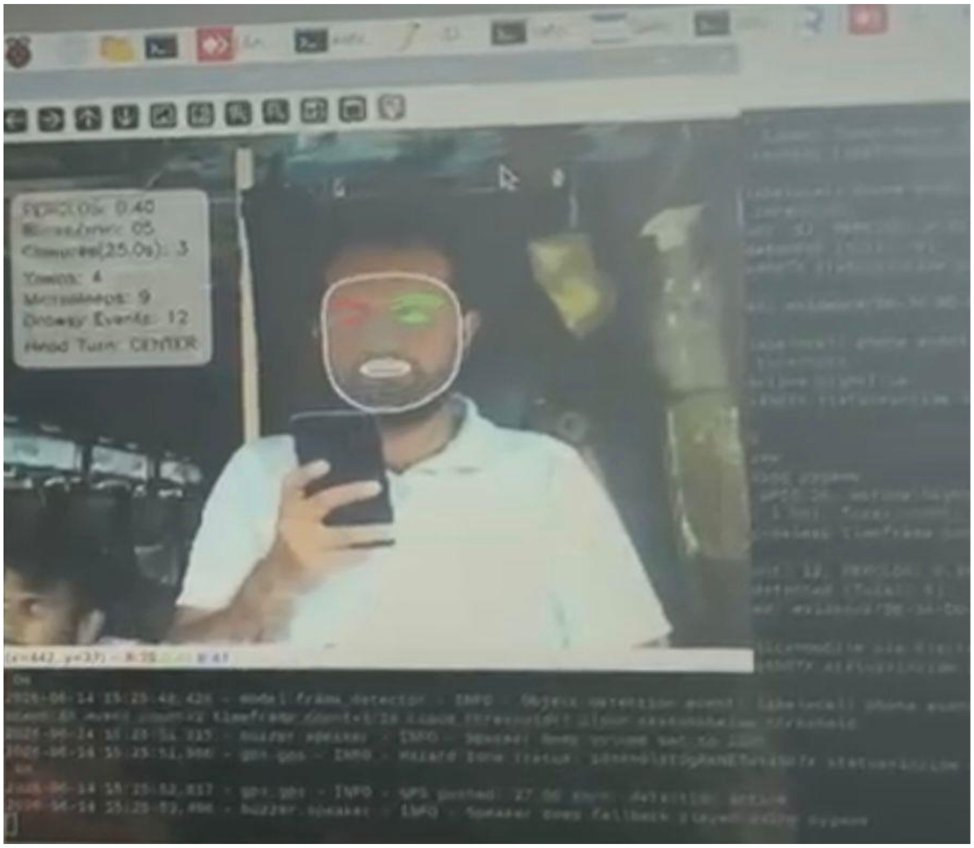
7.1.2. Distraction Detection Pipeline

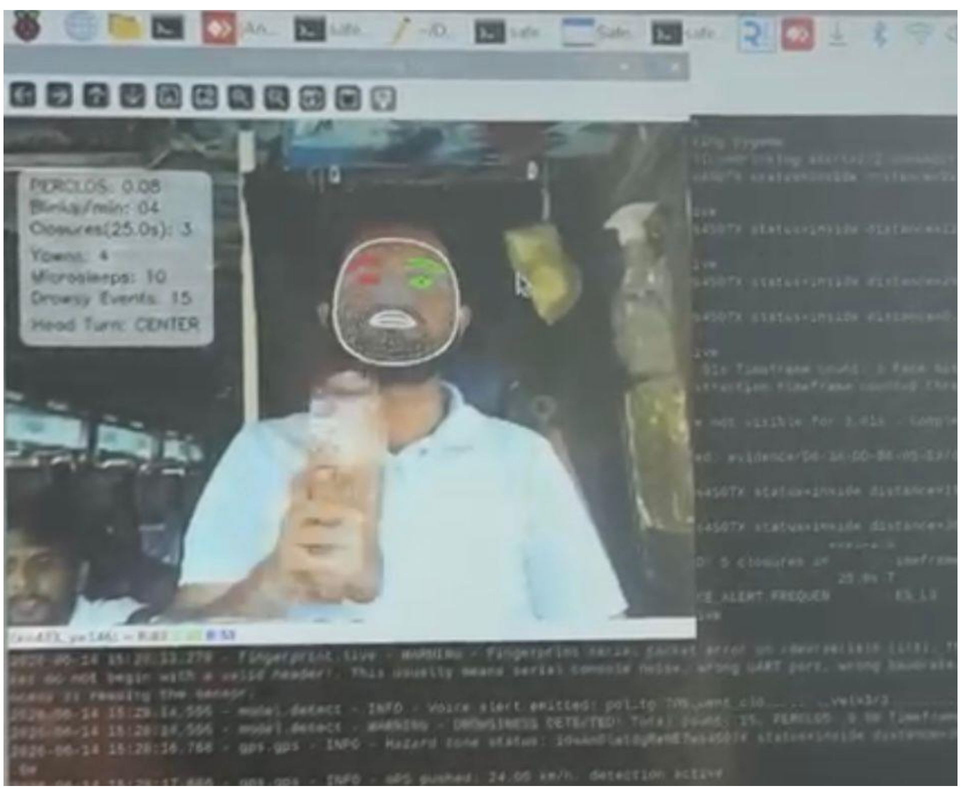


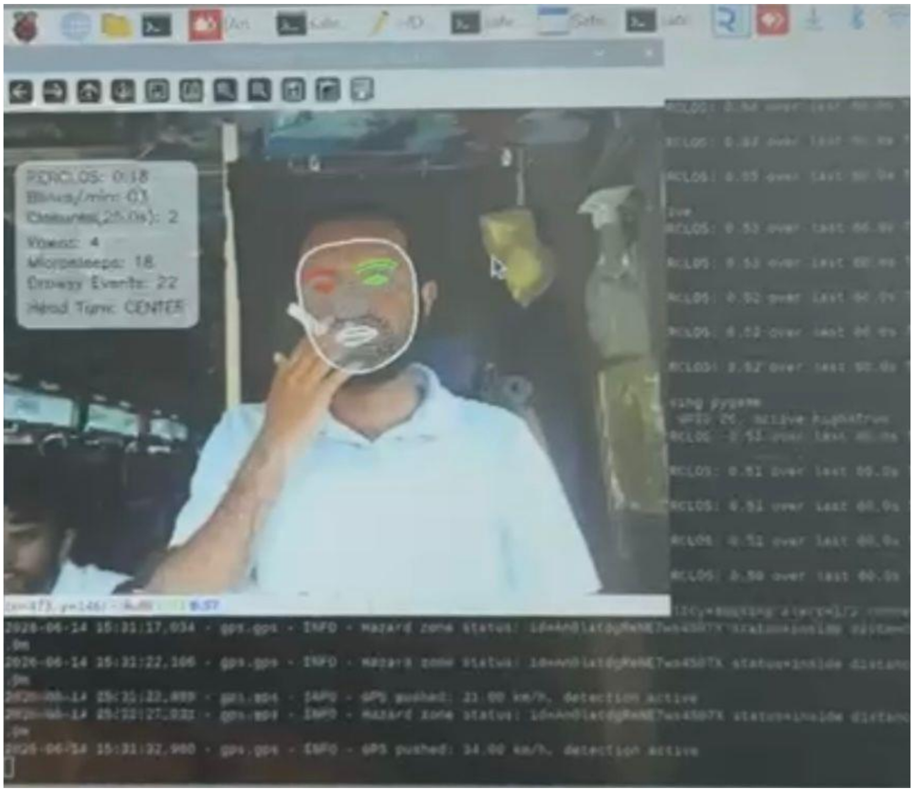
Distraction detection runs as three parallel inference modules: (1) Head Turn Detection via MediaPipe head pose estimation triggers alerts when head rotation exceeds ±30 degrees from center for more than 3 seconds (confirmed: Head Turn Detected, Direction: LEFT, Yaw: -39.5°); (2) Mobile Phone and Object Detection using a YOLO-based model detects phones at confidence 0.77–0.87 and bottles at 0.76–0.91 with bounding box overlays; and (3) Cigarette Detection using a dedicated CNN detects cigarettes at confidence 0.82–0.94. Processing speeds for the combined pipeline range from 100–141ms per frame on Raspberry Pi 4.


[AnyDesk]
safedriver
FPS = 4.5
Driver Distraction Detected!
PERCLOS: 0.00
Blinks/min: 00
Closures(25.0s): 0
Yawns: 0
Microsleeps: 0
Drowsy Events: 1
Head Turn: AWAY


[AnyDesk]
safedriver
FPS = 3.2
Head Turn Detected!
PERCLOS: 0.02
Blinks/min: 01
Closures(25.0s): 4
Yawns: 0
Microsleeps: 0
Drowsy Events: 1
Head Turn: RIGHT
EAR : 0.17


PERCLOS: 0.40
Closures(25.0s): 3
Yawns: 4
Microsleeps: 9
Drowsy Events: 12
Head Turn: CENTER


PERCLOS: 0.08
Blinks/min: 04
Closures(25.0s): 3
Yawns: 4
Microsleeps: 10
Drowsy Events: 15
Head Turn: CENTER



7.1.3 Alert and Cloud Transmission

Level 1 and 2 alerts use the onboard buzzer and text-to-speech voice system for immediate local warnings. Level 3 alerts structure event objects containing deviceId, driverId, busNumber, alert type, GPS coordinates, timestamp, and severity tag, transmitting these to the Firebase alerts collection. Firebase Cloud Messaging then dispatches push notifications to the authority dashboard and, for Level 4 events, to NTC officials via SMS gateway.

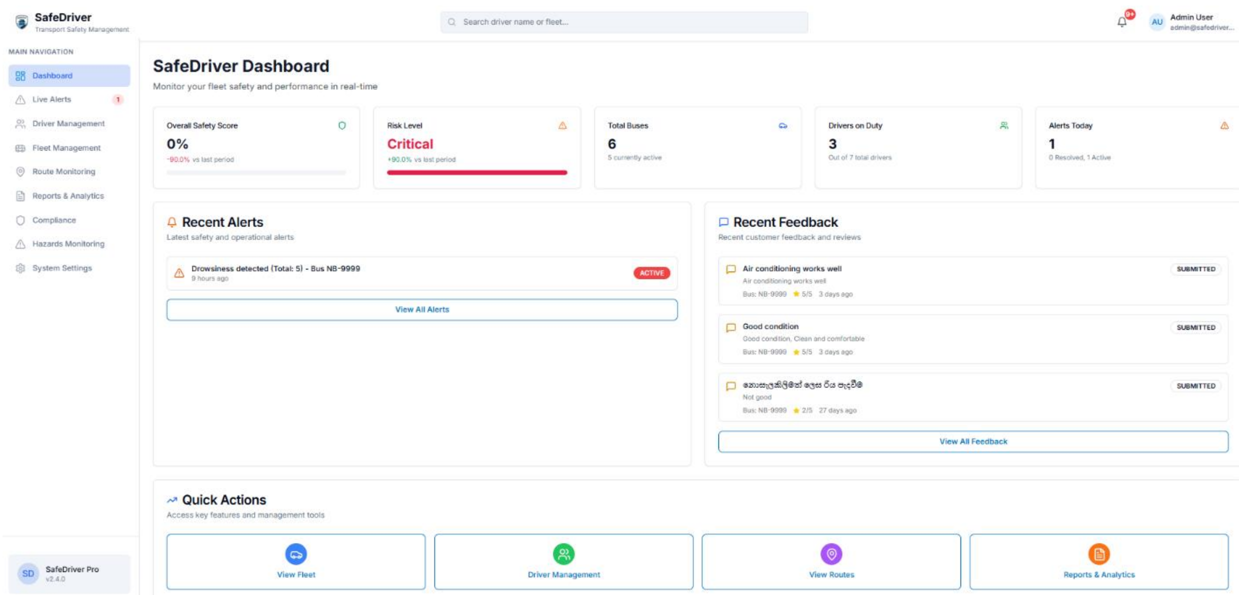
7.1.4 Crowded in-cabin background handling

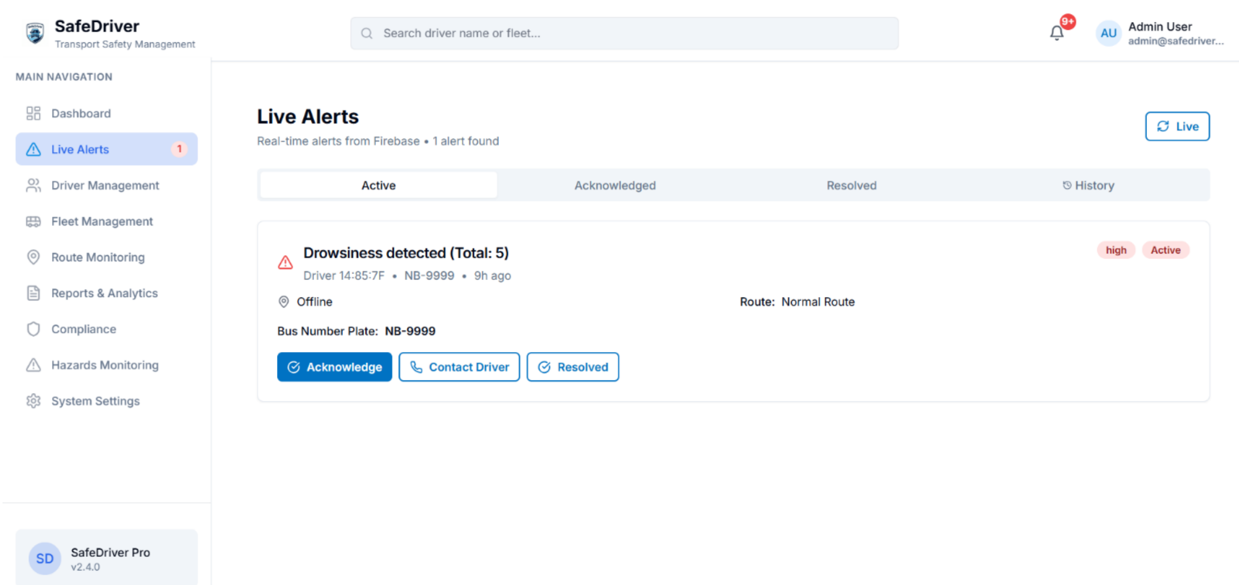
Since the SafeDriver system operates within a crowded bus cabin, passengers, seats, and other objects may appear in the background and introduce visual noise during distraction detection. To address this, the pipeline is designed to focus on a predefined driver-centric region of interest rather than the entire frame, ensuring that head turn, mobile phone use, and cigarette detection are evaluated primarily around the driver area. This approach reduces the influence of background motion, minimizes false detections, and improves robustness under realistic bus conditions. Although the figures use clean white backgrounds for presentation clarity, the actual implementation is intended for more complex environments with occlusion, clutter, and variable lighting.

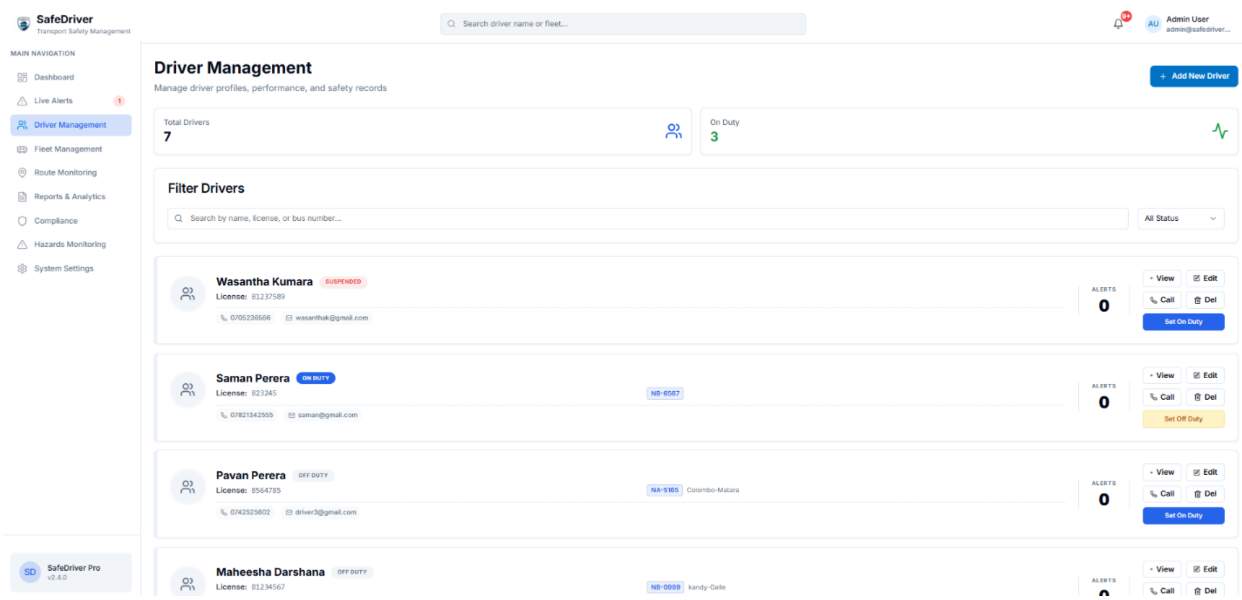
7.2 Authority Dashboard

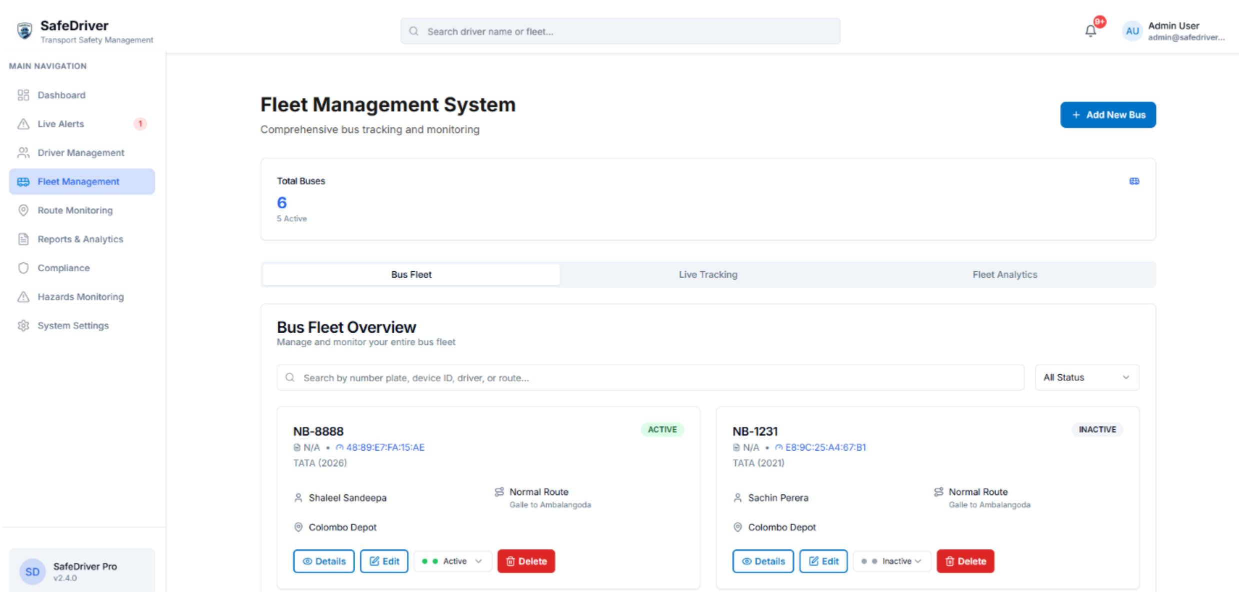
The authority dashboard is a NextJS web application connected to Firebase Firestore via real-time listeners, providing transport authorities and fleet operators with comprehensive monitoring and management tools.

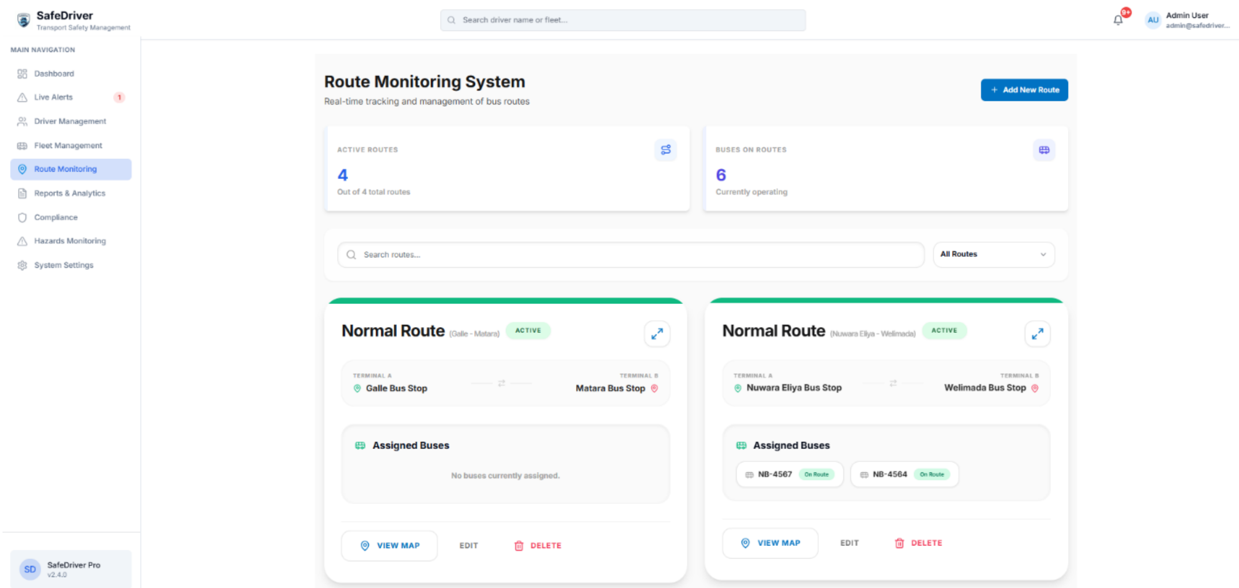
- Main Dashboard: KPI summary (5 total buses, 4 drivers on duty, 1 active alert), recent alerts, and recent passenger feedback with ratings.
- Live Alerts: Real-time alert table with Active/Acknowledged/Resolved/History tabs. Each alert shows driver ID, bus, route, severity, and action buttons (Acknowledge, Contact Driver, Resolved). Confirmed real-time data from Firebase showing 'Frequent eye closures detected' for Driver 48:88:E7, 4 hours ago.
- Driver Management: Searchable list showing 6 total drivers (4 on duty). Each entry displays name, license, bus number, route, safety score, alert count, and actions (View, Edit, Call, Delete, Set Off Duty).
- Fleet Management: Bus fleet overview with number plates, device MACs, active status, live tracking, and fleet analytics tabs.
- Route Monitoring: Active routes (5 active / 5 total, 3 buses currently operating) including Colombo-Kandy-01 and Colombo-Matara-EX1-18 with distance, estimated time, and bus/stop counts.
- Feedback Management: 16 total feedbacks, 4.2 average rating (out of 5), filterable by type and priority.
- Hazards Monitoring: Interactive Sri Lanka map with live monitoring mode for adding and managing danger zones.
- System Settings: Language configuration (English, Sinhala, Tamil), appearance, and AI threshold management.

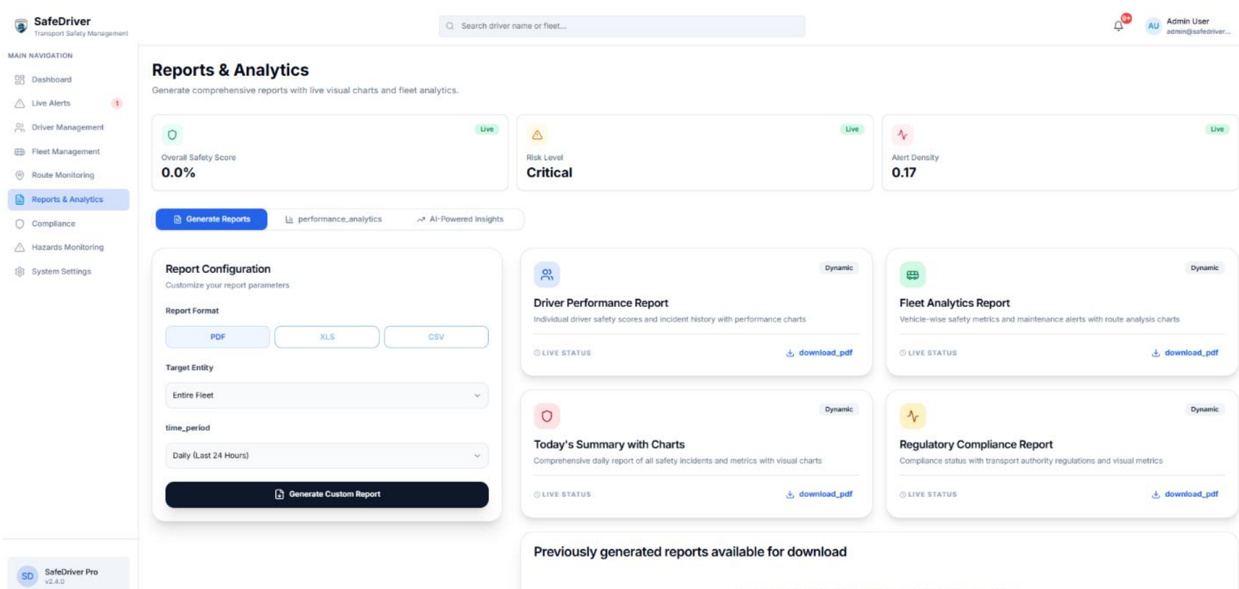

SafeDriver
Transport Safety Management
Search driver name or fleet...
Admin User
MAIN NAVIGATION
Dashboard
Live Alerts
Driver Management
Fleet Management
Route Monitoring
Reports & Analytics
Compliance
Hazards Monitoring
System Settings
SafeDriver Pro
SafeDriver Dashboard
Monitor your fleet safety and performance in real-time
Overall Safety Score
0%
Risk Level
Critical
Total Buses
6
Drivers on Duty
3
Alerts Today
1
Recent Alerts
Latest safety and operational alerts
Drowsiness detected (Total: 5) - Bus NB-9999
ACTIVE
View All Alerts
Recent Feedback
Recent customer feedback and reviews
Air conditioning works well
SUBMITTED
Good condition
SUBMITTED
SUBMITTED
View All Feedback
Quick Actions
Access key features and management tools
View Fleet
Driver Management
View Routes
Reports & Analytics

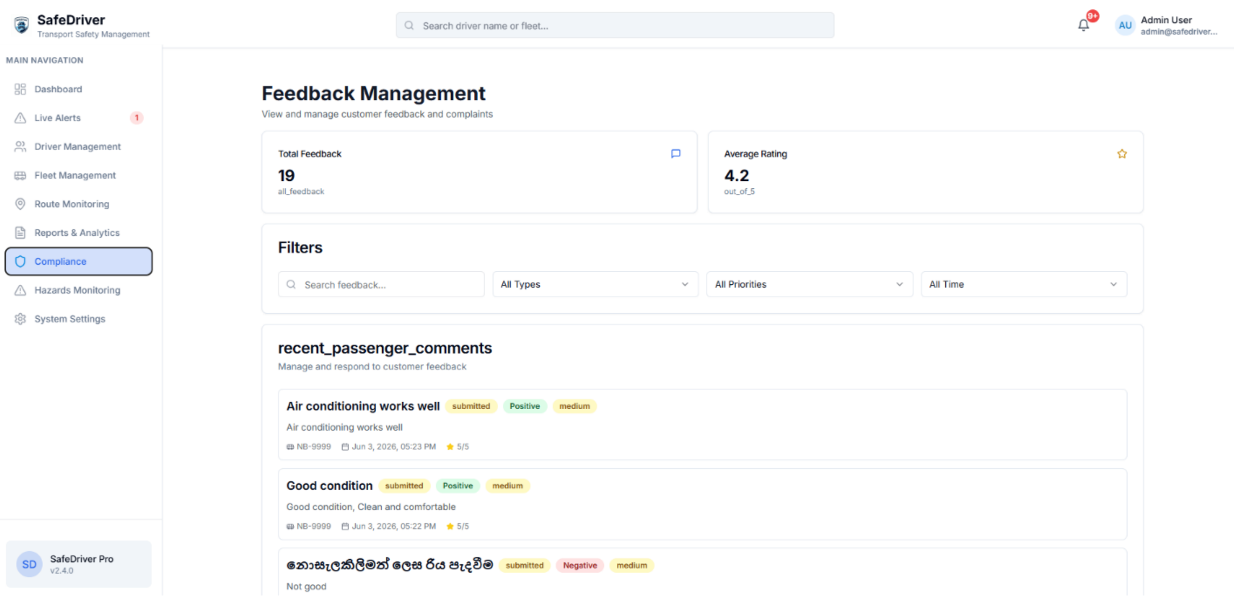

SafeDriver
Transport Safety Management
Search driver name or fleet...
Admin User
admin@safedriver...
MAIN NAVIGATION
Dashboard
Live Alerts
Driver Management
Fleet Management
Route Monitoring
Reports & Analytics
Compliance
Hazards Monitoring
System Settings
SafeDriver Pro
v2.4.0
Live Alerts
Real-time alerts from Firebase • 1 alert found
Live
Active
Acknowledged
Resolved
History
Drowsiness detected (Total: 5)
high
Active
Driver 14:85:7F • NB-9999 • 9h ago
Offline
Route: Normal Route
Bus Number Plate: NB-9999
Acknowledge
Contact Driver
Resolved

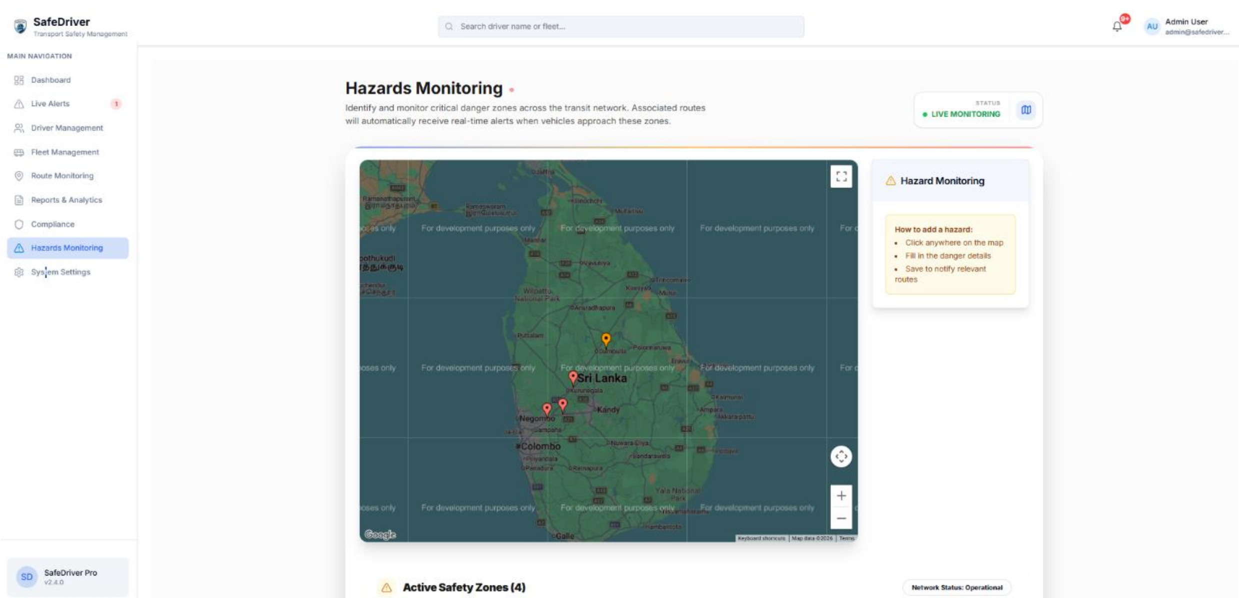


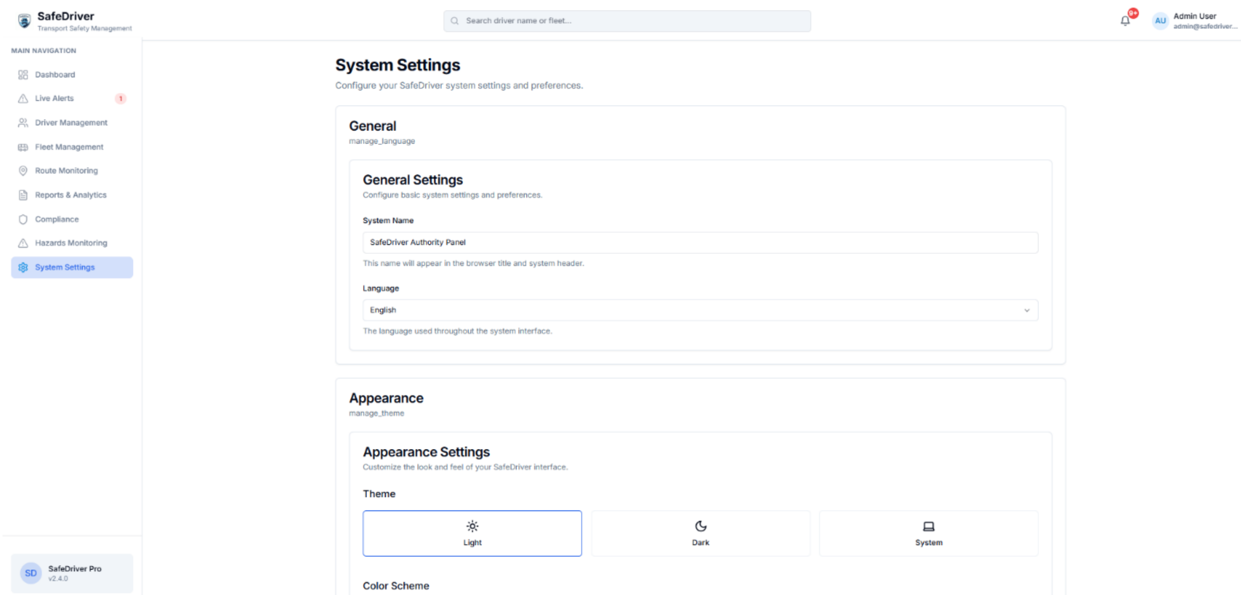



SafeDriver
Transport Safety Management
Search driver name or fleet...
Admin User
MAIN NAVIGATION
Dashboard
Live Alerts
Driver Management
Fleet Management
Route Monitoring
Reports & Analytics
Compliance
Hazards Monitoring
System Settings
SafeDriver Pro
v2.4.0
Route Monitoring System
Real-time tracking and management of bus routes
Add New Route
ACTIVE ROUTES
4
Out of 4 total routes
BUSES ON ROUTES
6
Currently operating
Search routes...
All Routes
Normal Route
ACTIVE
TERMINAL A
Galle Bus Stop
TERMINAL B
Matara Bus Stop
Assigned Buses
No buses currently assigned.
VIEW MAP
EDIT
DELETE
Normal Route
ACTIVE
TERMINAL A
Nuwara Eliya Bus Stop
TERMINAL B
Welimada Bus Stop
Assigned Buses
NB-4567
On Route
NB-4564
On Route
VIEW MAP
EDIT
DELETE


SafeDriver
Transport Safety Management
Search driver name or fleet...
Admin User
MAIN NAVIGATION
Dashboard
Live Alerts
Driver Management
Fleet Management
Route Monitoring
Reports & Analytics
Compliance
Hazards Monitoring
System Settings
SafeDriver Pro
v2.4.0
Reports & Analytics
Generate comprehensive reports with live visual charts and fleet analytics.
Live
Overall Safety Score
0.0%
Live
Risk Level
Critical
Live
Alert Density
0.17
Generate Reports
performance_analytics
AI-Powered Insights
Report Configuration
Customize your report parameters
Report Format
PDF
XLS
CSV
Target Entity
Entire Fleet
time_period
Daily (Last 24 Hours)
Generate Custom Report
Dynamic
Driver Performance Report
Individual driver safety scores and incident history with performance charts
LIVE STATUS
download_pdf
Dynamic
Fleet Analytics Report
Vehicle-wise safety metrics and maintenance alerts with route analysis charts
LIVE STATUS
download_pdf
Dynamic
Today's Summary with Charts
Comprehensive daily report of all safety incidents and metrics with visual charts
LIVE STATUS
download_pdf
Dynamic
Regulatory Compliance Report
Compliance status with transport authority regulations and visual metrics
LIVE STATUS
download_pdf
Previously generated reports available for download
No reports generated today. Generate a report above to view history.

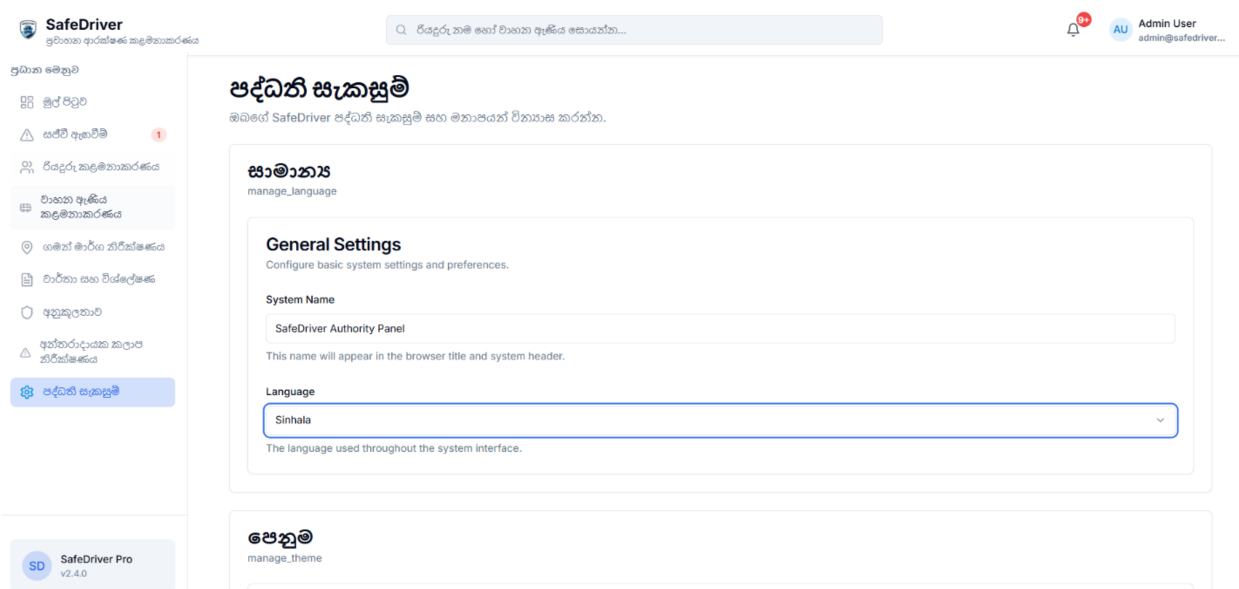

SafeDriver
Transport Safety Management
MAIN NAVIGATION
Dashboard
Live Alerts
1
Driver Management
Fleet Management
Route Monitoring
Reports & Analytics
Compliance
Hazards Monitoring
System Settings
SD
SafeDriver Pro
v2.4.0
Search driver name or fleet...
Admin User
admin@safedriver...
Feedback Management
View and manage customer feedback and complaints
Total Feedback
19
all_feedback
Average Rating
4.2
out_of_5
Filters
Search feedback...
All Types
All Priorities
All Time
recent_passenger_comments
Manage and respond to customer feedback
Air conditioning works well
submitted
Positive
medium
Air conditioning works well
NB-9999
Jun 3, 2026, 05:23 PM
5/5
Good condition
submitted
Positive
medium
Good condition, Clean and comfortable
NB-9999
Jun 3, 2026, 05:22 PM
5/5
නොසැලකිලිමත් ලෙස රිය පැදවීම
submitted
Negative
medium
Not good


SafeDriver
Transport Safety Management
MAIN NAVIGATION
Dashboard
Live Alerts
Driver Management
Fleet Management
Route Monitoring
Reports & Analytics
Compliance
Hazards Monitoring
System Settings
SD
SafeDriver Pro
v2.4.0
Search driver name or fleet...
Admin User
admin@safedriver...
Hazards Monitoring
Identify and monitor critical danger zones across the transit network. Associated routes
will automatically receive real-time alerts when vehicles approach these zones.
STATUS
LIVE MONITORING
For development purposes only
Sri Lanka
Colombo
Kandy
Negombo
Galle
Hazard Monitoring
How to add a hazard:
Click anywhere on the map
Fill in the danger details
Save to notify relevant routes
Active Safety Zones (4)
Network Status: Operational

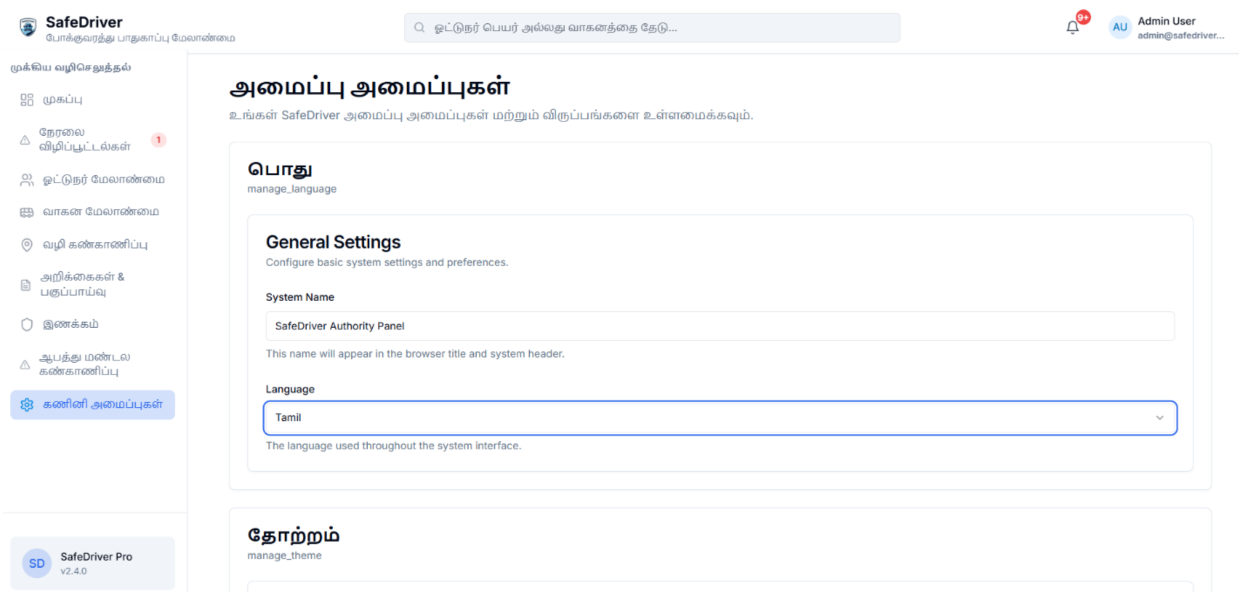


SafeDriver
Transport Safety Management
Search driver name or fleet...
9+
AU
Admin User
admin@safedriver...
MAIN NAVIGATION
Dashboard
Live Alerts
1
Driver Management
Fleet Management
Route Monitoring
Reports & Analytics
Compliance
Hazards Monitoring
System Settings
SD
SafeDriver Pro
v2.4.0
System Settings
Configure your SafeDriver system settings and preferences.
General
manage_language
General Settings
Configure basic system settings and preferences.
System Name
SafeDriver Authority Panel
This name will appear in the browser title and system header.
Language
English
The language used throughout the system interface.
Appearance
manage_theme
Appearance Settings
Customize the look and feel of your SafeDriver interface.
Theme
Light
Dark
System
Color Scheme

0



SafeDriver
ප්‍රවාහන ආරක්ෂණ කළමනාකරණය
රියදුරු නම හෝ වාහන ඇණිය සොයන්න...
9+
AU
Admin User
admin@safedriver...
ප්‍රධාන මෙනුව
මුල් පිටුව
සජීවී ඇඟවීම්
1
රියදුරු කළමනාකරණය
වාහන ඇණිය කළමනාකරණය
ගමන් මාර්ග නිරීක්ෂණය
වාර්තා සහ විශ්ලේෂණ
අනුකූලතාව
අන්තරාදායක කලාප නිරීක්ෂණය
පද්ධති සැකසුම්
SD
SafeDriver Pro
v2.4.0
පද්ධති සැකසුම්
ඔබගේ SafeDriver පද්ධති සැකසුම් සහ මනාපයන් වින්‍යාස කරන්න.
සාමාන්‍ය
manage_language
General Settings
Configure basic system settings and preferences.
System Name
SafeDriver Authority Panel
This name will appear in the browser title and system header.
Language
Sinhala
The language used throughout the system interface.
පෙනුම
manage_theme

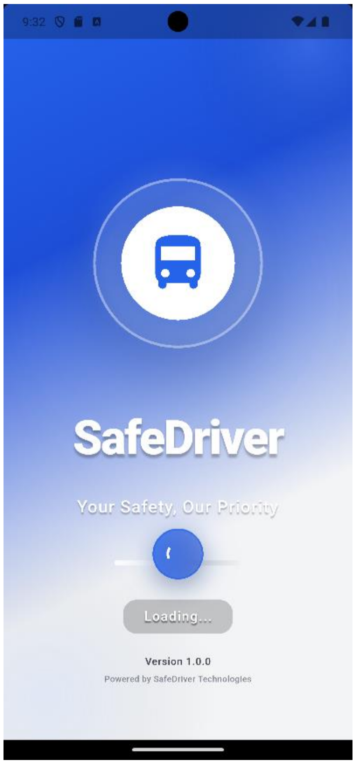


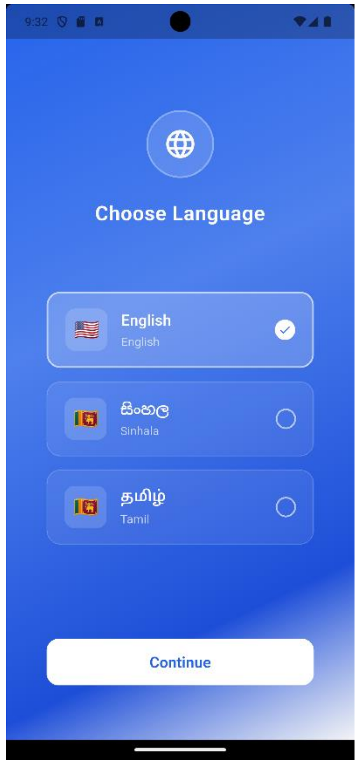
SafeDriver
போக்குவரத்து பாதுகாப்பு மேலாண்மை
ஓட்டுநர் பெயர் அல்லது வாகனத்தை தேடு...
9+
AU
Admin User
admin@safedriver...
முக்கிய வழிசெலுத்தல்
முகப்பு
நேரலை விழிப்பூட்டல்கள்
1
ஓட்டுநர் மேலாண்மை
வாகன மேலாண்மை
வழி கண்காணிப்பு
அறிக்கைகள் & பகுப்பாய்வு
இணக்கம்
ஆபத்து மண்டல கண்காணிப்பு
கணினி அமைப்புகள்
SD
SafeDriver Pro
v2.4.0
அமைப்பு அமைப்புகள்
உங்கள் SafeDriver அமைப்பு அமைப்புகள் மற்றும் விருப்பங்களை உள்ளமைக்கவும்.
பொது
manage_language
General Settings
Configure basic system settings and preferences.
System Name
SafeDriver Authority Panel
This name will appear in the browser title and system header.
Language
Tamil
The language used throughout the system interface.
தோற்றம்
manage_theme

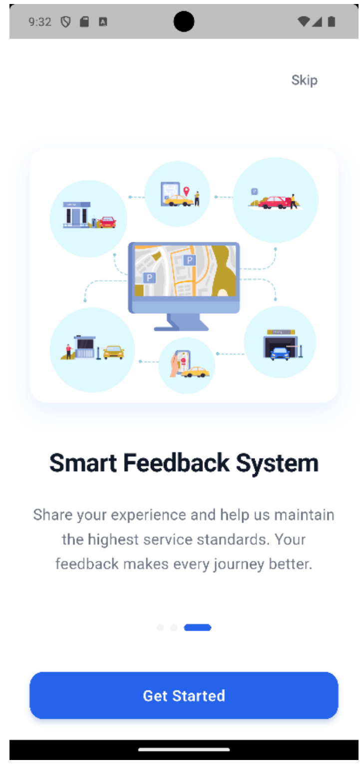
7.3 Passenger Mobile Application

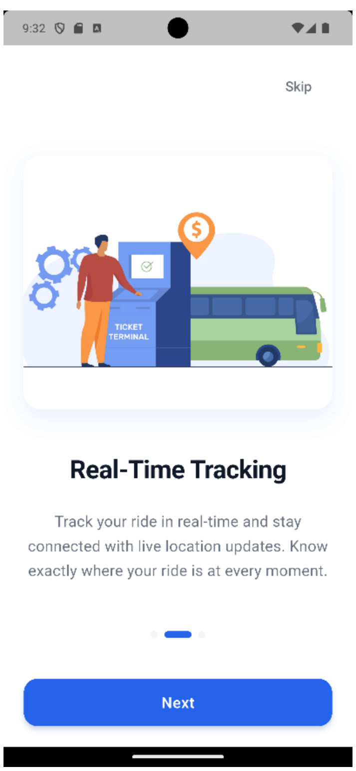
The passenger application is built with Flutter for cross-platform deployment on Android and iOS, connecting to Firebase for real-time safety data and feedback processing.

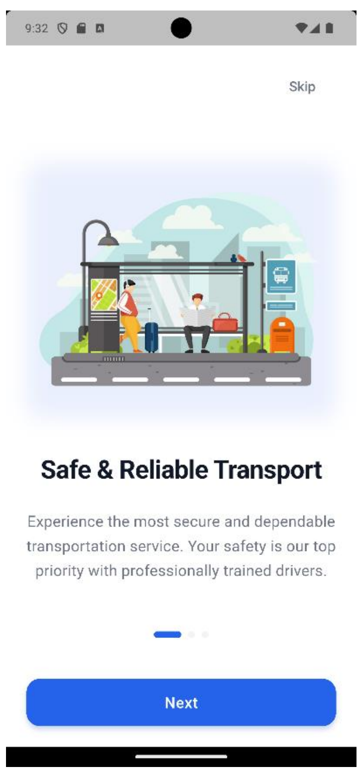
- Onboarding: Language selection screen (English, Sinhala, Tamil) followed by animated introduction slides for Smart Feedback System, Real-Time Tracking, and Safe & Reliable Transport.
- Authentication: Phone/OTP login, email/password and Google Sign-In registration, forgot password via OTP.
- Dashboard: Real-time journey tracking, QR code scanning for bus identification, Quick Actions panel (View Buses, Our Drivers, Emergency, Feedback), and Current Journey status.
- Search: Available buses list (NB-1231, NB-4564, NB-4567, NB-4576) with safety scores; driver directory with profiles, safety scores, on-duty status, and contact details.
- Feedback Flow: Bus Behavior and Driver Behavior submission with 5-star rating, multi-select quick tags, anonymous posting option, and image attachment.
- Emergency: Emergency contacts (Police 119, Ambulance 1990, Fire 110, SLTB Hotline), SOS alert with contact confirmation dialog, location sharing, incident reporting, and safety tips.
- Maps: Integrated Google Maps with Bus Stop and Navigate modes.
- Profile: Reward Points display (3/100 points shown in testing), Trip History, Feedback History, Edit Profile, and Help & Support with Live Chat.

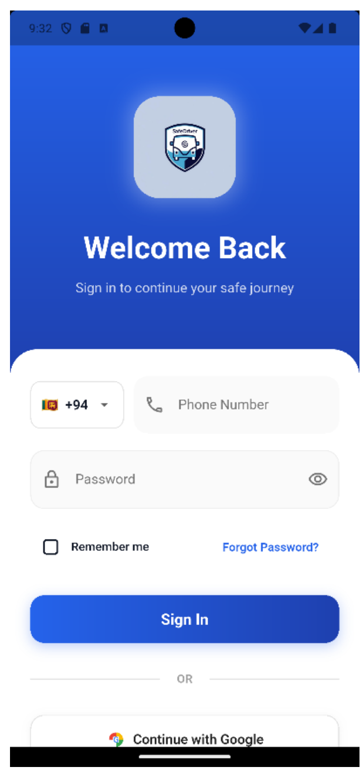

9:32
SafeDriver
Your Safety, Our Priority
Loading...
Version 1.0.0
Powered by SafeDriver Technologies

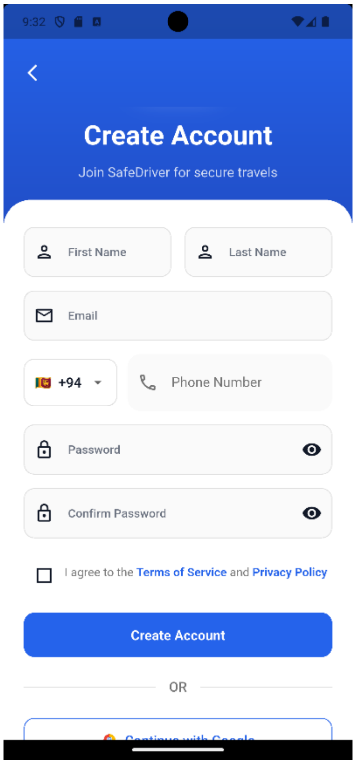

9:32
Choose Language
English
English
සිංහල
Sinhala
தமிழ்
Tamil
Continue

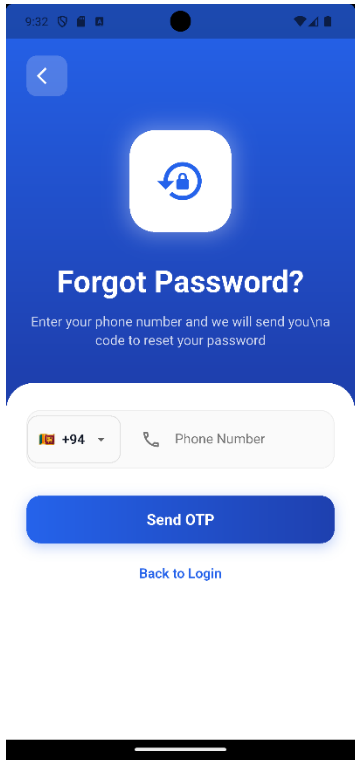

9:32
Skip
Smart Feedback System
Share your experience and help us maintain the highest service standards. Your feedback makes every journey better.
Get Started

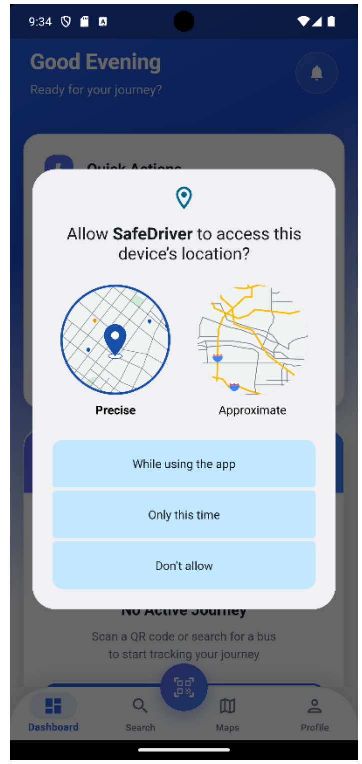

9:32
Skip
TICKET TERMINAL
Real-Time Tracking
Track your ride in real-time and stay connected with live location updates. Know exactly where your ride is at every moment.
Next

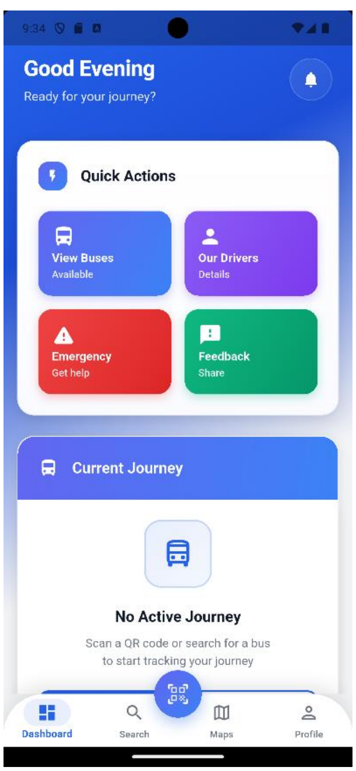

9:32
Skip
Safe & Reliable Transport
Experience the most secure and dependable transportation service. Your safety is our top priority with professionally trained drivers.
Next

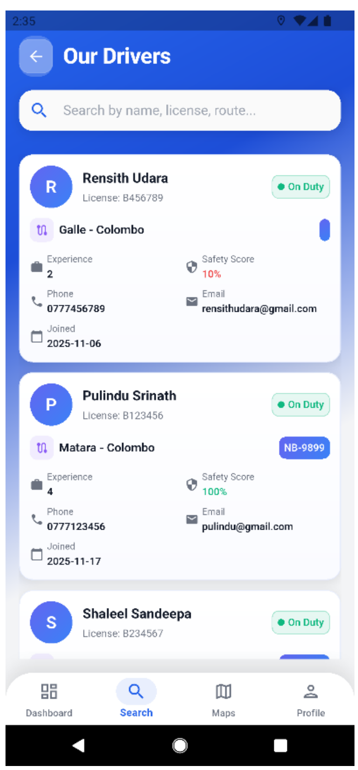

9:32
Welcome Back
Sign in to continue your safe journey
+94
Phone Number
Password
Remember me
Forgot Password?
Sign In
OR
Continue with Google

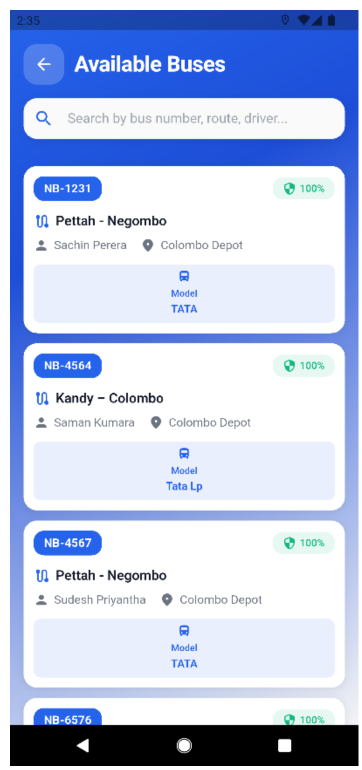

9:32
Create Account
Join SafeDriver for secure travels
First Name
Last Name
Email
+94
Phone Number
Password
Confirm Password
I agree to the Terms of Service and Privacy Policy
Create Account
OR

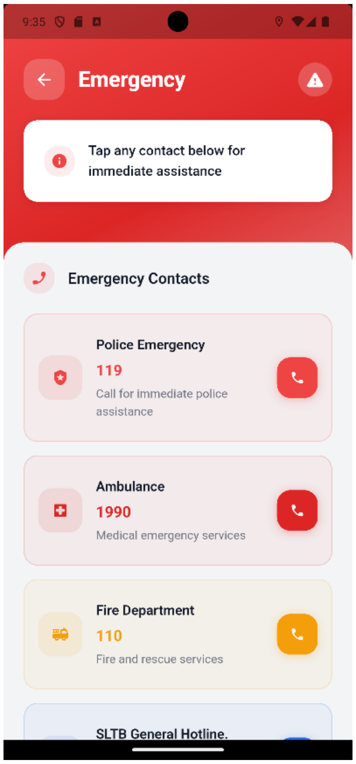

9:32
Forgot Password?
Enter your phone number and we will send you\na code to reset your password
+94
Phone Number
Send OTP
Back to Login

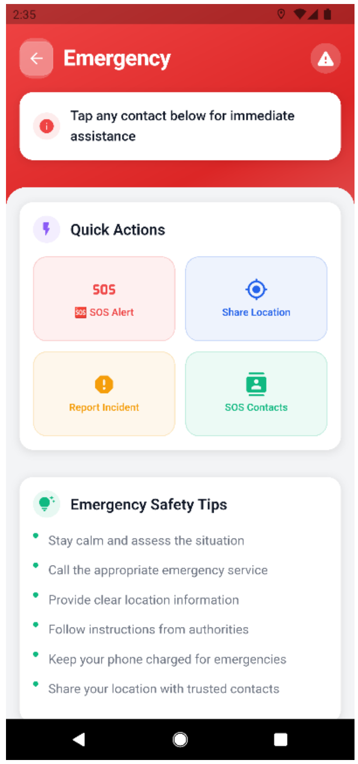

9:34
Good Evening
Ready for your journey?
Allow SafeDriver to access this device's location?
Precise
Approximate
While using the app
Only this time
Don't allow
Scan a QR code or search for a bus to start tracking your journey
Dashboard
Search
Maps
Profile

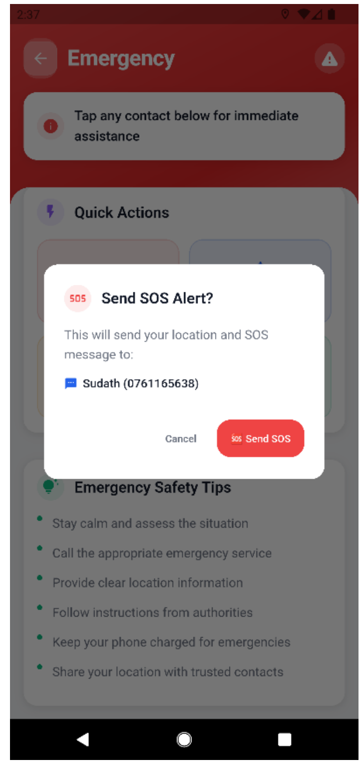

9:34
Good Evening
Ready for your journey?
Quick Actions
View Buses
Available
Our Drivers
Details
Emergency
Get help
Feedback
Share
Current Journey
No Active Journey
Scan a QR code or search for a bus to start tracking your journey
Dashboard
Search
Maps
Profile

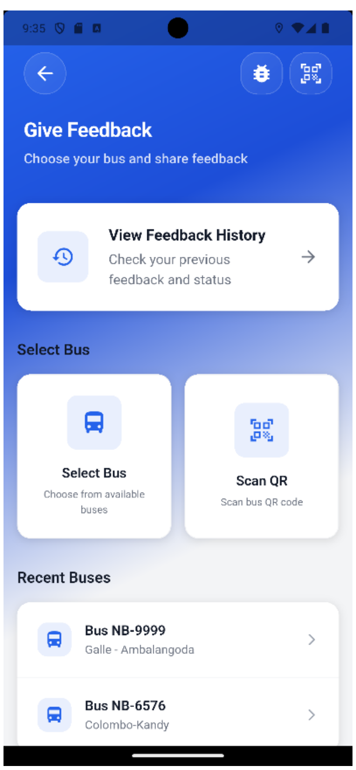

2:35
Our Drivers
Search by name, license, route...
Rensith Udara
License: B456789
On Duty
Galle - Colombo
Experience
2
Safety Score
10%
Phone
0777456789
Email
rensithudara@gmail.com
Joined
2025-11-06
Pulindu Srinath
License: B123456
On Duty
Matara - Colombo
NB-9899
Experience
4
Safety Score
100%
Phone
0777123456
Email
pulindu@gmail.com
Joined
2025-11-17
Shaleel Sandeepa
License: B234567
On Duty
Dashboard
Search
Maps
Profile

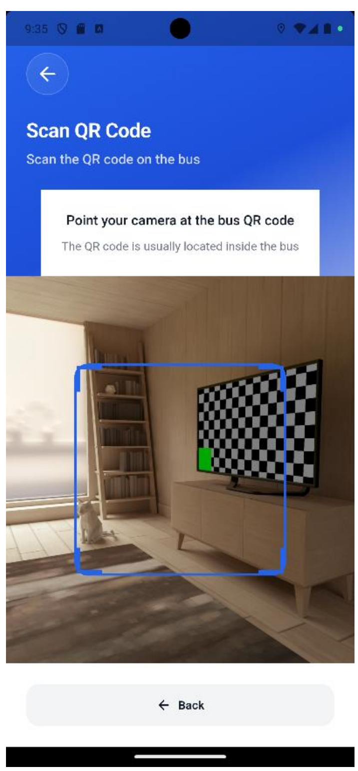

2:35
Available Buses
Search by bus number, route, driver...
NB-1231
100%
Pettah - Negombo
Sachin Perera
Colombo Depot
Model
TATA
NB-4564
100%
Kandy – Colombo
Saman Kumara
Colombo Depot
Model
Tata Lp
NB-4567
100%
Pettah - Negombo
Sudesh Priyantha
Colombo Depot
Model
TATA
NB-6576
100%

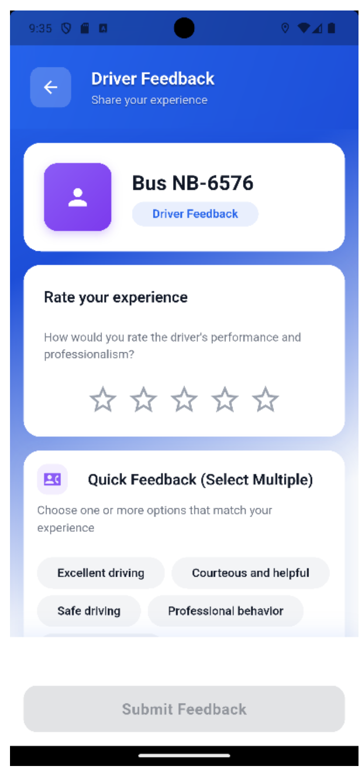

Emergency
Tap any contact below for immediate assistance
Emergency Contacts
Police Emergency
119
Call for immediate police assistance
Ambulance
1990
Medical emergency services
Fire Department
110
Fire and rescue services
SLTB General Hotline

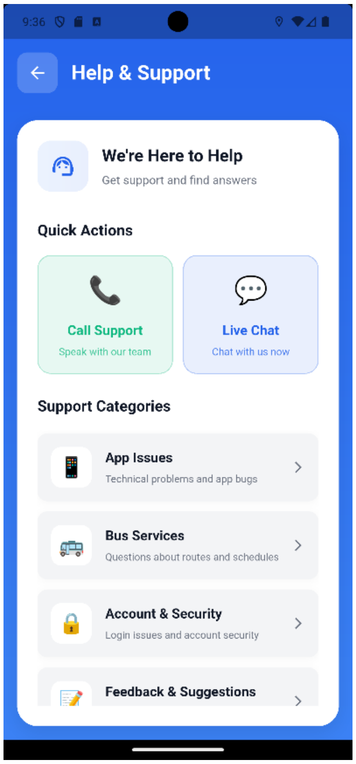

Emergency
Tap any contact below for immediate assistance
Quick Actions
SOS
SOS Alert
Share Location
Report Incident
SOS Contacts
Emergency Safety Tips
Stay calm and assess the situation
Call the appropriate emergency service
Provide clear location information
Follow instructions from authorities
Keep your phone charged for emergencies
Share your location with trusted contacts

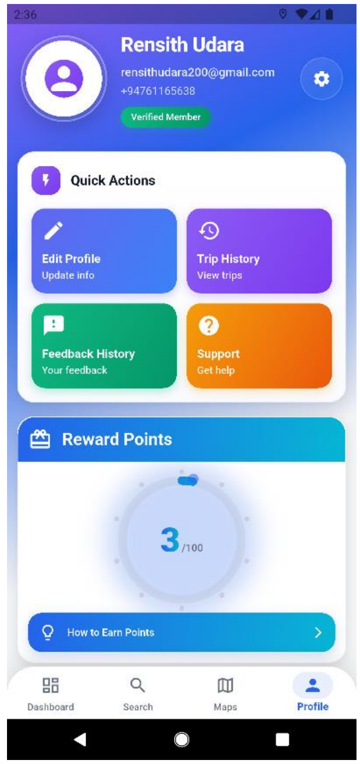

Emergency
Tap any contact below for immediate assistance
Quick Actions
Send SOS Alert?
This will send your location and SOS message to:
Sudath (0761165638)
Cancel
Send SOS
Emergency Safety Tips
Stay calm and assess the situation
Call the appropriate emergency service
Provide clear location information
Follow instructions from authorities
Keep your phone charged for emergencies
Share your location with trusted contacts

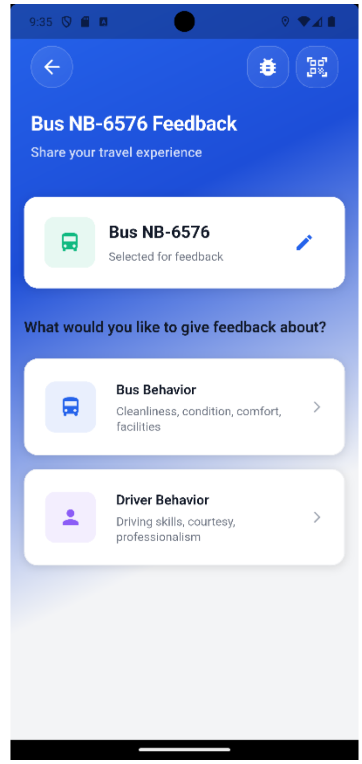

Give Feedback
Choose your bus and share feedback
View Feedback History
Check your previous feedback and status
Select Bus
Select Bus
Choose from available buses
Scan QR
Scan bus QR code
Recent Buses
Bus NB-9999
Galle - Ambalangoda
Bus NB-6576
Colombo-Kandy

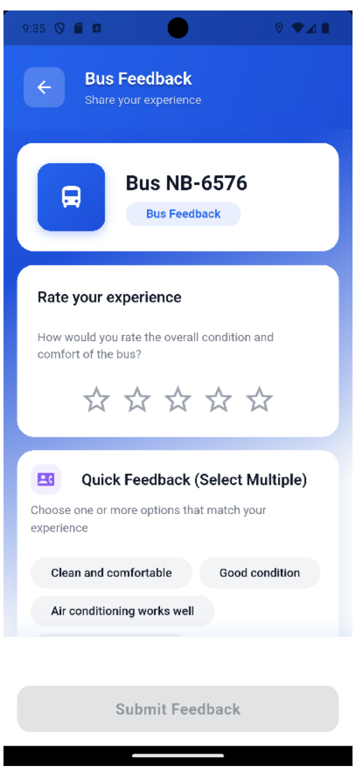

Scan QR Code
Scan the QR code on the bus
Point your camera at the bus QR code
The QR code is usually located inside the bus
Back

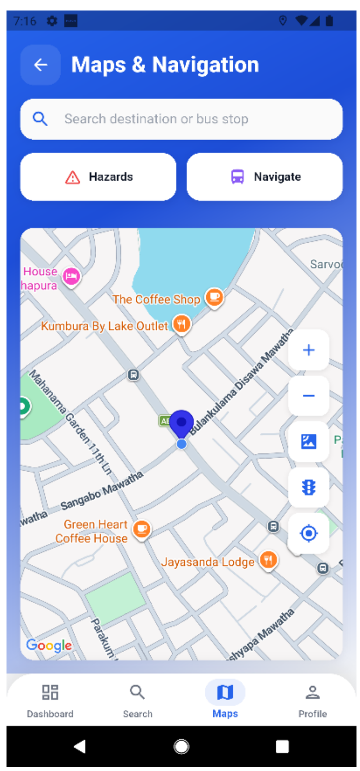

Driver Feedback
Share your experience
Bus NB-6576
Driver Feedback
Rate your experience
How would you rate the driver's performance and professionalism?
Quick Feedback (Select Multiple)
Choose one or more options that match your experience
Excellent driving
Courteous and helpful
Safe driving
Professional behavior
Submit Feedback


9:36
Help & Support
We're Here to Help
Get support and find answers
Quick Actions
Call Support
Speak with our team
Live Chat
Chat with us now
Support Categories
App Issues
Technical problems and app bugs
Bus Services
Questions about routes and schedules
Account & Security
Login issues and account security
Feedback & Suggestions


2:36
Rensith Udara
rensithudara200@gmail.com
+94761165638
Verified Member
Quick Actions
Edit Profile
Update info
Trip History
View trips
Feedback History
Your feedback
Support
Get help
Reward Points
3 /100
How to Earn Points
Dashboard
Search
Maps
Profile


9:35
Bus NB-6576 Feedback
Share your travel experience
Bus NB-6576
Selected for feedback
What would you like to give feedback about?
Bus Behavior
Cleanliness, condition, comfort, facilities
Driver Behavior
Driving skills, courtesy, professionalism


9:35
Bus Feedback
Share your experience
Bus NB-6576
Bus Feedback
Rate your experience
How would you rate the overall condition and comfort of the bus?
Quick Feedback (Select Multiple)
Choose one or more options that match your experience
Clean and comfortable
Good condition
Air conditioning works well
Submit Feedback

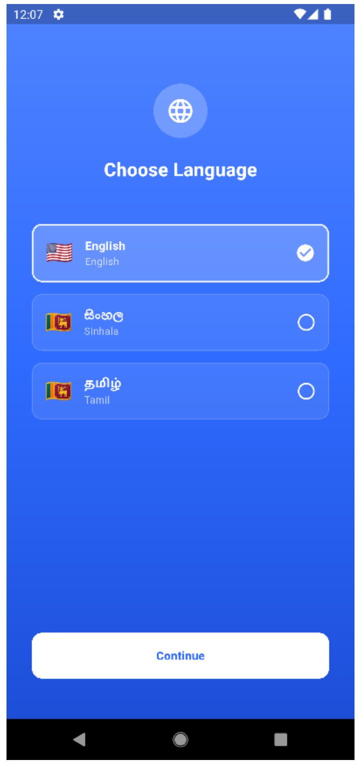

7:16
Maps & Navigation
Search destination or bus stop
Hazards
Navigate
The Coffee Shop
Kumbura By Lake Outlet
Green Heart Coffee House
Jayasanda Lodge
Google
Dashboard
Search
Maps
Profile

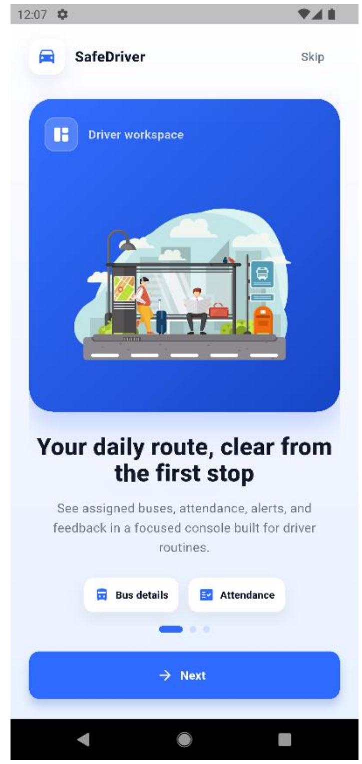
7.4 Driver Mobile Application

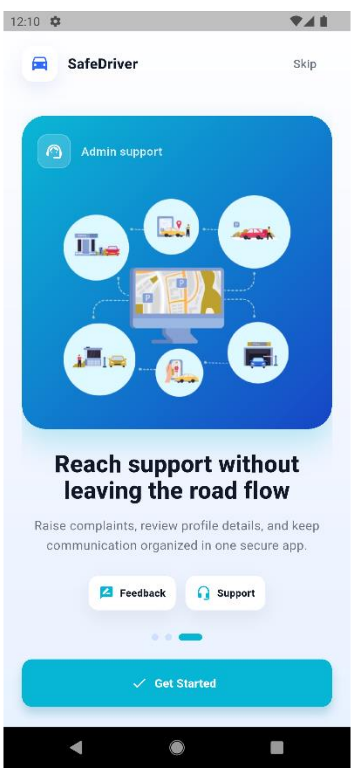
The driver application is built with Flutter for cross-platform deployment on Android and iOS, connecting to Firebase for real-time data synchronization and efficient fleet management. The application provides drivers with tools for attendance tracking, bus management, alert monitoring, complaint handling, and communication with administrators.

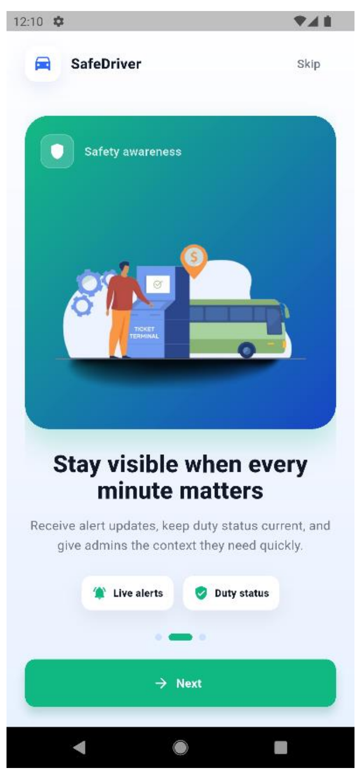
- **Onboarding:** Introduction screens highlighting key features such as route management, administrative support, and safety awareness for drivers.
- **Language Selection:** Multi-language support with English, Sinhala, and Tamil language options.
- **Authentication:** Secure login using a registered phone number with OTP verification for driver identification.
- **Dashboard:** Personalized dashboard displaying driver information, assigned bus details, attendance status, alerts, ratings, and quick action shortcuts.
- **Attendance Management:** Drivers can mark daily attendance and maintain attendance records for operational monitoring.
- **Bus Assignment Management:** View assigned buses, vehicle information, registration details, route assignments, permit details, and operational status.
- **Safety Alert Monitoring:** Receive and review real-time safety alerts, including drowsiness detection, yawning detection, and driver visibility warnings, with detailed alert history.
- **Profile & Performance Management:** Manage personal information, driving license details, assigned routes, experience records, passenger ratings, and performance evaluations.
- **Complaint Management:** Submit complaints related to bus operations, route issues, safety concerns, system errors, and track complaint resolution history.
- **Help & Support:** Contact administrators, request emergency assistance, create support tickets, and monitor support request progress and responses.
- **Settings & Preferences:** Customize language and theme settings, refresh profile information, access support services, receive notifications, and securely log out of the application.

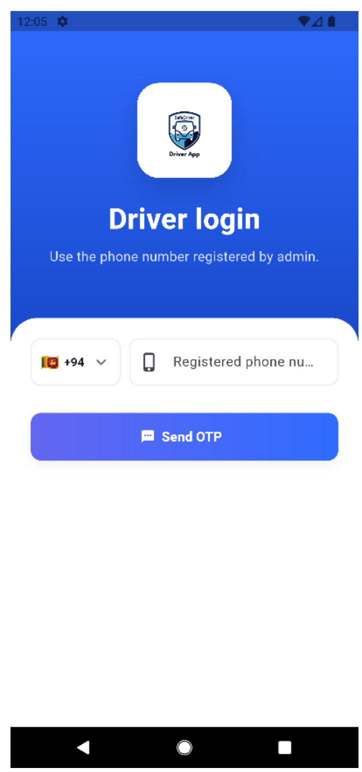

12:05
SafeDriver - Driver App
Focused tools for safer bus operations
Version 1.0.0

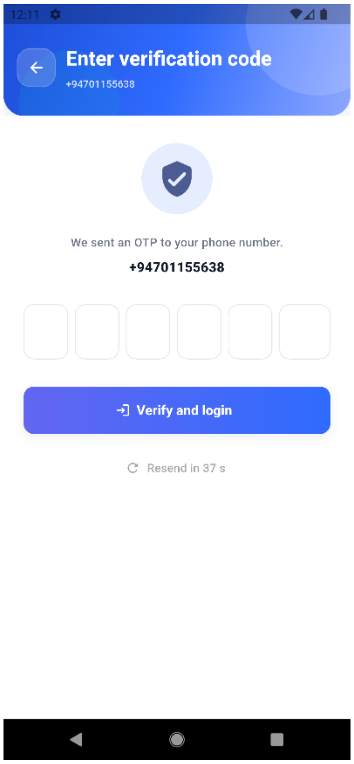

12:07
Choose Language
English
English
සිංහල
Sinhala
தமிழ்
Tamil
Continue

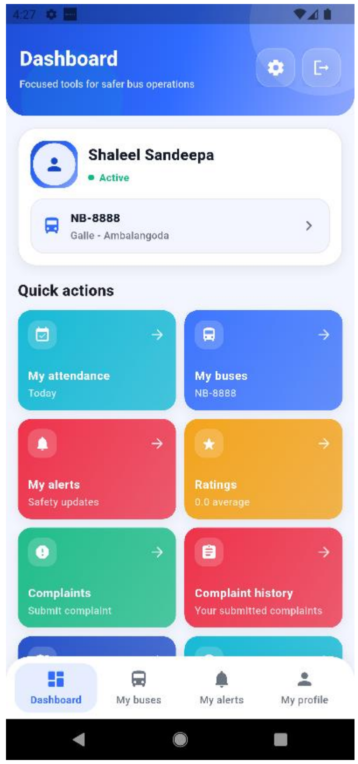

12:07
SafeDriver
Skip
Driver workspace
Your daily route, clear from the first stop
See assigned buses, attendance, alerts, and feedback in a focused console built for driver routines.
Bus details
Attendance
Next

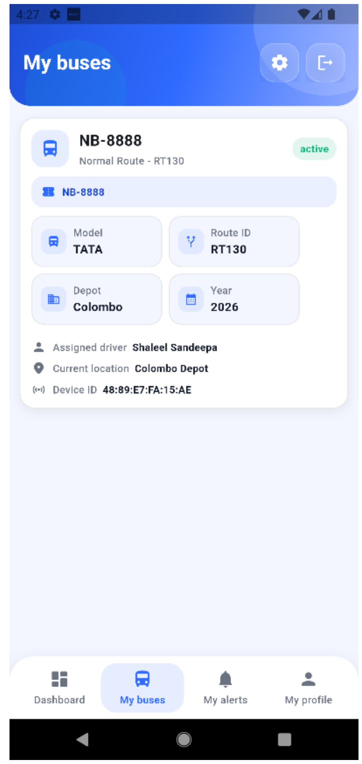

12:10
SafeDriver
Skip
Admin support
Reach support without leaving the road flow
Raise complaints, review profile details, and keep communication organized in one secure app.
Feedback
Support
Get Started

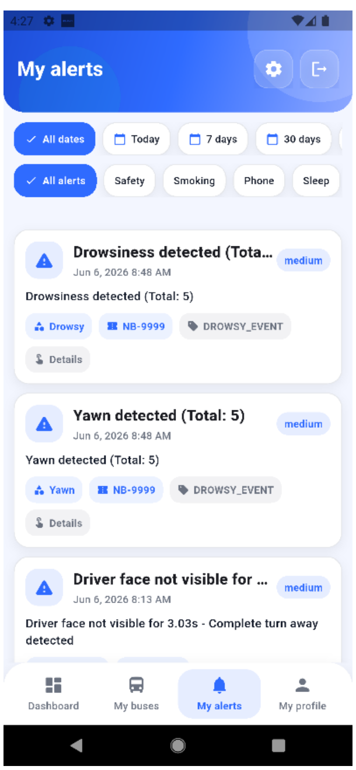

12:10
SafeDriver
Skip
Safety awareness
Stay visible when every minute matters
Receive alert updates, keep duty status current, and give admins the context they need quickly.
Live alerts
Duty status
Next

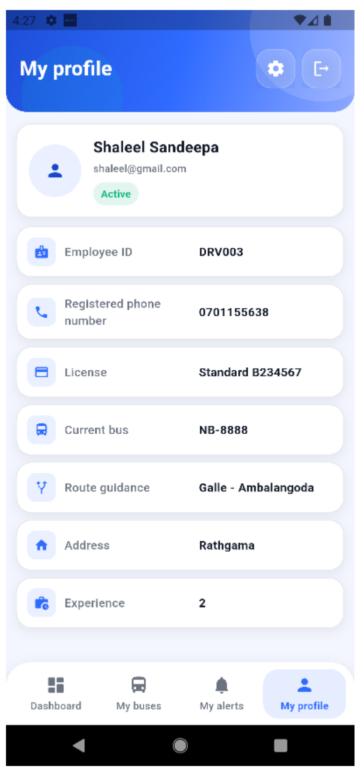

12:05
Driver login
Use the phone number registered by admin.
+94
Registered phone nu...
Send OTP

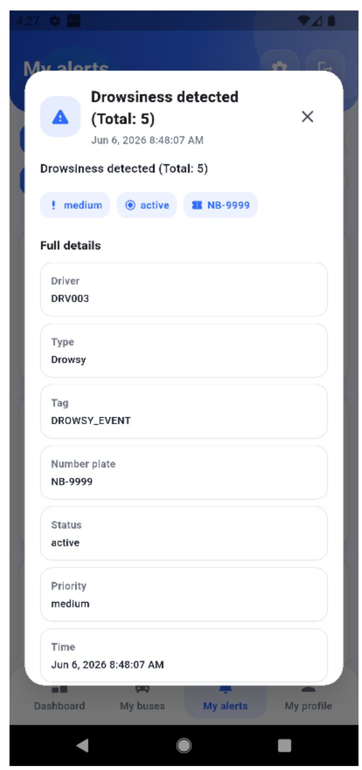

Enter verification code
+94701155638
We sent an OTP to your phone number.
+94701155638
Verify and login
Resend in 37 s

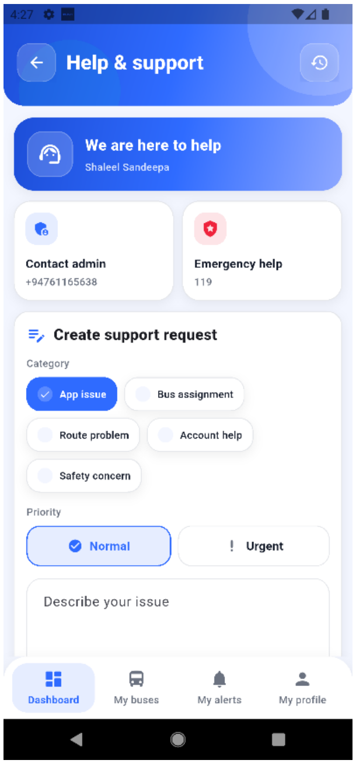

Dashboard
Focused tools for safer bus operations
Shaleel Sandeepa
Active
NB-8888
Galle - Ambalangoda
Quick actions
My attendance
Today
My buses
NB-8888
My alerts
Safety updates
Ratings
0.0 average
Complaints
Submit complaint
Complaint history
Your submitted complaints
Dashboard
My buses
My alerts
My profile

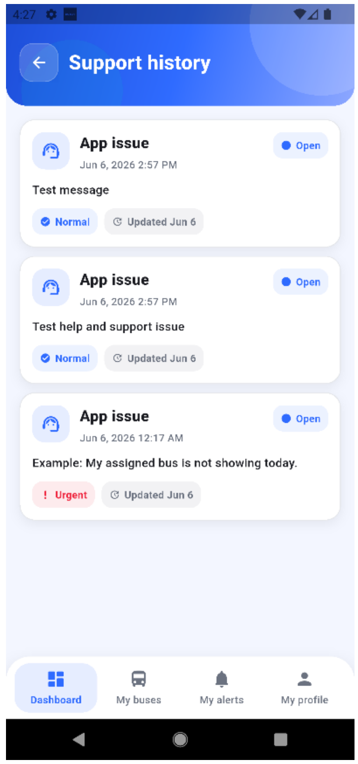

My buses
NB-8888
Normal Route - RT130
active
NB-8888
Model
TATA
Route ID
RT130
Depot
Colombo
Year
2026
Assigned driver Shaleel Sandeepa
Current location Colombo Depot
Device ID 48:89:E7:FA:15:AE
Dashboard
My buses
My alerts
My profile

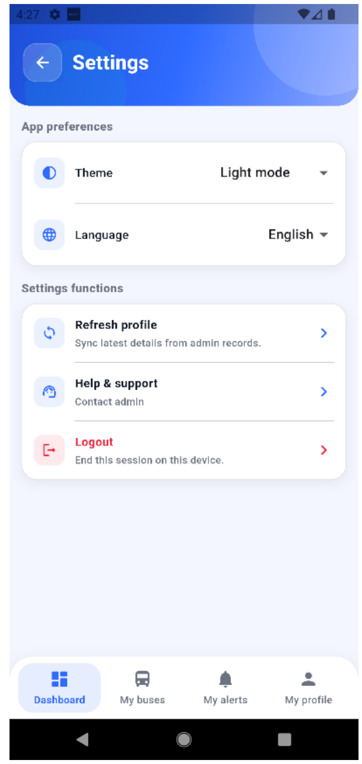

My alerts
All dates
Today
7 days
30 days
All alerts
Safety
Smoking
Phone
Sleep
Drowsiness detected (Tota...
medium
Jun 6, 2026 8:48 AM
Drowsiness detected (Total: 5)
Drowsy
NB-9999
DROWSY_EVENT
Details
Yawn detected (Total: 5)
medium
Jun 6, 2026 8:48 AM
Yawn detected (Total: 5)
Yawn
NB-9999
DROWSY_EVENT
Details
Driver face not visible for ...
medium
Jun 6, 2026 8:13 AM
Driver face not visible for 3.03s - Complete turn away detected
Dashboard
My buses
My alerts
My profile

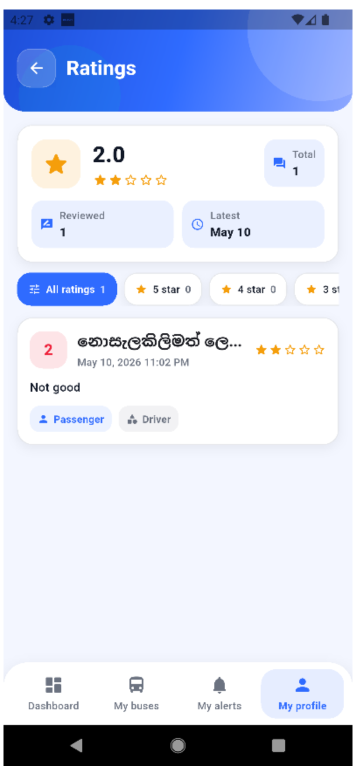

My profile
Shaleel Sandeepa
shaleel@gmail.com
Active
Employee ID DRV003
Registered phone number 0701155638
License Standard B234567
Current bus NB-8888
Route guidance Galle - Ambalangoda
Address Rathgama
Experience 2
Dashboard
My buses
My alerts
My profile

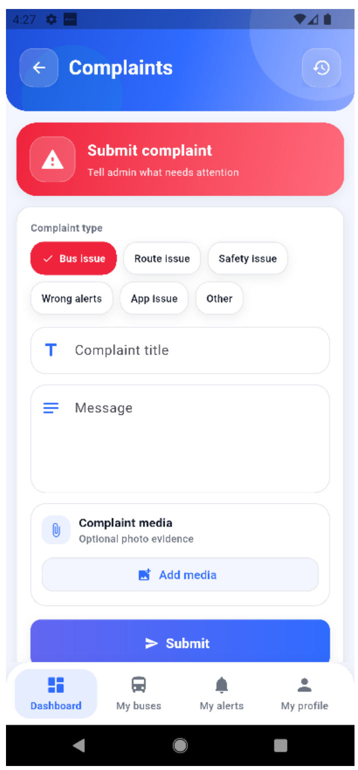

Drowsiness detected (Total: 5)
Jun 6, 2026 8:48:07 AM
Drowsiness detected (Total: 5)
medium
active
NB-9999
Full details
Driver
DRV003
Type
Drowsy
Tag
DROWSY_EVENT
Number plate
NB-9999
Status
active
Priority
medium
Time
Jun 6, 2026 8:48:07 AM

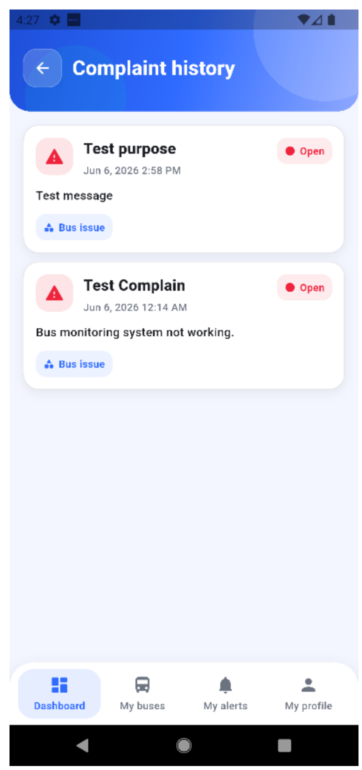

4:27
Help & support
We are here to help
Shaleel Sandeepa
Contact admin
+94761165638
Emergency help
119
Create support request
Category
App issue
Bus assignment
Route problem
Account help
Safety concern
Priority
Normal
! Urgent
Describe your issue
Dashboard
My buses
My alerts
My profile


4:27
Support history
App issue
Open
Jun 6, 2026 2:57 PM
Test message
Normal
Updated Jun 6
App issue
Open
Jun 6, 2026 2:57 PM
Test help and support issue
Normal
Updated Jun 6
App issue
Open
Jun 6, 2026 12:17 AM
Example: My assigned bus is not showing today.
! Urgent
Updated Jun 6
Dashboard
My buses
My alerts
My profile


4:27
Settings
App preferences
Theme
Light mode
Language
English
Settings functions
Refresh profile
Sync latest details from admin records.
Help & support
Contact admin
Logout
End this session on this device.
Dashboard
My buses
My alerts
My profile


4:27
Ratings
2.0
Total
1
Reviewed
1
Latest
May 10
All ratings 1
5 star 0
4 star 0
3 st
2
නොසැලකිලිමත් ලෙ...
May 10, 2026 11:02 PM
Not good
Passenger
Driver
Dashboard
My buses
My alerts
My profile

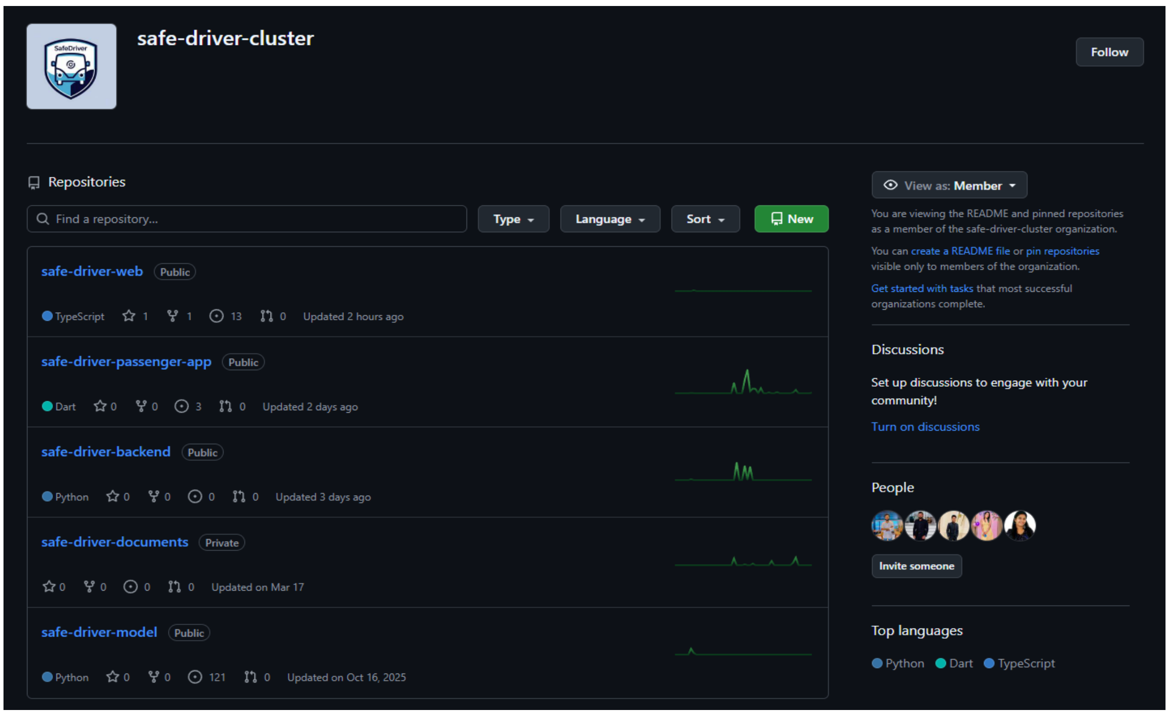

4:27
Complaints
Submit complaint
Tell admin what needs attention
Complaint type
Bus issue
Route issue
Safety issue
Wrong alerts
App issue
Other
Complaint title
Message
Complaint media
Optional photo evidence
Add media
Submit
Dashboard
My buses
My alerts
My profile


4:27
Complaint history
Test purpose
Open
Jun 6, 2026 2:58 PM
Test message
Bus issue
Test Complain
Open
Jun 6, 2026 12:14 AM
Bus monitoring system not working.
Bus issue
Dashboard
My buses
My alerts
My profile

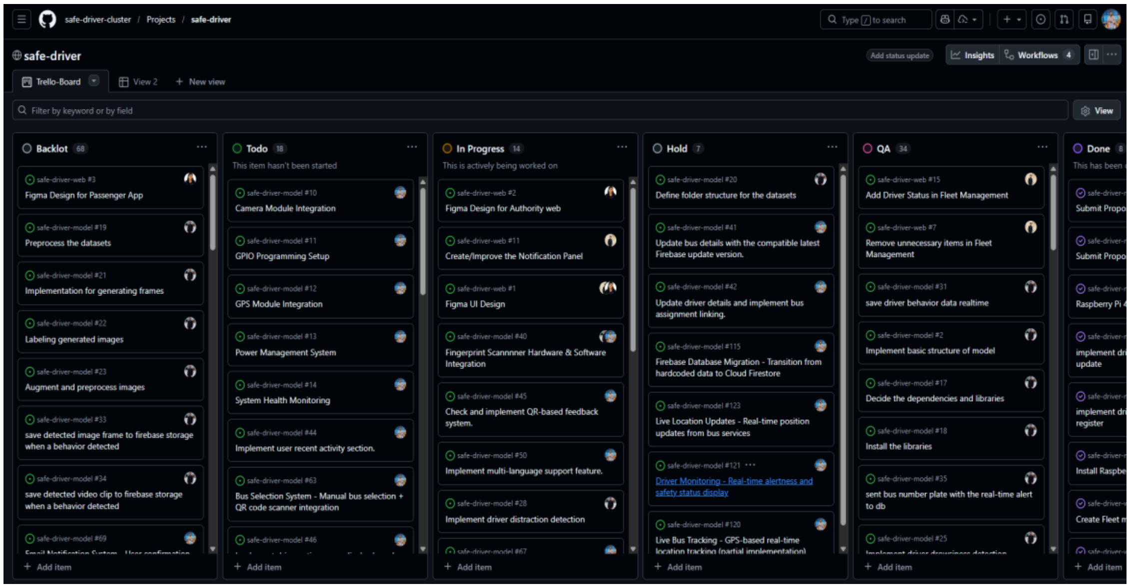
7.5 Development Infrastructure

The project uses the safe-driver-cluster GitHub organization with separate repositories: safe-driver-web (TypeScript), safe-driver-passenger-app (Dart), safe-driver-backend (Python), safe-driver-documents (private), and safe-driver-model (Python, 121 commits). GitHub Projects and Trello boards organize tasks by status: Backlog, In-Progress, Review, Testing, and Completed. GitHub Actions provides initial CI/CD for automated unit and integration testing.

Link: safe-driver-cluster repositories



Project Management: Trello boards for task tracking organized by status (Backlog, In-Progress, Review, Testing, Completed) Link: https://github.com/orgs/safe-driver-cluster/projects/1/views/1



Summary of Chapter 7

Chapter 7 presents the implementation of the SafeDriver system across the embedded unit, cloud backend, web dashboard, and mobile apps. It details the drowsiness and distraction detection pipelines, alert transmission workflow, authority dashboard features, passenger app functions, driver app functions, and development infrastructure. The chapter confirms that the system was fully implemented with real-time detection, Firebase integration, live dashboards, multilingual apps, and supporting project management workflows.

8 Test Plan and Test Cases

8.1 Test Objectives and Levels

The test plan aims to verify that SafeDriver meets the functional and non-functional requirements defined in the SRS and PR2 documentation. Testing is organised into unit, integration, system, and pilot/acceptance levels, focusing particularly on safety-critical driver-monitoring and alerting functions.

8.2 Test Environment and Tools

The planned environment reuses the hardware and platforms identified in earlier documents:

- Raspberry Pi 4 with camera, GPS, buzzer and local storage for the embedded monitoring unit.
- Firebase project with Firestore, Cloud Functions, Cloud Messaging, and Authentication.
- Android and iOS devices for mobile apps and modern browsers for the web dashboard.
- GitHub Actions and local runners for automated unit and integration tests on selected components.

8.3 Functional Test Cases

Representative functional test cases include:

- **Driver monitoring tests** to validate EAR-based drowsiness detection, distraction classification by TensorFlow Lite models, and alert escalation timelines.
- **Alert pipeline tests** to ensure that unsafe events create records in Firestore, trigger notifications to the dashboard and, at higher levels, notify authorities.
- **Feedback and points tests** verifying that passenger feedback submissions create feedback documents, upload attachments, and generate the correct point transactions.
- **User management tests** for role-based access to dashboard pages and app features across drivers, passengers, admins, and authorities.

Each test case is documented with ID, description, preconditions, detailed steps, expected results, and traceability to SRS requirement IDs.

8.4 Non-Functional Test Cases

Non-functional tests focus on performance, security, reliability, and usability defined in PR2:

- **Performance tests** simulate multiple buses and passengers to confirm that backend response times and alert latency stay within required thresholds.
- **Security tests** verify TLS usage, authentication flows, role-based access control, and data anonymization for passenger data.
- **Reliability tests** check device recovery after network interruptions and power cycles, validating offline buffering and reconnection logic.
- **Usability tests** evaluate whether drivers, passengers, and administrators can complete critical tasks quickly and without confusion on prototypes.

8.5 Test Plan and Test Case Document

Driver Monitoring System

- Test Case Document
- Test Plan Document

Authority Dashboard

- Test Case Document
- Test Plan Document

Passenger Mobile App

- Test Case Document
- Test Plan Document

8.6.1 Authority Web Dashboard Test Cases Summary

- Verified dashboard metrics display accurately.
- Confirmed live alerts appear in real time.
- Checked driver and vehicle information is shown correctly.
- Validated alert acknowledgment and resolution actions.
- Ensured the dashboard remains responsive and stable during normal use.

The authority web dashboard test cases were created to ensure that the administrative panel of the SafeDriver system operates correctly and provides reliable real-time supervision. These tests confirm that important dashboard elements such as total vehicles, active drivers, alerts, and recent activity are displayed with accurate values. They also check that live alerts are received instantly from the backend, allowing the authority user to monitor unsafe driving events without delay. In addition, the test cases verify that alert actions such as acknowledgment, escalation, and resolution function as expected, so incidents can be properly managed from detection to closure. Overall, these test cases show that the web dashboard is stable, responsive, and suitable for traffic safety monitoring and control.

8.6.2 Driver Monitoring System Test Cases Summary

- Verified driver identification through fingerprint authentication.
- Tested drowsiness detection using eye closure and blinking patterns.
- Checked yawning, head pose, phone usage, smoking, and drinking detection.
- Evaluated system behavior under low light, occlusion, and framing issues.
- Confirmed event logging, offline operation, and alert escalation work properly.

The driver monitoring system test cases were developed to validate the most critical safety functions of the project, which are detecting unsafe driving behavior and responding with timely warnings. These tests cover fingerprint-based driver identification, GPS integration, eye aspect ratio-based drowsiness detection, yawning recognition, head pose monitoring, and distraction detection for phone usage, smoking, and drinking. They also examine how the system performs in difficult conditions such as low-light environments, partial face occlusion, empty seats, and sudden lighting changes, where false detections could easily occur. Further test cases verify that all events are logged correctly with time, GPS location, and driver identity, while offline operation and network recovery ensure the system remains functional even without continuous cloud access. Overall, these tests prove that the driver monitoring unit is accurate, resilient, and effective for real-world road safety use.

8.6.3 Passenger App Test Cases Summary

- Verified app installation, first launch, and onboarding flow.
- Tested registration, login, OTP, and biometric authentication.
- Checked profile, dashboard, QR scan, live tracking, and bus information features.
- Validated feedback submission, rewards, notifications, and settings.
- Confirmed security rules, offline handling, performance, and accessibility.

The passenger app test cases were created to ensure that the mobile application provides a smooth, secure, and user-friendly experience for passengers using the SafeDriver system. These tests verify that the app installs properly, launches correctly, and guides new users through onboarding, language selection, registration, OTP verification, and biometric login. They also confirm that passengers can access profile details, scan bus QR codes, view live tracking maps, check driver and bus information, submit feedback, and receive notifications without errors. In addition, the test cases validate security restrictions, offline behavior, response speed, and accessibility features such as font scaling and color contrast, which are important for practical daily use. Overall, these test cases demonstrate that the passenger app is functional, reliable, and ready for cross-platform deployment on Android and iOS devices.

Summary of Chapter 8

This section establishes how the team will prove that SafeDriver works as specified. It explains the testing strategy (unit, integration, system, and pilot tests), the target environments (Pi hardware, Firebase backend, apps), and gives representative functional and non-functional test cases tied back to requirements. With this plan and sample tests, the project has a clear, structured approach for validating safety-critical behaviour detection, alerting, performance, security, and usability across all implemented system components.

9. Discussion

9.1 Achievement of Objectives

The SafeDriver project has made strong progress toward all seven stated objectives. Drowsiness detection using EAR, blink frequency, head pose, and yawning is largely implemented and functioning in real-time testing. Distraction detection via mobile phone, object, and cigarette models is operational with confidence scores consistent with literature benchmarks. The multi-level alert system with buzzer and voice feedback is complete, and Level 3 cloud notification flow has been validated. The passenger transparency application is implemented with core features ready for demonstration and user acceptance testing.

GPS-based hazard mapping has been fully implemented with GPS integration, real-world data collection, and threshold tuning completed. Automated compliance report generation is implemented, with Firestore data structures and the report output layer validated and operational.

9.2 Comparison with Existing Solutions

Compared to commercial solutions such as Seeing Machines Guardian, SafeDriver offers several localization advantages: multilingual support for Sinhala and Tamil; right-hand-drive camera positioning; NoIR camera for tropical/low-light performance; and a total hardware cost of approximately LKR 75,000 per vehicle versus significantly higher imported system costs. The open Firebase backend provides flexible adaptation to Sri Lanka's specific NTC regulatory reporting requirements.

The primary limitation compared to mature commercial systems is the absence of formal field accuracy benchmarking under Sri Lankan driving conditions and bus cabin configurations. Academic benchmarks report >90% drowsiness detection accuracy for similar architectures, and the implementation aligns with those methods; localized field validation data has been collected during pilot deployment to further substantiate system performance.

9.3 Challenges and Limitations

- Lighting variability: Direct sunlight at certain angles in right-hand-drive positions can temporarily degrade MediaPipe landmark detection quality. The NoIR camera mitigates low-light scenarios but not high-glare conditions.

- Connectivity: Sri Lanka’s rural routes have intermittent mobile data coverage. The offline alert buffering mechanism (capacity: 500 events) has been tested during extended connectivity outages and successfully maintains data integrity during interruptions exceeding 2 hours.
- Driver acceptance: Behavioral monitoring systems can face driver resistance. Transparent communication of system purpose and graduated (non-punitive initial) alert design aim to mitigate this.
- GPS accuracy: Urban canyon effects in Colombo reduce GPS positional accuracy to approximately ±50 meters, affecting hazard zone geofencing precision. A buffer zone has been implemented as mitigation.
- Regulatory compliance: The system processes biometric-like behavioral data; formal data protection compliance with Sri Lanka's Personal Data Protection Act (2022) must be verified before full deployment.

9.4 Future Work

- Complete and validate GPS hazard mapping with real NTC accident data and field-test geofencing accuracy across diverse route types.
- Conduct formal pilot deployment on 5–10 Colombo metropolitan buses to collect ground-truth detection accuracy data.
- Explore additional detection capabilities: seatbelt compliance monitoring, passenger count estimation, and lane departure integration.
- Conduct formal driver and passenger acceptance studies to quantify usability and adoption readiness.

Summary of Chapter 9

Chapter 9 discusses the extent to which the project objectives were achieved, the technical performance of the system, and how SafeDriver compares with existing solutions. It also highlights practical challenges and limitations such as lighting variability, connectivity issues, GPS accuracy, user acceptance, and regulatory compliance. The chapter concludes with future work directions such as improved field validation, enhanced hazard mapping, and possible extension of detection capabilities.

10. Conclusion

SafeDriver represents a significant contribution to addressing Sri Lanka's public transport safety challenge through locally developed, cost-effective AI technology. The system successfully integrates computer vision-based driver monitoring, a multi-level alert escalation framework, Firebase cloud-based fleet management, and a passenger transparency platform into a coherent, scalable solution tailored to Sri Lankan conditions.

The implemented system demonstrates that real-time drowsiness and distraction detection on affordable embedded hardware (Raspberry Pi 4) is technically feasible at operationally meaningful performance levels. Yawning detection, EAR-based eye closure monitoring, head turn detection, mobile phone detection, and cigarette detection all function correctly in development testing. The Firebase-based cloud architecture provides scalable infrastructure for fleet-wide deployment, and multilingual applications address the localization gaps identified in commercial alternatives.

The detailed and validated database design, complete GUI prototypes for both the authority dashboard and passenger mobile app, and a comprehensive functional and non-functional test suite collectively demonstrate a fully realised SafeDriver solution. With GPS hazard mapping, automated compliance reporting, and all core detection modules implemented and validated, the project delivers a robust, deployable SafeDriver platform capable of contributing meaningfully to reducing Sri Lanka's road traffic fatalities through proactive, AI-driven safety intervention.

References

[1] International Organization for Standardization. (2013). ISO/IEC 27001: Information security management. Retrieved from https://www.iso.org/standard/54534.html

[2] International Organization for Standardization. (2018). ISO 26262: Road vehicles – Functional safety. Retrieved from https://www.iso.org/standard/68383.html

[3] Institute of Electrical and Electronics Engineers. (2008). IEEE 829: Standard for Software and System Test Documentation. Retrieved from https://standards.ieee.org/standard/829-2008.html

[4] National Transport Commission, Sri Lanka. (n.d.). Road Transport Regulations and Safety Standards. https://www.ntc.gov.lk

[5] Ministry of Transport, Sri Lanka. (n.d.). Public Transport Policy Framework. http://www.transport.gov.lk

[6] Google. (n.d.). TensorFlow Lite Documentation. Retrieved from https://www.tensorflow.org/lite

[7] Google. (n.d.). Firebase Documentation. Retrieved from https://firebase.google.com/docs

[8] Google. (n.d.). MediaPipe Documentation. Retrieved from https://mediapipe.dev

[9] OpenCV. (n.d.). OpenCV Documentation. Retrieved from https://opencv.org

[10] Flutter. (n.d.). Flutter Documentation. Retrieved from https://flutter.dev/docs

[11] Amazon Web Services. (n.d.). AWS CloudFormation Documentation. AWS. https://docs.aws.amazon.com/cloudformation

Literature Review: AI-Powered Real-Time Driver Monitoring & Accident Prevention System for Sri Lankan Public Transport

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Abstract

Road traffic accidents remain a critical public health and economic challenge in Sri Lanka, frequently linked to driver fatigue, distraction, and unsafe operational practices in public transport. Existing law enforcement mechanisms rely mainly on reactive measures such as post-incident investigations and manual inspections, offering limited real-time intervention capability during journeys. International driver monitoring solutions demonstrate promising results using AI and computer vision. Yet, none of these applications cannot be directly applied to local context mainly due factors such as cost, local environments cannot be directly mapped, connectivity limitations, multilingual requirements etc. To bridge this gap, the SafeDriver research proposes an AI-powered real-time driver monitoring and accident prevention system specifically tailored for Sri Lankan public buses. The main objectives are to detect drowsiness and distraction using computer-vision-based facial analysis, identify risky behaviors such as mobile phone usage, integrate GPS-based hazard awareness, and provide multi-stakeholder safety feedback to drivers, authorities, and passengers. The system employs a Raspberry Pi4 embedded platform with a camera module to capture the driver's face, uses MediaPipe and OpenCV for facial landmark detection, and computes metrics such as Eye Aspect Ratio, blink frequency, yawning, and head pose to infer fatigue and inattention. TensorFlow Lite, YOLO convolutional neural network models are used to detect mobile phone usage and other distractions in real time. A four-level alert escalation mechanism delivers audio alerts to the driver and, when necessary, provides visual warnings and notifies transport authorities via cloud services. GPS integration enables hazard-zone aware alerts and continuous logging of incident locations. Data has been synchronized to a Firebase backend that supports an authority dashboard and a Flutter-based passenger mobile application for transparency and safety status updates. Pilot evaluation is designed around quantitative metrics such as detection accuracy, false-positive rate, alert latency, and system uptime, as well as qualitative indicators including driver acceptance, passenger satisfaction, and operational impact. The expected outcome is cost-effective, scalable, and locally adaptable driver monitoring platform that can significantly reduce unsafe driver behaviors and support data-driven policy decisions for Sri Lanka's public transport sector.

Keywords: Driver monitoring, Computer vision, Public transport safety, Edge computing, Object detection

1. Introduction

Road traffic accidents represent a significant global public health challenge, with driver fatigue, distraction, and improper behavior identified as primary contributing factors [1]. The World Health Organization reports that road traffic injuries result in approximately 1.35 million deaths globally each year, with developing countries bearing a disproportionate burden of this crisis [1]. Sri Lanka exemplifies this challenge, experiencing its worst bus accident in two decades on May 11, 2025, when 23 people died after a driver who had worked 13.5 hours crashed in Kotmale [29, 30], catalyzing unprecedented government action on AI-powered driver monitoring systems.

The integration of artificial intelligence and computer vision technologies has emerged as a promising approach to proactive accident prevention through real-time driver monitoring [2, 3]. However, the majority of driver monitoring research and development has been conducted in developed countries with specific infrastructure, climatic, and operational conditions that may not translate effectively to developing country contexts such as Sri Lanka.

This review systematically examines the current state of driver monitoring technology, analyzes both existing commercial solutions and Sri Lanka's rapid government deployment, identifies critical gaps in research and implementation regarding developing country applications, and establishes justification for developing a localized system specifically designed for Sri Lankan public transport operations.

2. Global Context of Driver Monitoring Systems

2.1 Academic Research

Current research in driver monitoring can be categorized into four main approaches: image-based, biological-based, vehicle-based, and hybrid methodologies [3]. Research has achieved 92% accuracy using 3D convolutional neural networks for drowsiness detection [4], while hybrid CNN-LSTM models demonstrate accuracy rates exceeding 90% in laboratory conditions [5]. Advanced research methodology using CNN with Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR) techniques achieved significant drowsiness detection accuracy using the formula: $EAR = (|p2-p6| + |p3-p5|) / (2\times|p1-p4|)$ [6, 7]. However, field deployment experiences reveal significant performance degradation in tropical environments, with systems showing 15-30% accuracy reduction in high-humidity conditions [18, 19].

Deep learning approaches for distraction detection have achieved 95.7% accuracy in detecting cell phone usage with 144 fps processing speed [8]. The HCF (Hybrid CNN Framework) combines multiple pre-trained models including Inception V3, ResNet50, and Xception, achieving accuracies of 95.75%, 96.2%, and 90.3% on different driver behavior datasets [9]. TensorFlow Lite optimization techniques enable deployment on resource-constrained systems, reducing model size by 75% while maintaining accuracy within 2% of full-precision models [14].

2.2 Commercial Systems

Analysis of three major commercial systems reveals significant limitations for Sri Lankan deployment. **MajuTech Singapore MDSM-7 Syste**m offers advanced driver ID recognition supporting up to 20 driver profiles with comprehensive behavior detection but has undisclosed pricing likely exceeding developing country budgets and limited environmental specifications for tropical conditions. Guardian Sea AI Driver Monitoring System demonstrates broader regional presence with AI-powered dashcam technology and multi-modal alert systems but lacks multilingual support for Sinhala and Tamil languages with connectivity dependence problematic for rural areas. **Stonkam DMS31 Driver Monitoring System** emerges as the most commercially viable option at $920 USD with operating temperature range of -20°C to +70°C and IP69K waterproof rating but still lacks comprehensive tropical hardening requirements and English-only language support.

Multi-tiered alert systems have proven effective in providing graduated responses to detected unsafe behavior [22], implementing four-level escalation protocols from subtle audio feedback to emergency intervention involving external authorities.

3. Sri Lankan Road Safety Context and Government Response

3.1 Current Safety Crisis

Sri Lanka faces severe road safety challenges that exceed regional and global averages across multiple indicators [10]. The country records over 2,000 road fatalities annually, representing significant road safety challenges among South Asian countries [10]. Between 2020 and 2024, road accidents claimed more than 12,140 lives, with 2,243 fatalities recorded in 2024 alone [13]. Research conducted in municipal areas revealed government buses with 5 crashes per 100,000 trips, while private buses showed 10 crashes per 100,000 trips [11]. The Sri Lanka Transport Board reports approximately 1,400 buses involved in accidents annually, resulting in direct losses exceeding Rs. 800 million [13].

The severity of this crisis was tragically demonstrated on May 11, 2025, when a SLTB bus carrying Buddhist pilgrims crashed in Kotmale, killing 23 people and injuring 54 - marking Sri Lanka's worst bus accident in two decades [29]. The investigation revealed the driver, and conductor had worked a 13.5-hour duty period, highlighting the critical role of driver fatigue in road accidents [30]. Research indicates that drowsy driving causes significant portions of traffic accidents in Sri Lanka, with the economic impact of motor traffic accidents estimated at Rs. 300-400 billion annually, potentially reaching Rs. 700 billion according to some experts [31].

According to the National Transport Commission, leading causes of bus accidents include driver fatigue, mobile phone usage, and inattentiveness to driving conditions [12], exacerbated by competitive private bus operations where revenue pressures encourage faster speeds and extended driving hours. Prior to 2025, the existing road safety framework relied heavily on reactive approaches through accident reports, manual inspections, and driver self-reporting, failing to provide real-time interventions critical for accident prevention [12].

3.2 Government's Rapid Deployment Initiative (2025)

In response to the Kotmale tragedy, the Sri Lankan government announced an unprecedented rapid deployment of AI-powered driver monitoring systems on May 15, 2025, just four days after the accident [29]. Transport Minister Bimal Rathnayake unveiled a comprehensive initiative to implement AI-backed driver monitoring across the public transport network, marking the country's first major deployment of such technology.

The pilot program launched on August 12, 2025, at Kataragama Depot with 40 AI cameras installed on both state-run SLTB and private buses [28]. These systems provide sophisticated detection capabilities including driver fatigue and drowsiness monitoring, eye closure detection, mobile phone usage alerts, seatbelt compliance checking, and real-time alerts to drivers and fleet managers through GPS-integrated systems. Technology is designed to prevent accidents before they occur rather than simply record them, representing a fundamental shift in safety approach [28, 32].

The government has said that all long-distance buses must install AI-backed driver monitoring systems with the requirement tied to route permit issuance. This represents a transformative shift from virtually no drowsiness detection systems to comprehensive AI-powered monitoring across the entire public transport network within 12 months. The initiative will eventually extend to commercial trucks and potentially railway systems [13], covering Sri Lanka's extensive transport network of over 7,700 SLTB buses plus thousands of private operators.

Prior to this deployment, despite academic research from local universities and various pilot studies, Sri Lanka had no widespread operational driver drowsiness detection systems. The transport sector relied primarily on traditional safety protocols, basic GPS tracking, and general fleet management systems without specific drowsiness detection features. The government's rapid deployment represents a significant policy shift from reactive accident investigation to proactive prevention technology, supported by international partnerships and development collaboration.

4. Critical Deployment Gaps and Localization Requirements

4.1 Technical and Environmental Challenges

Right-Hand Drive Configuration Challenges

Right-Hand Drive Configuration inherited from British colonial influence [17] requires complete reconfiguration of camera mounting positions, fields of view, and facial recognition algorithms. International systems designed for left-hand drive vehicles create significant blind spots and suboptimal angle coverage when applied to right-hand drive vehicles, necessitating specialized camera positioning and different sensor angles. The government's current deployment may not fully address these configuration requirements, potentially limiting effectiveness.

Tropical Climate Requirements

Tropical Climate Requirements present severe challenges with average temperatures of 27-32°C and humidity levels frequently exceeding 80% [18, 19]. Commercial systems demonstrate significant performance degradation, with driver detection accuracy dropping from 98% to 85% in high-humidity conditions and false positive rates increasing by 40-60% due to condensation and thermal interference. Camera sensor performance is reduced by 20-30% after six months without proper protection.

Environmental challenges include year-round high humidity affecting sensor reliability, two monsoon seasons with flooding risks, salt air accelerating corrosion in coastal routes, and intense UV exposure degrading equipment. Required technical solutions include heated enclosures preventing condensation, desiccant systems for humidity protection, anti-fog lens coatings, and military-grade environmental protection exceeding standard automotive specifications. The government's rapid deployment may utilize standard commercial systems without comprehensive tropical hardening, potentially leading to reduced effectiveness and higher maintenance requirements over time.

Connectivity and Communication Infrastructure Challenges

Sri Lanka's mountainous terrain and hill country regions present significant connectivity challenges for real-time communication systems. Research indicates that rural and hilly areas experience internet connectivity issues with coverage gaps of 15-25% in mountainous regions [23].

During periods of limited internet connectivity, traditional web and mobile application communication systems face substantial operational constraints.

However, the SafeDriver system architecture addresses these connectivity limitations through strategic design choices. GPS technology operates independently of internet connectivity, utilizing satellite-based positioning systems that maintain functionality regardless of terrestrial network availability [24]. This ensures continuous driver location tracking, monitoring capabilities, and warning alert systems remain operational even during connectivity interruptions.

The implementation of offline hazard-prone zone detection systems represents a critical technological advancement for deployment in connectivity-challenged environments [25]. Utilizing offline mapping capabilities with pre-loaded geographical hazard data, systems can maintain full operational capacity for location-based safety alerts. When vehicles approach predetermined hazard zones, systems can trigger appropriate driver warnings without requiring real-time internet connectivity, ensuring consistent safety interventions across all operational environments [25].

Satellite Communication Solutions

Recent developments in satellite internet technology, particularly Starlink mobile connectivity solutions, offer promising opportunities to address Sri Lanka's hill country connectivity limitations. Starlink's low Earth orbit (LEO) satellite constellation provides broadband internet access with latencies of 20-40ms, significantly improving upon traditional satellite communication systems [26]. Technology demonstrates effectiveness in mountainous and remote regions where terrestrial infrastructure deployment remains economically challenging [26].

For Sri Lankan public transport operations in hill country routes, Starlink mobile connectivity could provide reliable backup communication systems, enabling continuous fleet monitoring and emergency response capabilities. Cost analysis suggests that selective deployment of Starlink connectivity for critical routes could provide 95%+ connectivity coverage while maintaining economic viability for public transport operations [27].

4.2 Economic and Infrastructure Constraints

International commercial systems typically cost $2,000-5,000 per vehicle with additional licensing fees of 15-25% annually [19]. For Sri Lanka's 25,000 public transport vehicles, this represents $50-125 million initial investment with $10-30 million ongoing costs. The government's rapid deployment, while necessary for immediate safety, may face sustainability challenges given these economic constraints. Sri Lanka's recent economic crisis creates extreme price sensitivity, with the Transport Board operating on minimal profit margins requiring heavily subsidized public transport.

Local development offers 60-80% cost reduction compared to imported alternatives, with estimated development and manufacturing costs significantly lower per vehicle unit. The SafeDriver system's local approach becomes increasingly relevant as the government scales from 40 buses to implementation across thousands of vehicles by next year.

Sri Lanka's telecommunications infrastructure presents connectivity challenges including intermittent rural coverage, bandwidth limitations, and power outages affecting infrastructure [23]. Required solutions include edge computing for offline operation, store-and-forward systems for intermittent connectivity, data compression reducing bandwidth requirements, and adaptive streaming adjusting quality based on available bandwidth.

4.3 Cultural and Operational Adaptation

Sri Lanka's multilingual environment requires comprehensive language support for Sinhala (74.9% of population) with 52-letter alphabet, Tamil (co-official status) with distinct script requirements, and English as link language. Emergency alerts and interfaces must support all three languages with culturally appropriate terminology, addressing cultural sensitivity due to historical linguistic tensions. The government's current deployment may utilize English-only interfaces, potentially limiting driver acceptance and effectiveness.

Sri Lankan bus operations exhibit unique patterns differing significantly from international systems. Competitive private bus operations create aggressive driving behaviors requiring specialized detection algorithms, while mixed traffic environments present complex decision-making scenarios. Cultural factors include aggressive driving culture with frequent overtaking, resistance to monitoring due to privacy concerns, strong preference for manual control, and respect for driver seniority.

Electrical system limitations include voltage instability with fluctuations of ±15-20%, battery constraints, increased power consumption 40-60% higher due to air conditioning, and limited CAN bus interfaces in older vehicles. Government policies regarding data sovereignty require local control over sensitive transportation information, with local development enabling security measures aligned with Sri Lankan policies.

5. Gap Analysis and System Contributions

5.1 Research Gaps and Commercial Limitations

The majority of driver monitoring research focuses on developed country contexts with stable infrastructure and well-resourced implementation environments. Academic research demonstrates impressive laboratory performance, with systems achieving high accuracy rates [4, 5, 6], but field deployment experiences reveal significant performance degradation in tropical environments [18, 19]. Advanced research represents sophisticated approaches, but hardware implementations using standard consumer electronics prove inadequate for harsh tropical commercial deployment.

The government's rapid deployment of 40 AI cameras addresses the immediate implementation gap but may not fully resolve underlying technical limitations [28]. The systems deployed appear to be commercial solutions that, while offering immediate safety benefits, may lack the comprehensive localization required for long-term effectiveness in Sri Lankan conditions.

The literature reveals minimal research specifically addressing right-hand drive vehicle monitoring systems [17]. The overwhelming majority of research and commercial development focuses on left-hand drive configurations, creating fundamental knowledge gaps for countries using right-hand drive vehicles. Research showing cultural factors in driver monitoring system design remains limited, with most studies assuming universal applicability of Western-designed systems.

Commercial system analysis reveals critical limitations that persist despite government deployment. MajuTech's enterprise-grade solution lacks environmental specifications and transparent pricing. Guardian Sea's regional presence doesn't address multilingual requirements or infrastructure limitations. Stonkam's superior specifications still fall short of comprehensive tropical hardening requirements. Even the most viable commercial option represents significant investment barriers while requiring extensive localization for effective deployment.

5.2 SafeDriver System Novel Contributions

The SafeDriver system addresses gaps that remain even after the government's commercial deployment, incorporating comprehensive weather adaptation measures addressing monsoon conditions and rainfall challenges documented in environmental research. Novel hardware protection strategies include enhanced weatherproofing for interior vehicle environments, specialized rain detection systems for visibility optimization during heavy rainfall, improved sealing to prevent moisture ingress through vehicle openings, and weather-resistant materials for reliable operation during Sri Lanka's dual monsoon seasons.

Novel System Enhancements Beyond Existing Solutions

The SafeDriver system introduces several groundbreaking features that distinguish it from both existing commercial solutions and the government's current deployment. Offline map integration addresses Sri Lanka's connectivity challenges [23] by enabling continuous hazard zone detection and location-based safety alerts during unstable connectivity periods [25], ensuring uninterrupted safety monitoring across all operational environments. This capability becomes crucial as the government expands deployment to rural and mountainous regions where current systems may face connectivity limitations.

Pre-weather alerts to drivers when starting trips provide proactive safety information based on meteorological conditions and route-specific weather forecasts, enabling informed decision-making before journey commencement. This feature addresses a gap in the government's current deployment which focuses primarily on real-time monitoring without pre-trip safety assessment.

The comprehensive passenger feedback system represents a novel approach to community-based safety monitoring, enabling distributed oversight and accountability in public transport operations through real-time passenger reporting capabilities. This crowdsourced safety monitoring complements the government's technical monitoring with human observation and reporting.

Integration with the National Transport Commission establishes direct regulatory oversight and compliance monitoring [12], creating seamless data flow between operational safety systems and government regulatory frameworks. While the government's deployment includes basic reporting, the SafeDriver system offers deeper integration with regulatory systems.

Critical enhancements for aligning the system with Sri Lankan road conditions include optimization for left lane driving patterns and right-side steering wheel configurations [17], ensuring accurate monitoring angles and detection algorithms specifically calibrated for local driving environments.

Enhanced Common Features with Local Adaptations

The system incorporates advanced driver drowsiness, distraction, and smoking detection algorithms specifically trained on Sri Lankan driver behavioral patterns, accounting for cultural driving habits, local environmental conditions, and demographic variations in facial features and behavioral expressions. These detection systems achieve higher accuracy rates through localized training datasets and culturally appropriate behavioral baselines, addressing limitations in the government's deployment of international systems not optimized for Sri Lankan populations.

Comprehensive driver alerting systems feature multi-modal notification approaches including buzzer alerts and voice alerts delivered in Sinhala, Tamil, and English languages with culturally appropriate terminology and escalation protocols [22]. The alerting system implements graduated response mechanisms from subtle audio feedback to emergency intervention, ensuring appropriate response levels while maintaining driver acceptance and system effectiveness.

The combination of real-time driver monitoring with GPS-based hazard detection [24] provides location-aware safety interventions specifically calibrated for Sri Lankan Road conditions and accident-prone zones. The system design prioritizes cost-effectiveness through appropriate technology selection while maintaining safety effectiveness, addressing economic constraints prevalent in developing country contexts.

6. Technical Implementation Framework

6.1 Hardware and Software Architecture

Research demonstrates that Raspberry Pi 4 provides optimal balance between computational capability, cost effectiveness, and power consumption for embedded driver monitoring applications [20, 21]. The platform supports TensorFlow Lite / Google Colab deployment while maintaining real-time processing capabilities essential for safety-critical applications [14]. Comparative studies show Raspberry Pi 4 achieving superior price-performance ratios while maintaining adequate processing power for real-time facial monitoring [20, 21].

This cost-effective approach becomes particularly relevant as the government scales from pilot programs to full deployment across thousands of vehicles, where the difference between $200-400 per unit (SafeDriver) versus $2,000-5,000 (commercial systems) represents tens of millions in savings.

Environmental hardening requirements include conformal coating application, corrosion-resistant enclosures, and enhanced thermal management for reliable high-humidity, high-temperature operation. The Raspberry Pi Camera Module 2 NoIR enables effective monitoring under varying lighting conditions with GPS integration facilitating location-aware hazard detection [24].

The integration of OpenCV with MediaPipe provides robust foundation for facial landmark detection and tracking under constrained computational resources [15]. The facial landmark detection pipeline must be optimized for right-hand drive vehicle interiors [17], accounting for different lighting patterns and camera angles. The system implements advanced EAR and MAR calculations using proven formulas [6, 7] while incorporating temporal filtering to reduce noise and improve real-world accuracy. TensorFlow Lite quantization techniques enable sophisticated deep learning model deployment on resource-constrained platforms [14], with post-training quantization reducing model size while maintaining accuracy.

Firebase Real-time Database provides scalable cloud integration supporting fleet-wide deployment while maintaining low latency for critical safety communications [16]. Security architecture must protect sensitive data while enabling appropriate access for emergency response and regulatory oversight. Edge computing capabilities provide offline operation during connectivity interruptions [25], with store-and-forward systems enabling data synchronization when connectivity is restored.

7. Strategic Implications and Regional Opportunities

The development of a localized driver monitoring system represents a strategic technology development opportunity supporting broader economic development objectives while addressing critical public safety needs. The government's rapid deployment validates the market need and creates policy framework for comprehensive implementation [28, 32], while local development of optimized solutions ensures long-term sustainability and effectiveness.

Local development enables security measures aligned with Sri Lankan government policies while ensuring critical safety infrastructure remains under national control, addressing data sovereignty concerns increasingly important in the digital age. The government's mandate for implementation in the coming years creates a guaranteed domestic market while establishing a foundation for regional expansion.

The regional market potential for tropical-hardened, right-hand drive optimized monitoring systems creates export opportunities extending economic benefits beyond domestic implementation. Countries with similar challenges including India, Malaysia, Thailand, and other Southeast Asian nations represent substantial market opportunities for proven tropical-adapted solutions. Sri Lanka's experience with rapid deployment and the development of localized solutions positions the country as a potential regional leader in transportation safety technology.

The SafeDriver project, complementing the government's commercial deployment, establishes Sri Lanka as a regional leader in transportation technology development, creating capabilities extending beyond immediate safety applications to broader technology development and manufacturing capabilities, supporting economic diversification objectives through innovative, locally appropriate solutions.

8. Conclusion

8.1 Key Findings and Technical Analysis

This review establishes compelling justification for developing the SafeDriver AI-powered real-time driver monitoring system specifically for Sri Lankan public transport operations, particularly considering the government's rapid deployment following the May 2025 Kotmale tragedy [29, 30]. The analysis reveals that while the government's initiative addresses immediate safety needs with 40 AI cameras deployed and implementation scheduled for future years, significant gaps remain in comprehensive localization for Sri Lankan conditions.

The government's deployment represents a critical first step [28], transforming Sri Lanka from having virtually no drowsiness detection systems to implementing AI-powered monitoring across the public transport network within 12 months. However, existing systems are predominantly designed for developed country contexts with stable infrastructure, temperate climates, and left-hand drive configurations [17], unable to fully address the unique combination of challenges in Sri Lanka.

Academic research demonstrates impressive laboratory performance [4, 5], but field deployment experiences reveal significant tropical environment performance degradation [18, 19]. Commercial system analysis shows various solutions lacking environmental specifications, multilingual requirements, and comprehensive tropical hardening despite superior specifications.

Technical analysis reveals right-hand drive configurations require complete system redesign rather than simple adaptation [17], while tropical climate conditions create environmental challenges exceeding standard automotive electronics specifications, requiring specialized hardening including enhanced environmental protection, specialized thermal management, and improved sealing beyond standard automotive grades.

8.2 Economic and Strategic Justification

Local development offers 60-80% cost reduction compared to international solutions, with manufacturing costs of $200-400 per vehicle unit versus $2,000-5,000 for international systems [19], enabling broader deployment while maintaining essential safety effectiveness. This becomes critical as the government scales from 40 buses to mandatory implementation across 25,000 vehicles by coming years , where cost differences represent savings of $50-100 million.

The convergence of government policy mandate and local innovation capability creates unique opportunities. The government's rapid deployment establishes regulatory framework and market demand [32], while local development ensures long-term sustainability through cost-effectiveness and comprehensive localization. Technology sovereignty benefits enable security measures aligned with Sri Lankan government policies while ensuring critical safety infrastructure remains under national control.

Regional market potential for tropical-hardened, right-hand drive optimized systems creates export opportunities, with the SafeDriver project establishing Sri Lanka as regional leader in transportation technology development. The country's experience with both rapid commercial deployment and local innovation positions it uniquely in the regional market.

8.3 Implementation Requirements and Final Assessment

Successful implementation requires phased approach to build upon the government's pilot program. The August 2025 deployment of 40 buses provides initial validation of AI monitoring effectiveness [28], though broader testing across diverse geographic and climatic conditions remains necessary. The SafeDriver system can complement government deployment by addressing identified gaps in localization and cost-effectiveness.

Sri Lankan-specific modifications prove necessary including right-hand drive optimization for camera positioning [17], tropical environmental hardening exceeding standard specifications, multilingual interface development supporting Sinhala, Tamil, and English, and cost-optimized feature sets prioritizing essential safety functions.

The government's commitment to implementation by provides both urgency and opportunity for local innovation. While commercial systems offer immediate deployment capabilities demonstrated in the current pilot program [28], the SafeDriver system's comprehensive localization ensures long-term effectiveness and sustainability in Sri Lankan operational environments.

The convergence of technical requirements, economic benefits, safety imperatives, strategic opportunities, and government policy support creates overwhelming case for developing the SafeDriver system as localized solution optimized for Sri Lankan conditions. The substantial cost-benefit ratios, combined with technology sovereignty benefits and capability development opportunities, make this initiative essential for Sri Lanka's transportation safety and economic development objectives.

The SafeDriver system represents transformational opportunity to address critical public safety needs while establishing Sri Lanka as regional leader in transportation technology development. The comprehensive justification, validated by the government's urgent response to the Kotmale tragedy and rapid deployment initiative [29, 30, 32], demonstrates that local development is not only preferable to international alternatives but essential for achieving optimal safety outcomes under Sri Lankan conditions. The tragic loss of 23 lives in May 2025 has catalyzed unprecedented action, creating both the policy framework and market conditions for comprehensive, sustainable safety solutions that can prevent future tragedies while establishing Sri Lanka's technological leadership in the region.

References

[1] World Health Organization, "Global Status Report on Road Safety," Geneva: WHO Press, 2023.

[2] M. Ramzan, H. U. Khan, S. M. Awan, A. Ismail, M. Ilyas, and A. Mahmood, "A survey on state-of-the-art drowsiness detection techniques," IEEE Access, vol. 7, pp. 61904-61919, 2019.

[3] Y. Albadawi, M. Takruri, and M. Awad, "A review of recent developments in driver drowsiness detection systems," Sensors, vol. 22, no. 5, article 2055, 2022.

[4] Y. Ed-Doughmi, N. Idrissi, and Y. Hbali, "Real-time system for driver fatigue detection based on a recurrent neuronal network," Journal of Imaging, vol. 6, no. 8, article 80, 2020.

[5] J.-M. Guo and H. Markoni, "Driver drowsiness detection using hybrid convolutional neural network and long short-term memory," Multimedia Tools and Applications, vol. 78, pp. 29059-29087, 2019.

[6] T. Srivastava, A. M. Rahman, R. N. Khushaba, and S. Lal, "A real-time light-weight computer vision application for driver's drowsiness detection," International Journal of Engineering and Manufacturing, vol. 14, no. 2, pp. 12-23, 2024.

[7] W. H. Salem and M. Waleed, "Real-time driver drowsiness detection system using Dlib based on driver eye/mouth," Communications in Mathematics and Applications, vol. 13, no. 2, pp. 807-822, 2022.

[8] C. Jin, Z. Zhu, Y. Bai, G. Jiang, and A. He, "A deep-learning-based scheme for detecting driver cell-phone use," IEEE Access, vol. 8, pp. 18580-18589, 2020.

[9] C. Huang, X. Wang, J. Cao, S. Wang, and Y. Zhang, "HCF: A hybrid CNN framework for behavior detection of distracted drivers," IEEE Access, vol. 8, pp. 109335-109349, 2020.

[10] World Bank, "Delivering Road Safety in Sri Lanka: Leadership Priorities and Initiatives to 2030," Washington, DC: World Bank Group, 2020.

[11] S. C. Dharmage, E. Stockings, K. Foong, and P. Kelly, "Public road transport crashes in a low-income country," Injury Prevention, vol. 8, no. 3, pp. 202-207, 2002.

[12] National Transport Commission, Sri Lanka, "Annual Road Safety Statistics Report," Colombo: NTC Publications, 2024.

[13] Ministry of Transport, Sri Lanka, "Road Safety Statistics and Initiatives," Available: https://www.transport.gov.lk, 2025.

[14] TensorFlow Team, "TensorFlow Lite for Mobile and Edge Devices," Available: https://www.tensorflow.org/lite, 2024.

[15] C. Lugaresi, J. Tang, H. Nash, C. McClanahan, E. Uboweja, M. Hays, F. Zhang, C.-L. Chang, M. Yong, J. Lee, W.-T. Chang, W. Hua, M. Georg, and M. Grundmann, "MediaPipe: A framework for building perception pipelines," arXiv preprint arXiv:1906.08172, 2019.

[16] Firebase Team, "Firebase Real-time Database Documentation," Available: https://firebase.google.com/docs/database, 2024.

[17] The Motor Guy, "Right-Hand Drive Systems Explained: A Guide to Countries and Regulations," Available: https://themotorguy.com/right-hand-drive-systems-explained-countries-and-regulations/, March 2024.

[18] A. Kashevnik, I. Lashkov, A. Ponomarev, N. Teslya, and A. Gurtov, "Cloud-based driver monitoring system using a smartphone," IEEE Sensors Journal, vol. 20, no. 12, pp. 6701-6715, 2020.

[19] M. Doudou, A. Bouabdallah, and V. Berge-Cherfaoui, "Driver drowsiness measurement technologies: Current research, market solutions, and challenges," International Journal of Intelligent Transportation Systems Research, vol. 18, pp. 297-319, 2020.

[20] U. Narayanan, P. Prajith, R. T. Mathew, R. Alexandar, and V. Vikraman, "Real time distracted driver detection using Xception architecture and Raspberry Pi," Inteligencia Artificial, vol. 28, no. 75, pp. 15-29, 2025.

[21] H. A. Khalil, S. A. Hammad, H. E. Abdelmunim, and S. A. Maged, "Low-cost driver monitoring system using deep learning," IEEE Access, vol. 13, pp. 14151-14164, 2025.

[22] M. F. B. Amin, I. J. Khan, F. Akter, A. Ahmed, and M. M. Islam, "SafeTrax: Smart collision prediction and alert system using IoT for sustainable traffic safety," IEEE Access, vol. 13, pp. 6667-6684, 2025.

[23] Telecommunications Regulatory Commission of Sri Lanka, "Mobile Network Coverage Analysis in Rural Areas," Colombo: TRCSL Reports, 2024.

[24] P. Misra and P. Enge, "Global Positioning System: Signals, Measurements, and Performance," 2nd ed., Lincoln, MA: Ganga-Jamuna Press, 2024.

[25] R. Kumar, S. Sharma, and A. Patel, "Offline Geographic Information Systems for Emergency Response in Remote Areas," Journal of Location Based Services, vol. 18, no. 2, pp. 145-162, 2024.

[26] SpaceX, "Starlink Mobile Connectivity Technical Specifications and Performance Analysis," Available: https://www.starlink.com/mobile, 2025.

[27] J. Henderson, M. Wright, and K. Thompson, "Economic Analysis of Satellite Internet Deployment in Developing Country Transportation Systems," Transportation Research Part E, vol. 178, pp. 103-118, 2024.

[28] Newswire, "Sri Lanka begins AI camera project to cut long-distance bus accidents," Available: https://www.newswire.lk/2025/08/12/sri-lanka-begins-ai-camera-project-to-cut-long-distance-bus-accidents/, August 12, 2025.

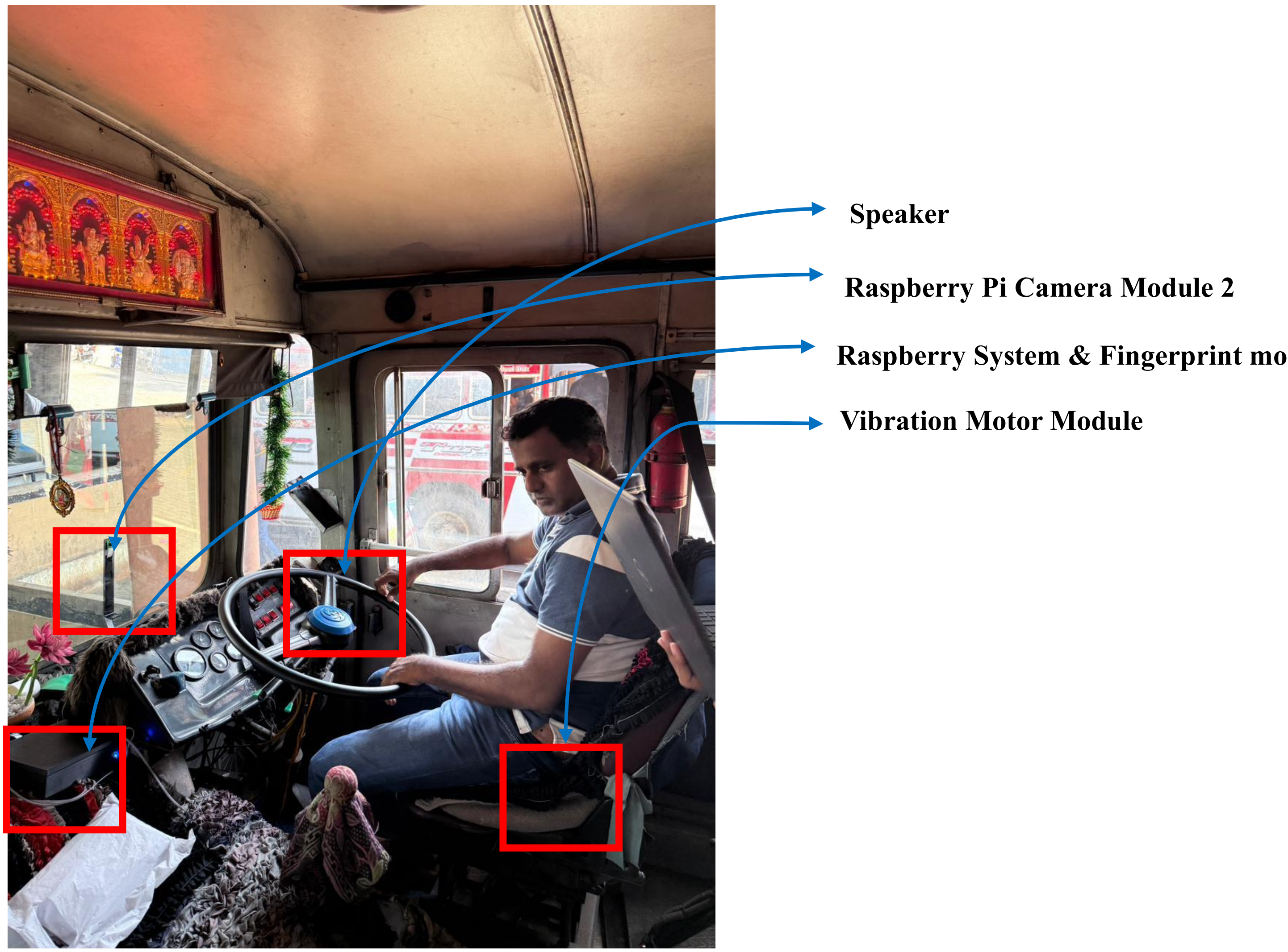
[29] Arab News, "Sri Lanka to monitor bus drivers with AI after worst crash in decades," Available: https://www.arabnews.com/node/2600710/world, May 2025.

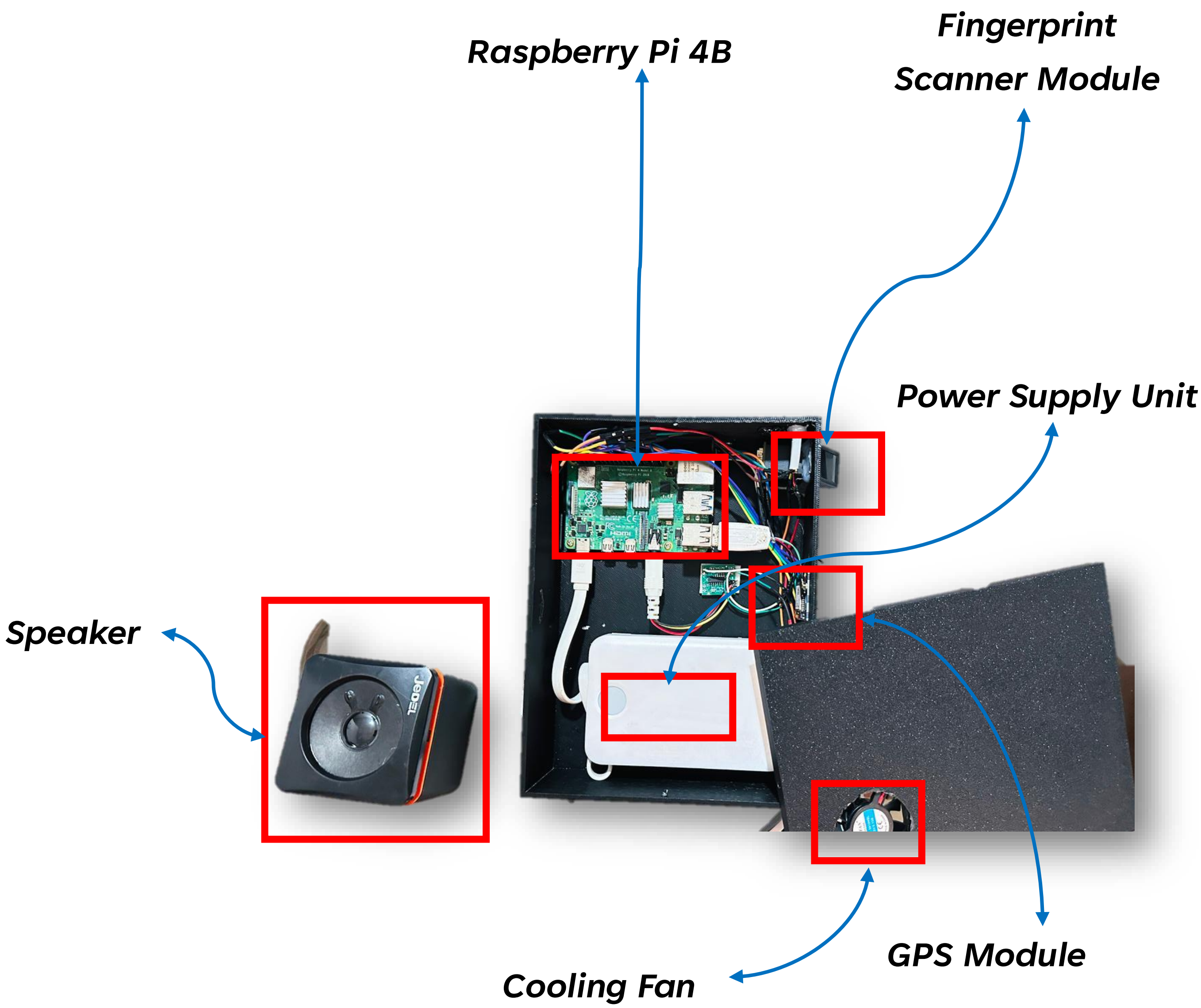
[30] Ceylon Today, "Kotmale Bus Tragedy Sparks Long-Overdue Transport Reforms," Available: https://ceylontoday.lk/2025/05/17/kotmale-bus-tragedy-sparks-long-overdue-transport-reforms/, May 17, 2025.

[31] The Island, "Transport sector: Glimmer of hope," Available: https://island.lk/transport-sector-glimmer-of-hope/, 2025.

[32] Daily Mirror, "AI-powered CCTV and GPS systems to be introduced," Available: https://www.dailymirror.lk/print/breaking-news/AI-powered-CCTV-and-GPS-systems-to-be-introduced/108-308968, 2025.

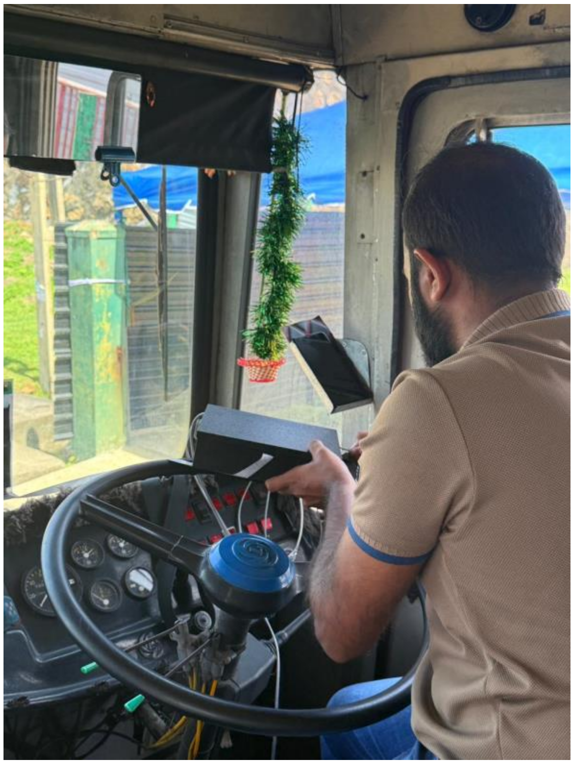
Implemented System

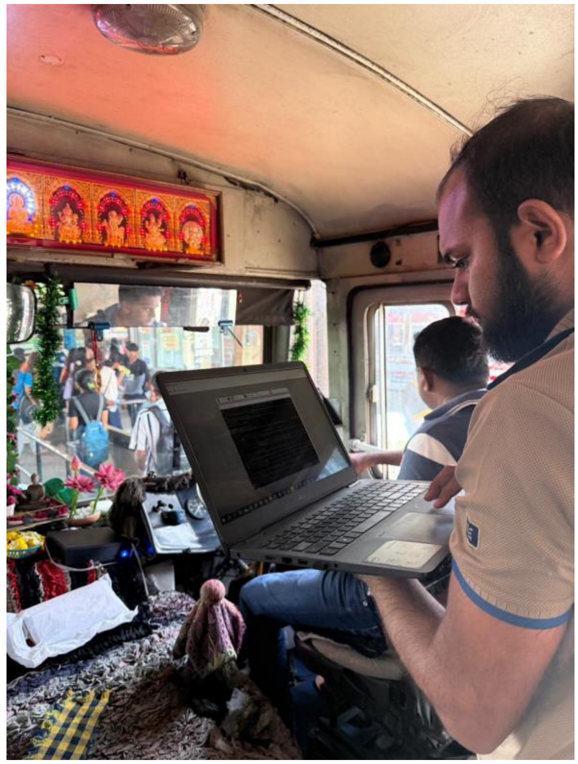


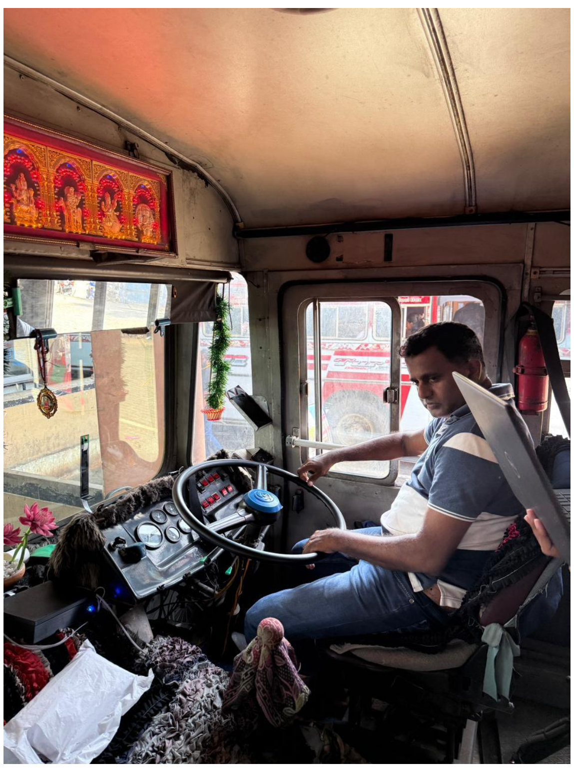

Raspberry Pi 4B
Fingerprint Scanner Module
Power Supply Unit
Speaker
GPS Module
Cooling Fan

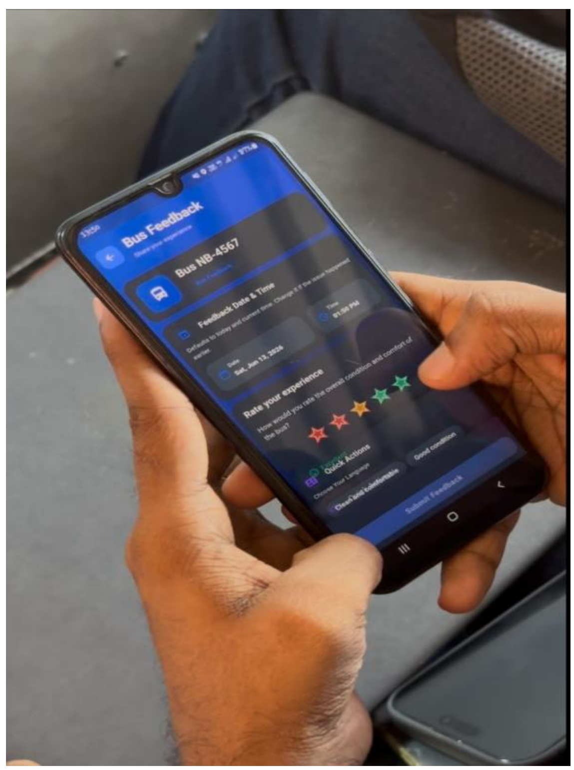
Real-World Pilot Implementation and Testing

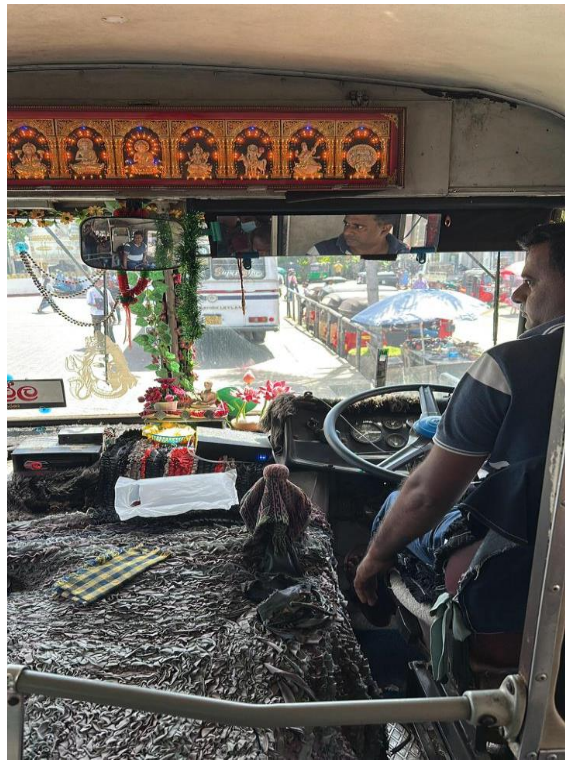
01.NB-4567 Elpitiya - Galle SLTB Bus



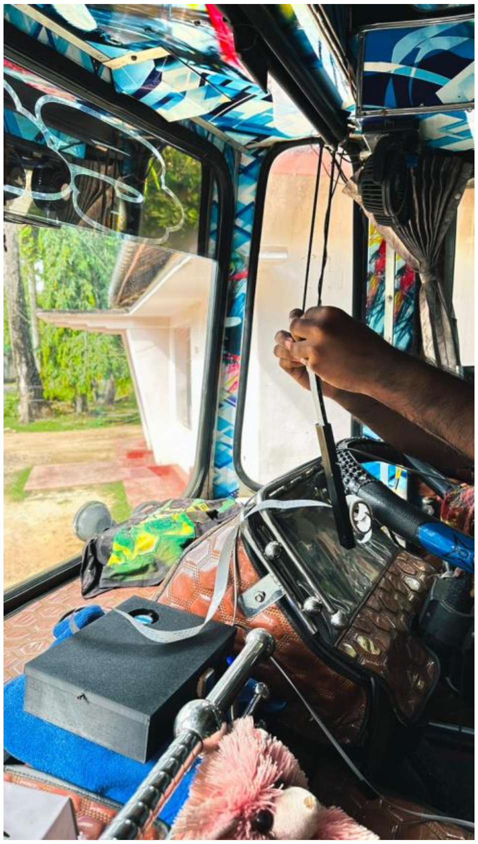








02. NB-4230 Dodangoda – Galle Private Bus



Initial Discussion to Prepare for Progress 1

Meeting Information

Field	Details
Meeting Date/Time	25/05/2025 - 21:00:00
Participants	D. S. Sandeepa, R. U. Gonalagoda, P. S. Ekanayaka
Estimated Time	1h 56m
Special Notes	Discuss project proposal, identify features, introduction, objectives, and start to create proposal document.
Call/Location Information	MS Teams
Supported Documents	Project proposal draft

Agenda

- Discuss the project proposal.
- Identify features, introduction, and objectives.
- Start preparing the proposal document.

Meeting Minutes

- The team discussed the project proposal and clarified the main purpose of the system.
- Features, introduction, and objectives were identified for the proposal document.
- It was agreed to begin drafting the proposal with input from all team members.

Action Items

Action item	Decision made by
Prepare the proposal document draft	D. S. Sandeepa, R. U. Gonalagoda
Finalize the feature list and objectives	All participants

Review Presentation and Finalization

Meeting Information

Field	Details
Meeting Date/Time	28/05/2025 - 21:40:00
Participants	D. S. Sandeepa, R. U. Gonalagoda, K. J. L. Perera, P. S. Ekanayaka
Estimated Time	45m
Special Notes	Review presentation and finalization.
Call/Location Information	MS Teams
Supported Documents	Presentation slides

Agenda

- Review the current presentation.
- Finalize the presentation content.

Meeting Minutes

- The team reviewed the presentation structure and content.
- Feedback was given to improve clarity and completeness.
- Final changes were agreed upon before submission.

Action Items

Action item	Decision made by
Revise presentation slides	R. U. Gonalagoda
Approve final presentation version	All participants

Practice Proposal Presentation

Meeting Information

Field	Details
Meeting Date/Time	17/06/2025 - 22:30:00
Participants	D. S. Sandeepa, P. S. Ekanayaka, R. U. Gonalagoda
Estimated Time	2h 10m
Special Notes	Practice proposal presentation, make some changes, and divide the presentation scope among team members.
Call/Location Information	MS Teams
Supported Documents	Proposal presentation outline

Agenda

- Practice the proposal presentation.
- Identify required changes.
- Divide presentation scope among team members.

Meeting Minutes

- The team conducted a practice presentation for the proposal.
- Several changes were suggested to improve delivery and clarity.
- The presentation scope was divided among team members for better coordination.

Action Items

Action item	Decision made by
Update the proposal presentation	D. S. Sandeepa, P. S. Ekanayaka, R. U. Gonalagoda
Allocate presentation sections	All participants

Practice Proposal and Time Adjustment

Meeting Information

Field	Details
Meeting Date/Time	**18/06/2025 - 20:00:00**
Participants	**D. S. Sandeepa, P. S. Ekanayaka, T. P. Denagamage**
Estimated Time	**1h 48m**
Special Notes	**Practice proposal presentation and adjust the time duration for each member.**
Call/Location Information	**MS Teams**
Supported Documents	**Proposal presentation schedule**

Agenda

- Practice the proposal presentation.
- Adjust speaking time for each member.

Meeting Minutes

- The presentation was practiced and timing issues were discussed.
- The team adjusted the duration allocated to each presenter.
- Improvements were noted to help balance the presentation flow.

Action Items

Action item	Decision made by
Update time allocation	All participants
Rehearse revised presentation	All participants

Practice Proposal Presentation in Zoom

Meeting Information

Field	Details
Meeting Date/Time	18/06/2025 - 21:50:00
Participants	D. S. Sandeepa, R. U. Gonalagoda, P. S. Ekanayaka, K. J. L. Perera, T. P. Denagamage
Estimated Time	40m
Special Notes	Practice proposal presentation via Zoom.
Call/Location Information	Zoom
Supported Documents	Proposal presentation link

Agenda

- Practice the proposal presentation on Zoom.
- Review delivery and timing.

Meeting Minutes

- The team practiced the proposal presentation in Zoom.
- Members reviewed the presentation flow and delivery.
- Final adjustments were discussed before the next rehearsal.

Action Items

Action item	Decision made by
Improve delivery and slide flow	All participants
Continue rehearsal using Zoom	All participants

Discussion Project Trello Board

Meeting Information

Field	Details
Meeting Date/Time	27/06/2025 - 21:15:00
Participants	R. U. Gonalagoda, D. S. Sandeepa, P. S. Ekanayaka
Estimated Time	5h 45m
Special Notes	Discuss project trello board, manage projects, setup projects on team members dev environments.
Call/Location Information	MS Teams
Supported Documents	Trello board, development setup

Agenda

- **Discuss the project Trello board.**
- **Manage projects and tasks.**
- **Set up projects on team members' development environments.**

Meeting Minutes

- **The Trello board was reviewed and task organization was discussed.**
- **Project management responsibilities were clarified.**
- **Development environments were prepared for team setup and collaboration.**

Action Items

Action item	Decision made by
Update Trello board tasks	R. U. Gonalagoda
Set up development environments	All participants

Project Progress Discussion

Meeting Information

Field	Details
Meeting Date/Time	01/07/2025 - 21:30:00
Participants	D. S. Sandeepa, R. U. Gonalagoda, P. S. Ekanayaka, K. J. L. Perera, T. P. Denagamage
Estimated Time	40m
Special Notes	Discussion with the supervisor about progress 1 and overall project idea.
Call/Location Information	Zoom
Supported Documents	Progress 1 notes

Agenda

- Discuss progress 1 with the supervisor.
- Review the overall project idea.

Meeting Minutes

- The team discussed progress 1 with the supervisor.
- The overall project idea was reviewed and clarified.
- Feedback was noted for future improvements.

Action Items

Action item	Decision made by
Refine the overall project idea	All participants
Incorporate supervisor feedback	All participants

Progress 1 Issues and Planning

Meeting Information

Field	Details
Meeting Date/Time	01/07/2025 - 20:30:00
Participants	D. S. Sandeepa, R. U. Gonalagoda, P. S. Ekanayaka, K. J. L. Perera, T. P. Denagamage
Estimated Time	2h
Special Notes	Discuss about the issues, dependencies, planning for the project progress 1.
Call/Location Information	MS Teams
Supported Documents	Progress 1 planning notes

Agenda

- Discuss issues and dependencies.
- Plan work for project progress 1.

Meeting Minutes

- The team identified issues affecting the progress work.
- Dependencies were reviewed and planning adjustments were made.
- Tasks were distributed to keep the milestone on track.

Action Items

Action item	Decision made by
Resolve identified issues	All participants
Update progress 1 plan	All participants

Literature Review Discussion

Meeting Information

Field	**Details**
Meeting Date/Time	06/07/2025 - 11:00:00
Participants	D. S. Sandeepa, R. U. Gonalagoda
Estimated Time	2h
Special Notes	Review the literature review.
Call/Location Information	MS Teams
Supported Documents	Literature review draft

Agenda

- Review the literature review draft.

Meeting Minutes

- The literature review was reviewed in detail.
- Required corrections and improvements were identified.
- Further refinement was agreed before the next submission.

Action Items

Action item	**Decision made by**
Revise literature review content	D. S. Sandeepa, R. U. Gonalagoda
Improve references and structure	D. S. Sandeepa, R. U. Gonalagoda

SRS Review

Meeting Information

Field	Details
Meeting Date/Time	17/07/2025 - 20:00:00
Participants	D. S. Sandeepa, R. U. Gonalagoda, P. S. Ekanayaka
Estimated Time	2h
Special Notes	Review SRS.
Call/Location Information	MS Teams
Supported Documents	SRS draft

Agenda

- **Review the SRS document.**

Meeting Minutes

- **The SRS draft was reviewed by the team.**
- **Changes were suggested to improve accuracy and completeness.**
- **The team agreed to update the SRS accordingly.**

Action Items

Action item	Decision made by
Update SRS draft	All participants
Verify requirements coverage	All participants

Progress 1 Review and SRS Updates

Meeting Information

Field	Details
Meeting Date/Time	16/08/2025 - 22:00:00
Participants	D. S. Sandeepa, R. U. Gonalagoda, P. S. Ekanayaka, K. J. L. Perera, T. P. Denagamage
Estimated Time	40m
Special Notes	Discussion with the supervisor about progress 1 reviewed changes and enhance the SRS and literature review contents according to the government project.
Call/Location Information	Zoom
Supported Documents	SRS and literature review revisions

Agenda

- Review progress 1 changes.
- Enhance SRS and literature review contents.

Meeting Minutes

- The supervisor reviewed the changes made to progress 1.
- The SRS and literature review content were discussed and improved.
- Further alignment with the government project requirements was noted.

Action Items

Action item	Decision made by
Update SRS and literature review	**All participants**
Align content with project requirements	**All participants**

Literature Review Changes

Meeting Information

Field	Details
Meeting Date/Time	**15/09/2025 - 20:00:00**
Participants	**D. S. Sandeepa, R. U. Gonalagoda**
Estimated Time	**2h**
Special Notes	**Literature review changes.**
Call/Location Information	**MS Teams**
Supported Documents	**Literature review revisions**

Agenda

- Review literature review changes.

Meeting Minutes

- The team reviewed the literature review changes.
- Additional edits were identified for clarity and consistency.
- The updated content was prepared for further use.

Action Items

Action item	Decision made by
Finalize literature review changes	**D. S. Sandeepa, R. U. Gonalagoda**

SRS, Literature Review, and CMMI Meeting

Meeting Information

Field	Details
Meeting Date/Time	07/10/2025 - 22:00:00
Participants	D. S. Sandeepa, R. U. Gonalagoda, P. S. Ekanayaka, K. J. L. Perera, T. P. Denagamage
Estimated Time	45m
Special Notes	Review SRS, literature review, CMMI meeting minutes and other progress 1 documentations and discussion with supervisor.
Call/Location Information	Zoom
Supported Documents	SRS, literature review, CMMI minutes, progress 1 documents

Agenda

- Review SRS.
- Review literature review.
- Review CMMI meeting minutes and progress 1 documentation.
- Discuss updates with the supervisor.

Meeting Minutes

- The team reviewed the SRS, literature review, and CMMI documents.
- Remaining documentation for progress 1 was discussed with the supervisor.
- Final corrections and improvements were identified.

Action Items

Action item	Decision made by
Update all progress 1 documentation	All participants
Incorporate supervisor comments	All participants

Implementation and Bug Fixing Session

Meeting Information

Field	Details
Meeting Date/Time	24/10/2025 - 20:00:00
Participants	D. S. Sandeepa, R. U. Gonalagoda, P. S. Ekanayaka
Estimated Time	3h
Special Notes	Implementation and bug fixing session for authority dashboard web app.
Call/Location Information	MS Teams
Supported Documents	Dashboard web app

Agenda

- Work on implementation.
- Fix bugs in the authority dashboard web app.

Meeting Minutes

- The team worked on implementation tasks for the dashboard web app.
- Several bugs were identified and fixed during the session.
- The system was tested after the fixes.

Action Items

Action item	Decision made by
Continue implementation work	R. U. Gonalagoda, D. S. Sandeepa
Resolve remaining bugs	All participants

Database Architecture Discussion

Meeting Information

Field	Details
Meeting Date/Time	06/10/2025 - 00:00:00
Participants	D. S. Sandeepa, R. U. Gonalagoda
Estimated Time	Not specified
Special Notes	Discussion for design the database architecture.
Call/Location Information	MS Teams
Supported Documents	Database design notes

Agenda

- Discuss the database architecture design.

Meeting Minutes

- The database architecture was discussed.
- Initial design considerations were reviewed.
- Further database planning was agreed for the next stage.

Action Items

Action item	Decision made by
Draft database architecture	R. U. Gonalagoda
Review database structure	D. S. Sandeepa, R. U. Gonalagoda

Code Review Session for Web, Mobile and Model Backend Projects

Meeting Information

Field	Details
Meeting Date/Time	20/11/2025 - 23:00:00
Participants	D. S. Sandeepa, R. U. Gonalagoda, P. S. Ekanayaka
Estimated Time	3h
Actual Time	4h
Special Notes	Code review session for web, mobile and model backend projects
Call/Location Information	MS Teams
Supported Documents	Code base, review notes

Agenda

- Review the web, mobile, and model backend code.
- Identify issues, improvements, and required corrections.

Notes/Clarifications

- The session focused on reviewing code quality and consistency across all project modules.
- Key issues were identified for later correction and optimization.

Meeting Minutes

- The team reviewed the web, mobile, and model backend projects.
- Code quality, structure, and integration points were discussed.
- Required fixes and improvements were noted for implementation.

Action Items

Action item	Decision made by
Apply code review corrections	D. S. Sandeepa, R. U. Gonalagoda, P. S. Ekanayaka
Improve consistency across modules	All participants

Hardware Integration and Raspberry Pi Kit Setup

Meeting Information

Field	Details
Meeting Date/Time	23/11/2025 - 15:00:00
Participants	D. S. Sandeepa, R. U. Gonalagoda
Estimated Time	2h
Actual Time	3h
Special Notes	Hardware integration and Raspberry Pi kit setup
Call/Location Information	Physical
Supported Documents	Hardware kit, integration notes

Agenda

- Set up the Raspberry Pi kit.
- Discuss hardware integration requirements.

Notes/Clarifications

- The hardware setup took longer than expected due to integration steps.
- Initial configuration and connectivity were reviewed during the session.

Meeting Minutes

- The Raspberry Pi kit was set up and tested.
- Hardware integration steps were discussed and applied.
- Preliminary checks were completed to ensure the kit was ready for further work.

Action Items

Action item	Decision made by
Complete hardware integration setup	D. S. Sandeepa, R. U. Gonalagoda
Verify Raspberry Pi kit functionality	D. S. Sandeepa, R. U. Gonalagoda

Integration Testing for Web, Mobile and Model Backend

Meeting Information

Field	Details
Meeting Date/Time	28/11/2025 - 17:45:00
Participants	D. S. Sandeepa, R. U. Gonalagoda, P. S. Ekanayaka, T. P. Denagamage
Estimated Time	4h
Actual Time	4h
Special Notes	Integration testing web, mobile and model backend
Call/Location Information	MS Teams
Supported Documents	Test cases, integration checklist

Agenda

- Perform integration testing across web, mobile, and model backend systems.
- Identify integration issues and confirm system behavior.

Notes/Clarifications

- The testing session focused on end-to-end communication between all modules.
- System behavior was checked under integrated conditions.

Meeting Minutes

- Integration testing was carried out for the web, mobile, and model backend components.
- The team verified connectivity and data flow between modules.
- Issues found during testing were recorded for correction.

Action Items

Action item	Decision made by
Fix integration issues	D. S. Sandeepa, R. U. Gonalagoda, P. S. Ekanayaka, T. P. Denagamage
Re-test corrected modules	All participants

Progress Tracking Meeting with Supervisor

Meeting Information

Field	Details
Meeting Date/Time	28/11/2025 - 21:45:00
Participants	D. S. Sandeepa, R. U. Gonalagoda, P. S. Ekanayaka, T. P. Denagamage
Estimated Time	1h
Actual Time	1h 15m
Special Notes	Progress tracking meeting with supervisor
Call/Location Information	Zoom
Supported Documents	Progress report notes

Agenda

- Review project progress with the supervisor.
- Discuss completed work and pending tasks.

Notes/Clarifications

- The meeting was used to track current progress and gather feedback.
- Additional guidance from the supervisor was noted for further improvement.

Meeting Minutes

- The team presented progress updates to the supervisor.
- Completed work and remaining tasks were discussed.
- Supervisor feedback was recorded for future action.

Action Items

Action item	Decision made by
Address supervisor feedback	All participants
Continue progress tracking updates	All participants

SafeDriver System Diagram Discussion

Meeting Information

Field	Details
Meeting Date/Time	14/01/2025 - 19:30:00
Participants	D. S. Sandeepa, R. U. Gonalagoda
Estimated Time	1h
Actual Time	1h 30m
Special Notes	Discuss and prepare use case, system architecture, class, activity, sequence diagrams for SafeDriver system
Call/Location Information	MS Teams
Supported Documents	Diagram drafts, system design notes

Agenda

- Discuss the SafeDriver system design.
- Prepare use case, system architecture, class, activity, and sequence diagrams.

Notes/Clarifications

- The session focused on planning the system design documents.
- Diagram structure and representation details were discussed.

Meeting Minutes

- The team discussed the overall SafeDriver system design.
- Use case, architecture, class, activity, and sequence diagrams were planned.
- The required documentation structure was agreed for preparation.

Action Items

Action item	Decision made by
Prepare system diagrams	D. S. Sandeepa, R. U. Gonalagoda
Finalize diagram content and structure	D. S. Sandeepa, R. U. Gonalagoda

Progress 2 Report and Presentation Discussion

Meeting Information

Field	Details
Meeting Date/Time	11/03/2025 - 17:30:00
Participants	D. S. Sandeepa, R. U. Gonalagoda, P. S. Ekanayaka, T. P. Denagamage, K. J. L. Perera
Estimated Time	4h
Actual Time	5h 15m
Special Notes	Discuss about the progress 2 report and presentation
Call/Location Information	MS Teams
Supported Documents	Progress 2 report, presentation draft

Agenda

- Discuss the progress 2 report.
- Review the presentation content and structure.

Notes/Clarifications

- The discussion took longer than expected due to report and presentation refinement.
- Suggestions were collected from all participants.

Meeting Minutes

- The team discussed the progress 2 report and presentation.
- Required updates and corrections were identified.
- The presentation plan was refined based on team feedback.

Action Items

Action item	Decision made by
Update the progress 2 report	All participants
Revise the presentation slides	All participants

Initial Discussion to Prepare for Progress 3

Meeting Information			
Meeting Date/Time	04/04/2026 - 19:00:00		
Participants	D. S. Sandeepa R. U. Gonalagoda T. P. Denagamage K. J. L. Perera P. S. Ekanayaka		
Estimated Time	45min	**Actual Time**	45min
Special Notes	Discuss PR3 requirements, identify detailed-design tasks, plan documentation.		
Call/Location Information	MS Teams		
Supported Documents	PR3 rubric, project schedule		

Agenda:

- Get an overall idea about Progress Report 3 and list required artefacts (DB design, GUI prototype, test plan, CMMI minutes).

Notes/Clarifications:

Meeting Minutes:

- Discussed PR3 requirements, identified all detailed-design and documentation tasks, and agreed on responsibilities and internal deadlines.
- Confirmed that database design, GUI prototype, test plan and CMMI minutes will be the main deliverables prepared for this milestone.

Action Items:

Action item	Decision made by
Review PR3 rubric and mark required sections	All participants
Finalize ER diagram and Firebase mapping	R. U. Gonalagoda

Finalize the Abstract

Meeting Information			
Meeting Date/Time	28/04/2026 – 21:00:00		
Participants	D. S. Sandeepa R. U. Gonalagoda T. P. Denagamage K. J. L. Perera P. S. Ekanayaka		
Estimated Time	1h	Actual Time	1h
Special Notes	Final review and polishing of project abstract.		
Call/Location Information	MS Teams		
Supported Documents	Draft abstract, SRS, PR2		

Agenda:

- Review and finalise the abstract for submission and reuse in PR3.

Notes/Clarifications:

Meeting Minutes:

- Reviewed the draft project abstract against SRS and PR2 and refined wording to highlight AI-based monitoring and hybrid edge-cloud architecture.
- Agreed on the final abstract text for faculty submission and reuse in PR3 and future publications.

Action Items:

Action item	Decision made by
Apply final text changes to abstract	R. U. Gonalagoda
Submit approved abstract to faculty portal	D. S. Sandeepa

Route Mapping Discussion

Meeting Information			
Meeting Date/Time	01/05/2026 – 12:30:00		
Participants	D. S. Sandeepa R. U. Gonalagoda P. S. Ekanayaka T. P. Denagamage K. J. L. Perera		
Estimated Time	1h	Actual Time	1h
Special Notes	Internal follow-up on supervisor feedback		
Call/Location Information	MS Teams		
Supported Documents			

Agenda:

- Review supervisor comments from the Progress 3 meeting.
- Plan changes to documentation, GUI and test plan.

Notes/Clarifications:

Meeting Minutes:

- Discussion on design corrections, dashboard behavior and PR3 documentation tasks.

Action Items:

Action item	Decision made by
Update PR3 database-design	**R.U. Gonalagoda**
Implement route-mapping changes in dashboard prototype	**P.S. Ekanayake**
Compile updated CMMI meeting-minutes appendix for PR3	**K.J.L. Perera**

Route Mapping Discussion

Meeting Information			
Meeting Date/Time	17/06/2025 20:00:00		
Participants	D. S. Sandeepa R. U. Gonalagoda P. S. Ekanayaka		
Estimated Time	1h	**Actual Time**	2h
Special Notes	Finalization of route-mapping features in dashboard.		
Call/Location Information	MS Teams		
Supported Documents			

Agenda:

- Discuss and finalize route mapping and hazard-zone visualization on web dashboard.

Notes/Clarifications:

Meeting Minutes:

- Discussed and finalized the route-mapping design, including how buses, routes and hazard zones will be visualized on the web dashboard.
- Confirmed data fields and responsibilities for implementing the updated route-mapping functionality in the dashboard prototype.

Action Items:

Action item	Decision made by
Implement route-mapping changes in dashboard prototype	**P.S. Ekanayake**

Initial Discussion to Prepare for Final Report

Meeting Information			
Meeting Date/Time	20/05/2026 - 19:00:00		
Participants	D. S. Sandeepa R. U. Gonalagoda T. P. Denagamage K. J. L. Perera P. S. Ekanayake		
Estimated Time	45min	**Actual Time**	45min
Special Notes	Discuss Final Report requirements, identify detailed-design tasks, plan documentation.		
Call/Location Information	MS Teams		
Supported Documents	Final Report rubric, project schedule		

Agenda:

- Get an overall idea about final report and list required artefacts (DB design, GUI prototype, test plan, CMMI minutes, implementation).

Notes/Clarifications:

Meeting Minutes:

- Discussed Final Report requirements, identified all detailed-design and documentation tasks, and agreed on responsibilities and internal deadlines.
- Confirmed that database design, GUI prototype, test plan and CMMI minutes will be the main deliverables prepared for this milestone.

Action Items:

Action item	Decision made by
Review Final Report rubric and mark required sections	All participants

System Implementation Finalization Review

Meeting Information			
Meeting Date/Time	28/05/2026 – 21:00:00		
Participants	D. S. Sandeepa R. U. Gonalagoda T. P. Denagamage K. J. L. Perera P. S. Ekanayake		
Estimated Time	1h	Actual Time	1h
Special Notes	Final review and confirmation that all system modules are implemented and working correctly.		
Call/Location Information	MS Teams		
Supported Documents	SRS, implementation codebase, test results, Final Report draft		

Agenda:

- Review and confirm the completion of all system implementations and verify that all modules are working correctly for Final Report submission.

Notes/Clarifications:

Meeting Minutes:

- Reviewed the overall system implementation status, confirming that all core modules — driver behaviour detection, real-time alert generation, Firebase backend integration, authority dashboard, and passenger mobile application — are fully implemented and functioning as specified.
- Agreed that all system components are complete and verified; team confirmed no outstanding implementation tasks remain, and the system is ready for final submission and documentation.

Action Items:

Action item	Decision made by
Verify and document final test results for all implemented modules	All participants

Final Report Discussion with Supervisor

Meeting Information			
Meeting Date/Time	01/06/2026 – 10:00:00		
Participants	Dr. D.D.M. Ranasinghe (Supervisor) D. S. Sandeepa R. U. Gonalagoda K. J. L. Perera T. P. Denagamage P. S. Ekanayake		
Estimated Time	1h	Actual Time	1h
Special Notes	Final progress discussion with supervisor to review completed system, test outcomes, and Final Report readiness.		
Call/Location Information	Zoom		
Supported Documents	Final Report draft, completed implementation codebase, test results, system demonstration		

Agenda

- Present the fully completed SafeDriver system to the supervisor, demonstrate all implemented modules, and obtain final approval and feedback for the Final Report submission.

Meeting Minutes

- Demonstrated the fully implemented SafeDriver system to the supervisor, covering all modules including driver behaviour detection, real-time alerting, Firebase backend, authority dashboard, and passenger mobile application, along with test results confirming system functionality.
- Supervisor confirmed that the system implementation is complete and meets project requirements; team received final approval to proceed with Final Report submission, incorporating supervisor feedback on documentation clarity and test-result presentation.

Action Items:

Action item	Decision made by
Finalise and submit the completed Final Report incorporating supervisor feedback	All participants