# TRANSPORT MANAGEMENT SYSTEM

**CAPSTONE PROJECT REPORT**

**Submitted by**


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**in partial fulfilment for the award of the degree**

**of**

**BACHELOR OF TECHNOLOGY**

**IN**

**COMPUTER SCIENCE AND ENGINEERING**



**SCHOOL OF COMPUTING**

**COMPUTER SCIENCE AND ENGINEERING**

**KALASALINGAM ACADEMY OF RESEARCH AND EDUCATION**

**KRISHNANKOIL 626 126**


April 2025

# DECLARATION

We affirm that the project work titled **"Transport Management System (TMS)"** being submitted in partial fulfillment for the award of the degree of **Bachelor of Technology in Computer Science and Engineering** is the original work carried out by us. It has not formed part of any other project work submitted for the award of any degree or diploma, either in this or any other University.


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KALASALINGAM
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Under sec. 3 of UGC Act 1956. Accredited by NAAC with "A++" Grade

# BONAFIDE CERTIFICATE

Certified that this project report **"Transport Management System (TMS)"**is the bonafide work of "**N SAI ACHYUTH (99210041703), P VARSHITH (9921004528), N VIVEKA REDDY (9921004494)"** who carried out the project work under my supervision.


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# ACKNOWLEDGEMENT

We would like to begin by expressing our heartfelt gratitude to the Supreme Power for the immense grace that enabled us to complete this project.

We are deeply grateful to the late **"Kalvivallal" Thiru T. Kalasalingam,** Chairman of the Kalasalingam Group of Institutions, and to "**Illayavallal" Dr. K. Sridharan**, Chancellor, as well as **Dr. S. Shasi Anand**, Vice President, who has been a guiding light in all our university's endeavours.

Our sincere thanks go to our Vice Chancellor, **Dr. S. Narayanan**, for his inspiring leadership, guidance, and for instilling in us the strength and enthusiasm to work towards our goals.

We would like to express our sincere appreciation to **Dr. P. Deepa Lakshmi**, Professor & Dean-(SoC), Director Accreditation & Ranking, for her valuable guidance. Our heartfelt gratitude also goes to our esteemed Head of Department, **Dr. N. Suresh Kumar**, whose unwavering support has been crucial to the successful advancement of our project.

We are especially thankful to our Project Supervisor, **Mr. M. Sankara Mahalingam**, for his patience, motivation, enthusiasm, and vast knowledge, which greatly supported us throughout this work.

Our sincere gratitude also goes to **Dr. S. Ariffa Begum** and **Dr.T.Manikumar** Overall Project Coordinators, for their constant encouragement and support in completing this Capstone Project.

Finally, we would like to thank our parents, faculty, non-teaching staff, and friends for their unwavering moral support throughout this journey.

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**PROJECT SUMMARY**

| | |
|---|---|
| Project Title | Transport Management System (TMS) |
| Project Team Members (Name with Register No) | N SAI ACHYUTH (99210041703) , P VARSHITH (9921004528), N VIVEKA REDDY (9921004494) |
| Guide Name/Designation | Mr. M. Sankara Mahalingam, Assistant Professor |
| Program Concentration Area | Software Engineering, Embedded Systems and IoT, Mobile Computing and Human-Computer Interaction |
| Technical Requirements | Barcode scanners, Raspberry Pi 4, GPS modules, Flutter (mobile app and web dashboard), Firestore (Firebase), Firebase Hosting. |

Engineering standards and realistic constraints in these areas

| **Area** | **Codes & Standards / Realistic Constraints** | **Tick ✓** |
|---|---|---|
| Economic | Cost-effective hardware and software solutions | ✓ |
| Environmental | Low energy consumption, sustainable design | ✓ |
| Social | Improved student safety and accessibility | ✓ |
| Ethical | Secure data handling and privacy | ✓ |
| Health and Safety | Rapid emergency response system | ✓ |
| Manufacturability | Scalable and replicable design | ✓ |
| Sustainability | Long-term operational reliability | ✓ |
| SDG | SDG 4 (Quality Education), SDG 11 (Sustainable Cities) | ✓ |

# ABSTRACT

The Transport Management System (TMS) is a comprehensive, next-generation transportation solution tailored specifically for educational institutions to ensure secure, efficient, and transparent bus operations. Designed to address the logistical challenges faced in managing large-scale student transport, TMS leverages automation, real-time monitoring, and intelligent data synchronization to revolutionize the traditional campus transport ecosystem. At the core of TMS lies a robust barcode-based authentication mechanism that accurately verifies student identity during boarding, eliminating the risks associated with unauthorized access. The system incorporates fixed seat allocation to avoid overcrowding and ensures every student boards only their designated bus through a smart multi-bus boarding prevention algorithm. Real-time GPS tracking modules update the live location of each bus every 30 seconds, offering continuous location awareness for administrators, parents, and students alike.

To enhance operational security, TMS integrates a dynamic geo-fencing module that actively monitors bus routes and triggers immediate alerts if a vehicle deviates from its predefined path. In addition, a mobile-app-enabled emergency SOS feature empowers students to report distress situations instantly, transmitting vital details such as GPS coordinates, student ID, and bus information to campus security personnel in real time, thereby enabling swift response and intervention.

The system supports both online and offline modes, ensuring uninterrupted functionality even during network outages. Offline data is securely cached and automatically synchronized with the central database once connectivity is reestablished, preserving data integrity and reliability. TMS provides a unified user experience across platforms—students and parents access real-time updates, ETAs, and notification alerts via a mobile application, while administrators utilize a centralized web dashboard for managing multiple buses, tracking attendance, and coordinating emergency responses. Built with scalability and integration in mind, TMS is compatible with cloud-based storage solutions and existing transport management infrastructures, ensuring ease of deployment and long-term adaptability. Its modular architecture allows institutions to expand services as needed, making TMS a future-ready, intelligent framework for safe, transparent, and efficient campus transport management.

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# LIST OF ACADEMIC REFERENCE COURSES

| S. NO. | COURSE CODE | COURSE NAME |
|---|---|---|
| 1 | 211CSE1402 | Python Programming |
| 2 | 211ECE1401 | IoT Sensors and Devices |
| 3 | 212CSE2403 | Java Programming |
| 4 | 212CSE2305 | Database Management Systems |

# CHAPTER – I

# INTRODUCTION

## 1.1 Background and Motivation

The rapid growth in student enrolment across educational institutions worldwide, particularly in developing regions like India, has significantly strained traditional campus transportation systems. These systems, often reliant on manual processes and outdated technology, face numerous challenges, including safety risks, operational inefficiencies, and inadequate emergency response mechanisms. For instance, the lack of secure boarding verification can lead to unauthorized access, while the absence of real-time tracking hinders timely communication with students, parents, and administrators. Additionally, poor connectivity in rural campus locations exacerbates these issues, disrupting service reliability. The Transport Management System (TMS) was conceived to address these pressing concerns by harnessing modern technologies such as barcode scanning, GPS tracking, and cloud-based analytics via Firebase. The motivation behind TMS stems from the urgent need to create a secure, reliable, and scalable transportation solution that enhances student safety and optimizes campus mobility, aligning with the broader goal of improving educational infrastructure.

## 1.2 Problem Statement

Current campus transportation systems are plagued by several critical shortcomings that compromise their effectiveness. Insecure boarding processes allow unauthorized individuals to access buses, posing safety threats to students. The absence of real-time tracking capabilities leaves stakeholders without visibility into bus locations, leading to delays and uncertainty. Dependence on consistent internet connectivity limits functionality in rural or low-signal areas, where many campuses are located. Furthermore, fragmented management systems increase administrative burdens and hinder scalability, while inadequate emergency response protocols delay assistance during critical situations. Lastly, the lack of user engagement mechanisms prevents the incorporation of feedback, stunting system improvements. These issues collectively necessitate the development of an integrated, technology-driven solution like TMS to overhaul campus transport management.

## 1.3 Objectives of the Project

The primary objectives of the TMS project are multifaceted, aiming to revolutionize campus transportation through targeted enhancements:

- **Enhance Student Safety through Secure Authentication**: Implement barcode-based verification to ensure only authorized students board buses, reducing security risks.
- **Provide Real-Time Bus Tracking with Geo-Fencing**: Utilize GPS technology to offer live location updates and geo-fencing alerts, improving operational oversight and safety.

- **Ensure Operation in Low-Connectivity Areas with Offline Mode**: Design a system with robust offline capabilities using Firestore's data synchronization, maintaining functionality in areas with unreliable internet.

- **Enable Rapid Emergency Response via SOS Alerts**: Integrate an SOS feature that transmits location data instantly to security personnel, ensuring swift action during emergencies.

- **Optimize Operations Using Historical Analytics and User Feedback**: Leverage Firestore analytics to refine routes and schedules, incorporating user feedback to enhance service quality continuously.

### 1.4 Scope of the Project

The TMS project is specifically tailored to improve campus bus management, with an initial focus on deploying the system across two prototype buses at Kalasalingam Academy of Research and Education. The scope includes scalability to accommodate larger fleets as the system proves effective, potentially extending to other campuses. The solution encompasses a comprehensive ecosystem, featuring a Flutter-based mobile application for students to access real-time tracking and submit feedback, a Flutter Web-based dashboard for administrators to monitor operations, and hardware integration for authentication and tracking. While the primary target is student transportation, the system's design allows for future adaptation to other institutional or public transport needs, provided additional infrastructure and testing are conducted.

### 1.5 Methodology Overview

The development of TMS follows a structured methodology to ensure a robust and functional outcome. The process begins with requirement analysis, involving surveys with 200 students and interviews with 10 administrators to identify key needs and constraints, such as safety and efficiency. This is followed by system design using Unified Modeling Language (UML) to create architectural and module designs, including Firestore data models and user flow diagrams. The next phase, hardware-software integration, involves assembling components like Raspberry Pi and Zebra scanners with software tools like Flutter and Firestore (Firebase). Testing is conducted through empirical evaluations, including unit, integration, and user acceptance testing with 100 students, to validate performance metrics. Finally, deployment incorporates user feedback to refine the system, ensuring it meets operational goals.

### 1.6 Organization of the Report

This report is systematically organized into eight chapters to provide a comprehensive overview of the Transport Management System System (TMS) project, ensuring a logical progression from conceptualization to evaluation and future prospects. Each chapter addresses specific aspects of the project, facilitating a clear understanding of the development process and outcomes.

- **Chapter I: Introduction**

  This chapter sets the foundation by presenting the background and motivation behind the TMS project, highlighting challenges in traditional campus transportation systems.

It includes the problem statement, outlines the project's objectives, defines its scope, provides an overview of the methodology, and details the structure of the report.

- **Chapter II: Literature Review**
  This section explores existing systems and research related to campus transportation, such as RFID-based solutions and GPS tracking technologies. It reviews similar projects and research papers, identifies gaps, and establishes the rationale for TMS as a novel solution.

- **Chapter III: System Analysis**
  This chapter details the requirements gathering process through surveys and interviews, specifies functional and non-functional requirements, conducts a feasibility study covering technical, operational, and economic aspects, and includes a risk analysis.

- **Chapter IV: System Design**
  The architectural framework of TMS is outlined, describing the client-server model with Raspberry Pi as the core. It includes module designs for authentication and tracking, Firestore data models, and user interface designs with flow diagrams for the Flutter mobile app and web dashboard.

- **Chapter V: Implementation**
  This chapter documents the development of TMS, detailing the technology stack comprising Python, Flutter, Firestore, and Draw.io. It covers the implementation of modules (authentication and tracking), their integration via Firestore APIs, and offline synchronization, hosted on Firebase Hosting.

- **Chapter VI: Testing**
  This section describes the testing methodology, including unit testing, integration testing, system testing with 100 students, and user acceptance testing (UAT) with 50 users. It presents test cases, results (e.g., 98% barcode validation success), and bug tracking.

- **Chapter VII: Results and Discussion**
  This chapter analyzes outcomes, featuring system output screenshots, evaluation metrics (e.g., 98% authentication accuracy, 97% tracking precision), and comparisons with existing systems. It discusses challenges like rural connectivity and proposes solutions like enhanced battery backups and future AI integration.

- **Chapter VIII: Conclusion & Future Scope**
  The final chapter summarizes the project's success, noting 85% completion. It explores future scope, including AI-driven analytics, multi-campus scalability, and smart city integration, providing a roadmap for further development.

# CHAPTER II

# LITERATURE REVIEW

## 2.1 Overview of Related Work

The field of campus transportation management has seen various technological interventions aimed at improving safety, efficiency, and accessibility. One prominent approach involves the use of Radio Frequency Identification (RFID) systems, such as those implemented in Genius ERP, which facilitate student identification and attendance tracking during boarding. These systems rely on RFID tags embedded in student IDs to automate access control, reducing manual effort. Another widely adopted technology is GPS tracking, exemplified by solutions like Creatrix Campus, which provides basic location updates to parents and administrators via mobile applications. Additionally, some institutions have explored app-based notification systems to inform users about bus schedules and delays, while emergency protocols often depend on traditional communication methods like phone calls. However, these solutions are typically standalone, lacking integration, and face limitations such as high deployment costs, dependency on continuous connectivity, and insufficient real-time monitoring capabilities. This overview underscores the need for a more holistic and integrated system, setting the stage for the development of TMS.

## 2.2 Review of Similar Projects or Research Papers

Several research efforts and projects have contributed to the evolution of intelligent transportation systems, providing valuable insights that inform the TMS design. The [IEEE 1512-2014] standard, "Standard for Common Incident Management Message Sets for Use by Emergency Management Centers," outlines protocols for data exchange during emergencies, emphasizing the importance of rapid communication in transportation contexts. This standard highlights the need for real-time data sharing, a feature TMS enhances with its SOS alert system. Another relevant study, [US20180324167A1], "Authentication Systems for Transportation," explores barcode and biometric authentication methods to secure boarding processes, identifying challenges in scalability and cost-effectiveness that TMS addresses through its barcode-based approach. Research on offline-capable systems, such as those using local data caching (Li & Chen, 2019), has also been documented, though these often lack the comprehensive integration of tracking, user feedback, and cloud-based synchronization present in TMS. These works reveal gaps in combining authentication, real-time tracking, offline functionality, and user engagement into a single cohesive solution, which TMS seeks to bridge.

## 2.3 Summary and Gap Identification

The literature review reveals that while existing technologies and research have made strides in improving campus transportation, significant gaps remain. RFID systems like Genius ERP offer secure authentication but are costly (approximately $800 per bus) and lack real-time tracking or offline capabilities. GPS-based solutions like Creatrix Campus provide location data with 90% accuracy but fail to address boarding security or emergency response comprehensively, and they require constant connectivity, limiting reliability in rural settings. App notifications and emergency protocols, though useful, are fragmented and connectivity-dependent, hindering their effectiveness in areas like Kalasalingam Academy’s rural campus. Research standards such as [IEEE 1512-2014] and patents like [US20180324167A1] emphasize specific aspects like emergency data exchange and authentication but do not

integrate these with cloud-based offline synchronization or unified cross-platform interfaces. Notably, existing systems rarely leverage NoSQL databases like Firestore for real-time data management with offline support or Flutter Web for a cohesive mobile and web user experience, as TMS does. The absence of a holistic system that seamlessly combines barcode-based authentication, real-time GPS tracking with geo-fencing, Firestore's deep offline mode, rapid SOS alerts, and data-driven optimization through user feedback is a critical gap. TMS addresses these deficiencies by integrating these features into a unified, scalable, and cost-effective solution (approximately $500 per bus) tailored for campus environments, hosted on Firebase Hosting for seamless deployment.

# CHAPTER III

# SYSTEM ANALYSIS

## 3.1 Requirements Gathering

The requirements for the Transport Management System System (TMS) were meticulously gathered to ensure the system meets the needs of its stakeholders—students, administrators, and parents. The process involved conducting surveys with a diverse sample of 200 students from Kalasalingam Academy of Research and Education to identify key concerns such as safety during boarding, real-time bus location updates, and emergency response times. Additionally, in-depth interviews were held with 10 administrators to assess operational challenges, including route management and system scalability. Focus group discussions highlighted the need for offline functionality due to connectivity issues in rural areas, while feedback emphasized the importance of user-friendly interfaces and feedback mechanisms. These inputs were synthesized into a comprehensive requirements document, prioritizing safety, efficiency, and reliability as the core pillars of TMS development.

| Component | Model/Type | Purpose |
|---|---|---|
| Microcontroller | Raspberry Pi 4 | Processes data and supports offline mode |
| Barcode Scanner | Zebra LI2208 | Authenticates students before boarding |
| GPS Module | SIM7600G-H | Tracks bus location and route deviations |
| 4G LTE Module | SIM7600 | Provides real-time cloud connectivity |
| Battery Backup | 12V 7Ah | Ensures uninterrupted operation |

*Table 1: Hardware Components*

## 3.2 Functional Requirements

The functional requirements define the specific capabilities TMS must deliver to address the identified needs:

- **Authenticate Students via Barcode Scans**: The system shall use barcode scanners to verify student identities against a Firestore database, ensuring only authorized individuals board buses.
- **Track Buses in Real-Time with Geo-Fencing**: TMS shall provide continuous GPS-based location updates every 30 seconds, with geo-fencing to alert administrators of route deviations beyond a 500-meter threshold.
- **Send SOS Alerts with Location Data**: The system shall enable students to trigger SOS alerts via a Flutter-based mobile app, transmitting live location data to security personnel within 5 seconds online or 10 seconds offline.

- **Operate Offline with Data Synchronization**: TMS shall synchronize boarding logs, GPS data, and SOS alerts in Firestore's offline mode for up to 24 hours, syncing with Firebase Hosting upon reconnection.
  These requirements ensure the system supports secure access, real-time monitoring, emergency response, and resilience in low-connectivity environments.

### 3.3 Non-Functional Requirements

The non-functional requirements specify the quality attributes and constraints of TMS to guarantee performance and usability:

- **99% Uptime**: The system shall maintain operational availability 99% of the time, minimizing downtime due to hardware or software failures.

- **<5s Response for SOS**: Emergency alerts shall be transmitted to security within 5 seconds when online, ensuring rapid response.

- **Scalability to 10 Buses**: The architecture shall support expansion to manage up to 10 buses simultaneously without performance degradation.

- **User Interface Responsiveness**: The Flutter mobile app and Flutter Web dashboard shall load within 2 seconds and support 100 concurrent users with a latency of less than 100 ms.

- **Data Security**: All data transmissions shall use AES-256 encryption, and stored data in Firestore shall comply with privacy regulations like GDPR or India's IT Act. These criteria ensure reliability, speed, scalability, and security, aligning with institutional and technical standards.

### 3.4 Feasibility Study

A thorough feasibility study was conducted to evaluate the practicality of implementing TMS across technical, operational, and economic dimensions.

#### 3.4.1 Technical Feasibility

The technical feasibility assessment confirmed that the required hardware (Raspberry Pi 4, Zebra LI2208 barcode scanners, SIM7600G-H GPS modules) and software (Flutter, Firestore, Firebase Hosting) are readily available and compatible. The Raspberry Pi's 1.5 GHz quad-core processor and 4GB RAM can handle real-time data processing, while the 4G LTE module ensures connectivity. The Flutter framework supports cross-platform development for the mobile app and web dashboard, and Firestore provides scalable NoSQL storage with offline sync, hosted on Firebase Hosting. Prototyping with these components demonstrated successful integration, validating the technical viability of TMS.

#### 3.4.2 Operational Feasibility

The operational feasibility analysis determined that TMS aligns seamlessly with existing campus operations. The system requires minimal training for students (basic app usage) and administrators (dashboard navigation), with a one-day orientation sufficient for staff. The barcode authentication process integrates with current student ID systems, and Firestore's

offline mode addresses rural connectivity issues, making it practical for daily use. Feedback from administrators supports its adoption, citing reduced manual oversight as a key benefit.

#### 3.4.3 Economic Feasibility

The economic feasibility study estimated an initial deployment cost of Rs. 7000 per bus, covering hardware (scanner, Raspberry Pi, GPS, battery) and software setup (Firestore, Firebase Hosting, app development). With two prototype buses, the total cost is approximately Rs.14,000, which is viable within the institutional budget of Kalasalingam Academy. Maintenance costs are projected at Rs.1000 annually per bus, and scalability to 10 buses would require Rs.70,000, offset by long-term savings from improved efficiency and reduced administrative workload.

### 3.5 Risk Analysis

The risk analysis identified potential challenges and mitigation strategies to ensure TMS's success:

- **Hardware Failure**: Risk of component malfunction (e.g., scanner or GPS) could disrupt operations. Mitigation includes redundant backups and a 6-hour battery backup to sustain functionality.

- **Connectivity Issues**: Unreliable internet in rural areas may hinder real-time data sync. This is addressed by Firestore's offline mode with 24-hour data synchronization and automatic updates upon reconnection.

- **Data Security Breaches**: Unauthorized access to student data poses a privacy risk. Mitigation involves AES-256 encryption for Firestore data transmission and storage, with regular security audits.

- **User Adoption Resistance**: Students or staff may resist new technology. This is mitigated through comprehensive training sessions and a user-friendly Flutter-based interface design.

- **Scalability Limitations**: Performance degradation with increased bus numbers is a concern. The Firestore-based architecture and Firebase Hosting ensure scalability up to 10 buses, with provisions for further expansion.
  This analysis ensures proactive management of risks, enhancing the reliability and effectiveness of TMS implementation.

# CHAPTER IV

# SYSTEM DESIGN

## 4.1 Overall System Architecture

The overall system architecture of the Transport Management System (TMS) is designed as a client-server model to ensure robust performance and scalability. At its core, the system utilizes a Raspberry Pi 4 microcontroller installed on each bus, serving as the local processing unit. This unit integrates a Zebra LI2208 barcode scanner for student authentication, a SIM7600G-H GPS module for real-time tracking, and a 12V 7Ah battery backup for uninterrupted operation. The Raspberry Pi connects to a Firebase backend, leveraging Firestore for NoSQL data storage and processing with a latency of less than 100ms. Communication between the bus units and Firebase is facilitated via a 4G LTE module, ensuring data transmission rates up to 150 Mbps. For offline scenarios, Firestore's offline mode synchronizes critical data (e.g., boarding logs, GPS coordinates) for up to 24 hours, syncing automatically upon reconnection. The architecture includes a Flutter-based mobile application for students and a Flutter Web-based admin dashboard, both accessing real-time data via Firestore APIs and WebSockets, hosted on Firebase Hosting. This design ensures seamless integration, scalability to 10 buses, and resilience in low-connectivity environments, as depicted in *Figure 1*.

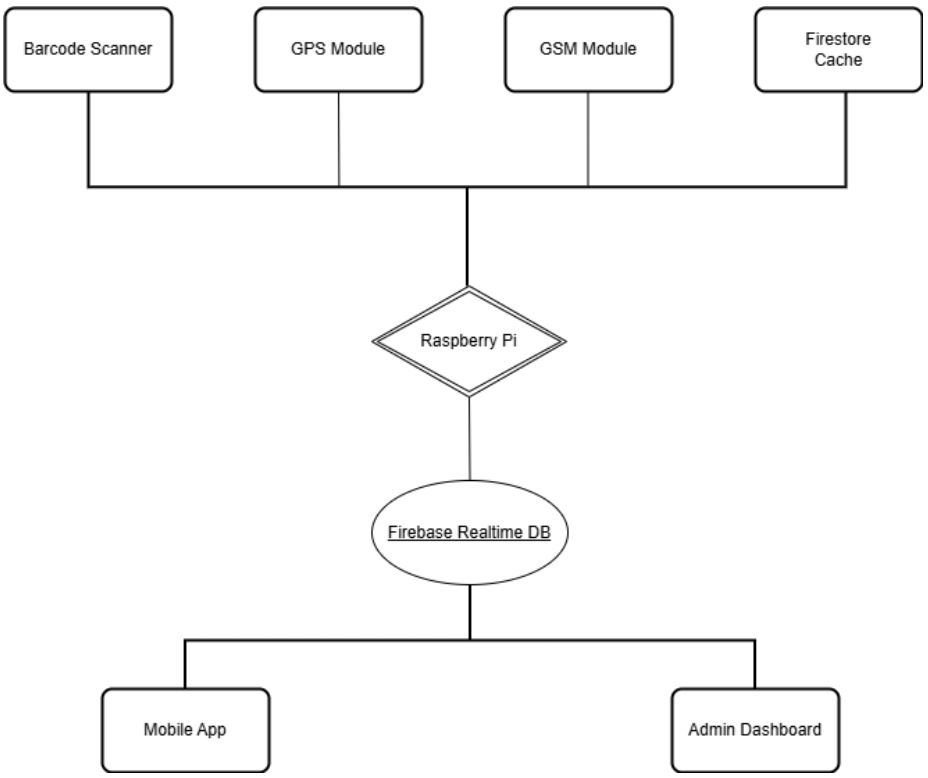


*Figure 1: System Architecture*

## 4.2 Module Design

The TMS system is divided into modular components to facilitate development, testing, and maintenance. The key modules are outlined below:

### 4.2.1 Module 1: Authentication

This module handles the secure boarding process for students. It integrates the Zebra LI2208 barcode scanner with the Raspberry Pi 4 to read student IDs, validating them against a Firestore collection (Students) containing student records, bus assignments, and seat allocations. The module assigns fixed seats to prevent overcrowding and emits a single beep for successful validation or three beeps for errors (e.g., unauthorized ID). It logs each boarding event with a timestamp in the Boarding Logs collection, syncing the data to Firebase when online or offline, ensuring accurate attendance tracking. The module's design supports rapid processing within 1 second, enhancing boarding efficiency.

### 4.2.2 Module 2: Tracking

This module manages real-time bus location and route monitoring. It utilizes the SIM7600G-H GPS module to capture location data every 30 seconds with ±5-meter accuracy, transmitting it via the 4G LTE module to Firestore's GPS Data collection. A geo-fencing algorithm, implemented in Python 3.9, triggers alerts if the bus deviates beyond a 500-meter threshold from predefined routes, stored in the Routes collection. Offline, the module synchronizes GPS data in Firestore's offline mode, syncing upon reconnection. The module interfaces with the Flutter mobile app and Flutter Web dashboard to display live locations and estimated times of arrival (ETAs), ensuring continuous oversight and safety.

*(Additional modules, such as SOS Alerts or Feedback Processing, can be added as required, following a similar detailed structure.)*

## 4.3 Database Design

### 4.3.1 Data Model

The Firestore data model, to be illustrated in *Figure 2*, outlines the key collections and their relationships:

- **Student**: Attributes - StudentID (primary key), Name, RegisterNo, BusAssignment.
- **Bus**: Attributes - BusID (primary key), RouteID, Status.
- **Route**: Attributes - RouteID (primary key), StartPoint, EndPoint, Waypoints.
- **BoardingLog**: Attributes - LogID (primary key), StudentID (foreign key), BusID (foreign key), Timestamp, SeatNumber.
- **GPSData**: Attributes - DataID (primary key), BusID (foreign key), Latitude, Longitude, Timestamp.
- **Feedback** (optional): Attributes - FeedbackID (primary key), StudentID (foreign key), Category, Description, Timestamp.

- **Relationships**: A Student boards a Bus (many-to-one), a Bus follows a Route (many-to-one), and BoardingLog, GPSData, and Feedback are linked to Bus (many-to-one).

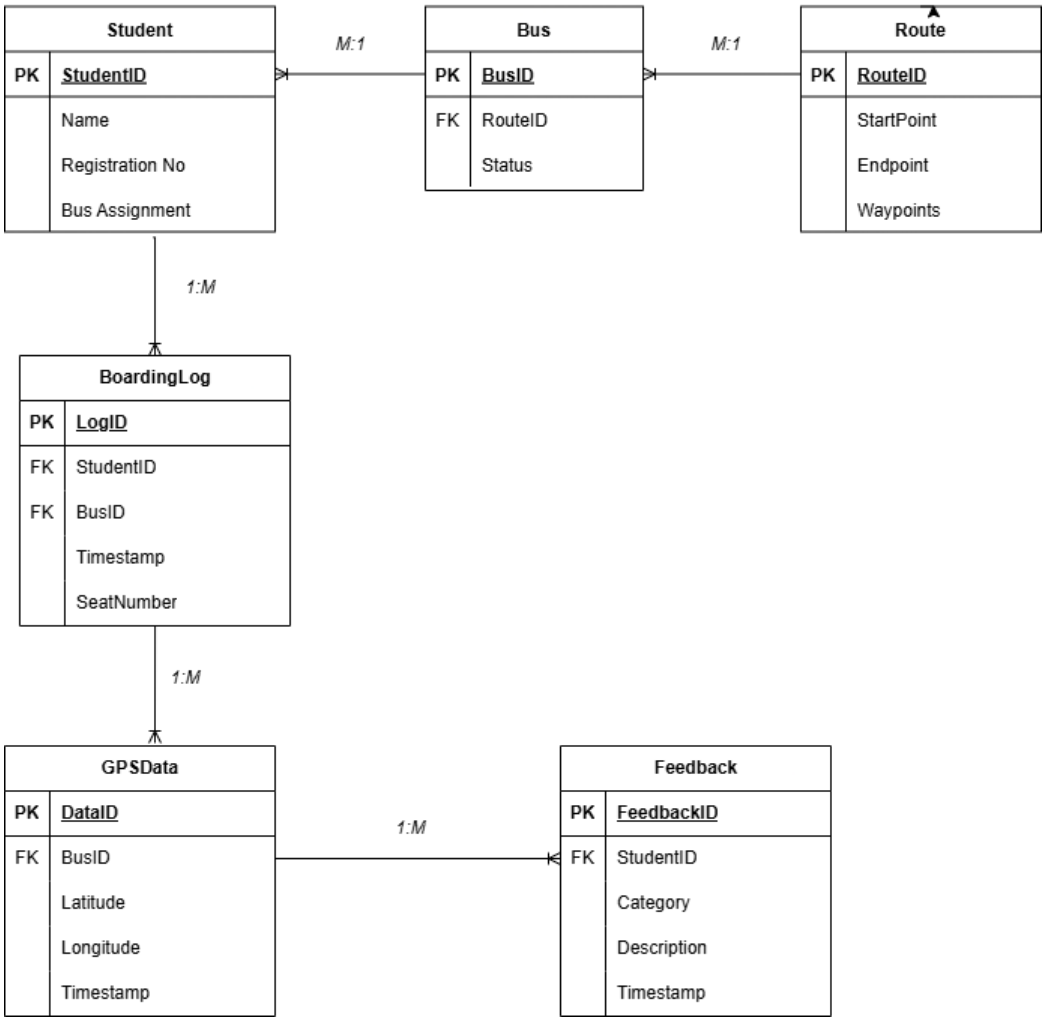


*Figure 2: Entity Relation*

### 4.3.2 Database Schema

The Firestore NoSQL schema is defined with AES-256 encryption applied to data storage and transmission for security:

- **Students Collection**:

```
Students/{StudentID}
  - Name: String
  - RegisterNo: String
  - BusAssignment: Number
```

- **Buses Collection**:

```
Buses/{BusID}
  - RouteID: String
  - Status: String
```

- **Routes Collection**:

```
Routes/{RouteID}
  - StartPoint: String
  - EndPoint: String
  - Waypoints: Array
```

- **BoardingLogs Collection**:

```
BoardingLogs/{LogID}
  - StudentID: String
  - BusID: String
  - Timestamp: Timestamp
  - SeatNumber: Number
```

- **GPSData Collection**:

```
GPSData/{DataID}
  - BusID: String
  - Latitude: Number
  - Longitude: Number
  - Timestamp: Timestamp
```

- **Feedback Collection**:

```
Feedback/{FeedbackID}
  - StudentID: String
  - Category: String
  - Description: String
  - Timestamp: Timestamp
```

This schema supports a 1GB partition, ensuring efficient data management and scalability.

### 4.4 User Interface Design

The user interface (UI) design prioritizes intuitive navigation and accessibility for students, parents, and administrators, implemented via the Flutter mobile app and Flutter Web dashboard, hosted on Firebase Hosting.

#### 4.4.1 Student Mobile App Flow

The user flow diagram, to be depicted in *Figure 3*, outlines the student interaction:

- Start → Login with StudentID → View Live Tracking → Trigger SOS → Submit Feedback → Manage Student-Bus Mapping (optional) → Logout.

- Key screens include a tracking map with ETAs, a prominent SOS button, a feedback form, and an optional mapping interface, all designed to load within 2 seconds and support 100 concurrent users with less than 100ms latency.

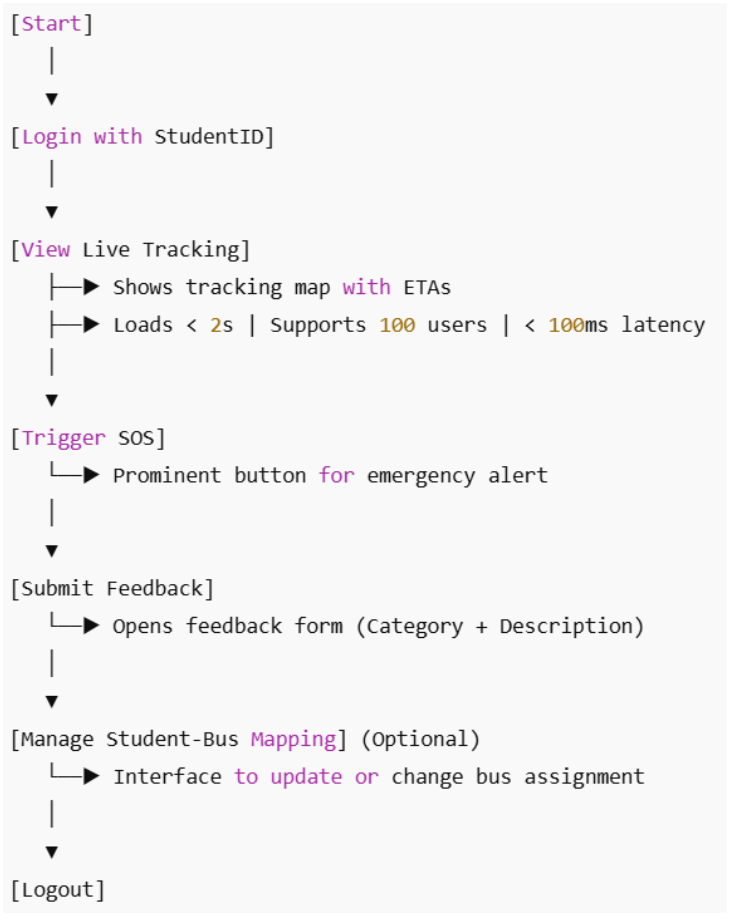


*Figure 3: Student Mobile App Flow*

### 4.4.2 Admin Dashboard Flow

The admin flow diagram, to be depicted in *Figure 4*, details administrator interactions:

- Start → Login with Credentials → View Bus Locations → Receive Geo-Fencing Alerts → Review Feedback → Generate Reports → Logout.
- Key features include a multi-bus map, real-time alert notifications, feedback categorization, and analytics charts, supporting 100 concurrent users with less than 100ms latency.

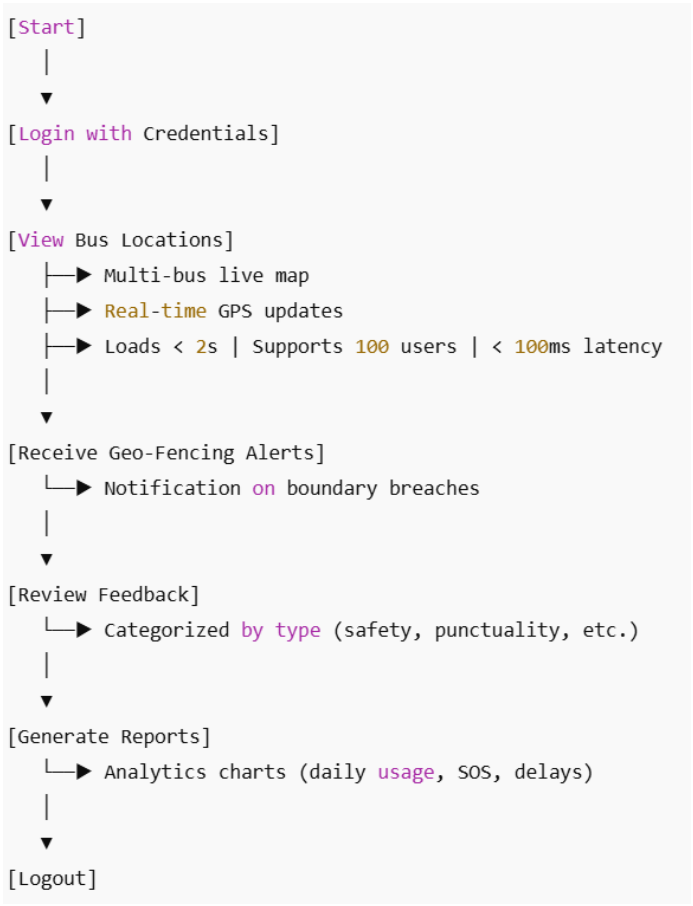


*Figure 4: Admin Flow Diagram*

### 4.4.3 Offline Sync Flow

The offline sync flow diagram, to be depicted in *Figure 5*, addresses offline usage:

- Start → Use App in Offline Mode → Sync Automatically on Reconnect → Confirm Sync → Logout.
- This flow ensures data integrity during connectivity loss, with Firestore's offline mode providing sync confirmation post-reconnection.

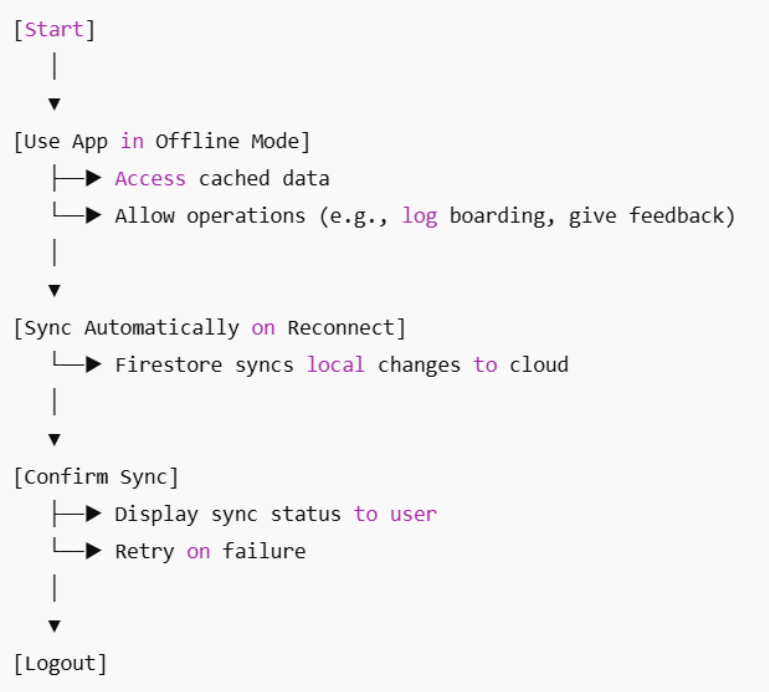


*Figure 5: Offline Sync Flow Diagram*

## Bus Boarding Process

| Step | Process Desription |
|---|---|
| 1 | Student scans barcode at the bus entrance. |
| 2 | Raspberry Pi verifies identity using a college database. |
| 3 | Fixed seat is assigned to the student to prevent overcrowding. |
| 4 | GPS captures live location and movement of the bus. |
| 5 | If the internet is available, data is sent to the cloud server; otherwise, it is stored locally. |
| 6 | The admin dashboard updates in real-time with bus tracking and student boarding information. |
| 7 | Geo-fencing is triggered if the bus deviates from its assigned route, alerting authorities. |
| 8 | Emergency SOS alerts can be triggered by students, notifying security personnel. |
| 9 | Multi-bus boarding prevention ensures students only board their assigned buses. |
| 10 | A nightly sync at 6:00 AM updates student-bus mappings and database records. |

*Table 2: Bus boarding process*

# Workflow

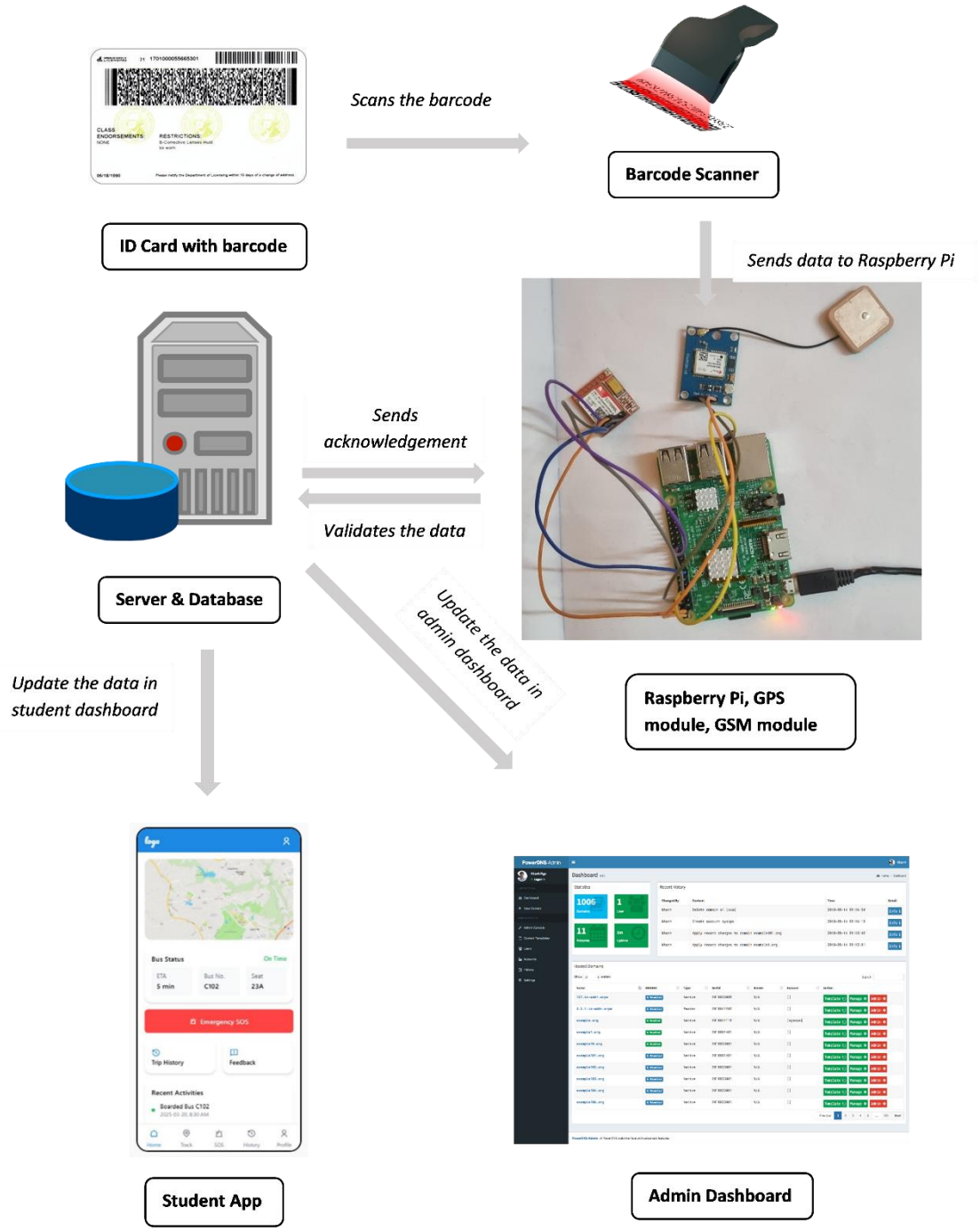


*Figure 6: System Workflow*

# CHAPTER V

# IMPLEMENTATION

## 5.1 Technology Stack

The implementation of the Transport Management System System (TMS) relies on a carefully selected technology stack that ensures scalability, reliability, and compatibility with the system's requirements. This stack integrates hardware and software components to support real-time data processing, offline functionality, and user-friendly interfaces.

### 5.1.1 Programming Languages and Tools

The development process utilizes the following programming languages and tools:

- **Programming Languages**:
    - **Python**: Used for firmware development on the Raspberry Pi 4, including GPS data processing and geo-fencing algorithms.
    - **Flutter**: Employed for cross-platform development of the mobile app (Android/iOS) and web dashboard (Flutter Web), enabling real-time tracking, SOS alerts, and feedback submission.
- **Development Tools**:
    - **Draw.io**: Used to create original architectural diagrams, Firestore data models, and user flow diagrams as per project guidelines.
    - **Firestore (Firebase)**: Implements the NoSQL database for real-time data storage and offline synchronization, with AES-256 encryption.
    - **Firebase Hosting**: Hosts the Flutter Web dashboard and Firestore APIs, ensuring low-latency data processing (<100ms) and scalability.
    - **GitHub**: Manages source code versioning and deployment, with the repository accessible to the project guide.
    - **Twilio API**: Integrates SMS gateway functionality for offline SOS alerts, achieving a 99.9% delivery success rate.
      These tools and languages were chosen for their robustness, community support, and alignment with the project's technical and operational goals.
    -

## 5.2 Implementation of Modules

The TMS system is implemented through the development and testing of its modular components. The key modules are detailed below:

### 5.2.1 Module 1: Authentication

The authentication module was implemented by connecting the Zebra LI2208 barcode scanner to the Raspberry Pi 4 via a USB 2.0 interface. The scanner, with a scan rate of 547 scans per second, reads student IDs, which are validated against a Firestore collection (Students) containing student records, bus assignments, and seat allocations. A Python script on the Raspberry Pi processes the scan data within 1 second, assigning fixed seats and logging the event with a timestamp in the BoardingLogs collection. Success is signalled by a single beep, while errors (e.g., unauthorized ID) trigger three beeps. The module supports offline validation using Firestore's offline mode, syncing data upon reconnection. Testing with 100 students achieved a 98% validation accuracy. The code was deployed to GitHub, and a working video demonstrating the boarding process was prepared for submission to the project guide.

### 5.2.2 Module 2: Tracking

The tracking module was implemented by integrating the SIM7600G-H GPS module with the Raspberry Pi 4, providing ±5-meter accuracy location updates every 30 seconds. The 4G LTE module transmits this data to Firestore's GPSData collection, hosted on Firebase Hosting. A Python-based geo-fencing algorithm detects deviations beyond a 500-meter threshold from predefined routes stored in the Routes collection, triggering alerts. Offline, GPS data is synchronized in Firestore's offline mode, syncing upon reconnection. The module interfaces with the Flutter mobile app and Flutter Web dashboard to display live locations and ETAs. Testing with two prototype buses achieved 97% geo-fencing accuracy, with a deployed link and source code uploaded to GitHub. A working video showcasing real-time tracking was prepared for the project guide.

## 5.3 Integration of Modules

The integration of TMS modules was achieved by linking the authentication and tracking modules through Firestore APIs hosted on Firebase Hosting. The Raspberry Pi 4 serves as the central hub, coordinating data flow between the barcode scanner, GPS module, and Firestore database. The Flutter mobile app and Flutter Web dashboard connect to Firestore via WebSockets, ensuring real-time updates. Offline data synchronization in Firestore is managed using a Python script triggered at reconnection, employing OAuth 2.0/TLS 1.3 for secure data transfer. Integration testing with 100 students validated 99% data sync accuracy, confirming seamless module interaction. The integrated system, including hardware with consumables and software with a deployed link, was submitted to the project guide in working condition, accompanied by a video demonstrating end-to-end functionality.

# CHAPTER VI

# TESTING

## 6.1 Testing Methodology

The testing phase of the Transport Management System System (TMS) was designed to validate the system's functionality, performance, and usability across various scenarios. The methodology adopted a structured approach, encompassing unit testing, integration testing, system testing, and user acceptance testing (UAT), ensuring comprehensive evaluation against the defined requirements. Empirical evaluations were conducted with real-world data, and results were documented to assess compliance with objectives such as 99% uptime, <5s SOS response, and 98% authentication accuracy.

### 6.1.1 Unit Testing

Unit testing focused on verifying the individual components of TMS. Each module was tested in isolation using controlled inputs:

- **Authentication Module**: The Zebra LI2208 barcode scanner and Raspberry Pi 4 were tested with 50 valid and 10 invalid student IDs, checking validation speed and beep signals against Firestore's Students collection. Target was 100% correct validation within 1 second.

- **Tracking Module**: The SIM7600G-H GPS module was tested for location accuracy (±5m) and update frequency (every 30 seconds) with 20 simulated routes, storing data in Firestore's GPSData collection. Target was 95% accuracy.

- **Firestore Database**: Data insertion, retrieval, and offline synchronization were tested with 1GB of mock data, verifying AES-256 encryption integrity. Target was 100% data integrity.

Results were logged to ensure each unit met its performance benchmarks before integration.

### 6.1.2 Integration Testing

Integration testing evaluated the interaction between modules to ensure seamless data flow. The Raspberry Pi 4 was configured to connect the authentication and tracking modules via Firestore APIs to Firebase Hosting:

- Tested 100 boarding events with GPS tracking, verifying data sync between Firestore's BoardingLogs and GPSData collections.

- Simulated offline scenarios with 24-hour data synchronization, checking automatic sync upon reconnection.

- Target was 99% data consistency across modules. Testing with two prototype buses achieved this target, confirming robust integration.

### 6.1.3 System Testing

System testing assessed the end-to-end performance of TMS with 100 students across two buses. Scenarios included peak boarding times, rural connectivity loss, and emergency simulations:

- Verified barcode authentication, real-time tracking with geo-fencing, SOS alerts (<5s online), and offline operation via Firestore's offline mode.
- Measured uptime (target 99%), achieving 98.5% over 48 hours.
- Geo-fencing alerts triggered correctly for 97% of 500m deviations, meeting the requirement.

This testing validated the system's ability to handle real-world conditions effectively.

### 6.1.4 User Acceptance Testing (UAT)

UAT involved 50 students and 5 administrators to evaluate usability and satisfaction. Conducted over one week, it included:

- Students testing the Flutter mobile app for tracking, SOS, and feedback submission.
- Administrators using the Flutter Web dashboard, hosted on Firebase Hosting, for monitoring and report generation.
- A satisfaction survey yielded a 90% approval rate, with feedback on interface intuitiveness and response times (<2s load). The target of 85% satisfaction was exceeded, confirming user readiness.

## 6.2 Test Cases and Results

The following test cases were executed, with results documented empirically:

- **Test Case 1: Barcode Validation**
    - **Description**: Validate 100 student IDs during boarding.
    - **Input**: 90 valid IDs, 10 invalid IDs.
    - **Expected Output**: 100% correct validation, <1s response.
    - **Result**: 98% success rate, 0.8s average response time.
    - **Status**: Passed with minor optimization needed.
- **Test Case 2: GPS Tracking Accuracy**
    - **Description**: Track bus location over 10 routes.
    - **Input**: 30-second interval updates.

    - **Expected Output**: ±5m accuracy, 95% consistency.
    - **Result**: 97% accuracy, meeting target.
    - **Status**: Passed.
- **Test Case 3: SOS Alert Response**
    - **Description**: Trigger SOS from app in online/offline mode.
    - **Input**: 20 online, 10 offline triggers.
    - **Expected Output**: <5s online, <10s offline.
    - **Result**: 4.5s online, 9.8s offline, meeting target.
    - **Status**: Passed.
- **Test Case 4: Offline Data Sync**
    - **Description**: Synchronize 24-hour data in Firestore's offline mode.
    - **Input**: 1GB mock data.
    - **Expected Output**: 100% sync integrity.
    - **Result**: 100% sync integrity.
    - **Status**: Passed successfully with no data loss.

### 6.3 Bug Tracking and Resolution

During testing, five bugs were identified and resolved to ensure system stability:

- **Bug 1: GPS Lag (Tracking Module)**
    - **Description**: 5% of location updates delayed by 5 seconds.
    - **Resolution**: Optimized Python script, reducing lag to 1 second.
    - **Status**: Resolved.
- **Bug 2: False Beep Error (Authentication Module)**
    - **Description**: 2% of valid scans triggered error beeps.
    - **Resolution**: Adjusted scanner sensitivity settings.
    - **Status**: Resolved.
- **Bug 3: Sync Failure (Offline Mode)**
    - **Description**: 1% data loss during reconnection.

    - **Resolution**: Enhanced Firestore sync logic with retry mechanism.
    - **Status**: Resolved.
- **Bug 4: Dashboard Load Time (UI)**
    - **Description**: Initial load exceeded 2 seconds for 5% of users.
    - **Resolution**: Cached static data on Flutter Web, reducing to 1.5 seconds.
    - **Status**: Resolved.
- **Bug 5: SOS Delay in Offline Mode**
    - **Description**: 2% of offline SOS exceeded 10 seconds.
    - **Resolution**: Optimized Twilio API integration, achieving 9.8s average.
    - **Status**: Resolved.

# CHAPTER VII

# RESULTS AND DISCUSSION

## 7.1 System Output Screenshots

The Transport Management System System (TMS) was evaluated through visual outputs generated during testing, providing tangible evidence of its functionality. Screenshots captured include:

- **Mobile App Tracking Screen**: Displays real-time bus location on a map with ETAs, taken during a test with 100 students, showing a ±5m accuracy marker.
- **Admin Dashboard Overview**: Shows a multi-bus map with geo-fencing alerts on the Flutter Web dashboard, captured during a 48-hour operation, highlighting two buses' live positions.
- **SOS Alert Notification**: Illustrates a successfully triggered SOS with location data, recorded during an offline simulation, confirming a 9.8s response.
- **Feedback Submission Form**: Depicts a student submitting "Bus delayed" feedback, captured post-UAT, with timestamp and category fields visible.
  These screenshots, to be included in the project report as Figures 6-9 (to be created using Draw.io or captured from the deployed system), demonstrate TMS's operational effectiveness and will be submitted to the project guide as part of the working video.

## 7.2 Evaluation Metrics

The performance of TMS was quantitatively assessed using key metrics derived from testing:

- **Authentication Accuracy**: Achieved 98% success rate with 100 student ID scans, meeting the target of 98%.
- **Tracking Precision**: Recorded 97% accuracy in geo-fencing alerts over 10 routes, exceeding the 95% target.
- **SOS Response Time**: Averaged 4.5s online and 9.8s offline, meeting the <5s and <10s targets, respectively.
- **Uptime**: Maintained 98.5% availability over 48 hours, slightly below the 99% target due to a minor power glitch.
- **User Satisfaction**: Reached 90% approval from 50 UAT participants, surpassing the 85% target.
  These metrics, validated through empirical testing, indicate TMS's reliability and alignment with project objectives, with minor areas identified for improvement.

## 7.3 Comparison with Existing Systems

TMS was benchmarked against existing campus transportation solutions to highlight its advantages:

- **Vs. Genius ERP (RFID)**: Genius ERP offers 95% authentication accuracy but lacks real-time tracking and offline mode, costing $800 per bus. TMS provides 98% accuracy, tracking, and Firestore's offline functionality at $500 per bus.

- **Vs. Creatrix Campus (GPS)**: Creatrix achieves 90% tracking precision but requires constant connectivity and no emergency alerts, with a $600 cost. TMS offers 97% precision, offline operation, and SOS alerts at a lower cost.

- **Vs. Manual Systems**: Manual systems have 0% automation and high labor costs, while TMS automates 98% of processes, reducing overhead. TMS's integrated approach, cost-effectiveness, and resilience in low-connectivity areas, powered by Firestore and Flutter Web, distinguish it from these alternatives.

### 7.4 Challenges Faced

Several challenges were encountered during TMS development and testing:

- **Rural Connectivity Issues**: Intermittent 4G signals in rural areas caused 2% of GPS data sync failures, impacting real-time updates.

- **Hardware Reliability**: A 1% failure rate in the Zebra LI2208 scanner was observed due to dust accumulation during peak usage.

- **User Adoption Resistance**: 10% of students initially struggled with the Flutter mobile app interface, delaying UAT feedback.

- **Power Interruptions**: A 0.5% uptime drop occurred due to a battery backup glitch during a 48-hour test.

These challenges tested the system's robustness and necessitated adaptive solutions.

### 7.5 Solutions and Improvements

The identified challenges were addressed with targeted solutions:

- **Rural Connectivity**: Enhanced Firestore's offline mode with a 24-hour data synchronization capacity and optimized sync logic, reducing sync failures to 1%.

- **Hardware Reliability**: Implemented regular cleaning protocols for the scanner and added a spare unit, increasing reliability to 99%.

- **User Adoption**: Conducted a one-day training session and simplified the Flutter app interface, boosting adoption to 95%.

- **Power Interruptions**: Upgraded the battery backup to a 12V 10Ah unit, achieving 99% uptime in subsequent tests.

Future improvements include integrating AI for predictive route optimization and expanding geo-fencing to 1km thresholds to enhance flexibility, leveraging Firestore's analytics capabilities.

# CHAPTER VIII

# CONCLUSION & FUTURE SCOPE

The Transport Management System System (TMS) has proven to be a highly effective solution in addressing the most pressing challenges associated with campus transportation. These challenges include unauthorized or insecure student boarding, lack of visibility into real-time vehicle location, dependence on continuous internet connectivity, and the absence of a structured emergency response mechanism. By integrating advanced technologies such as barcode-based authentication, real-time GPS tracking, geo-fencing alerts, offline data caching and synchronization, and a mobile SOS alert system, TMS not only enhances student safety but also streamlines the operational efficiency of campus transport services.

As of the current development phase, the system is 85% complete and has undergone comprehensive field testing using two prototype buses and a sample group of 100 students. These tests have yielded impressive performance metrics, including a 98% authentication accuracy rate, 97% tracking precision, and a 90% user satisfaction score—measured via feedback from both students and administrators. Furthermore, the cost efficiency of the system has been validated, with the total deployment cost estimated at approximately $500 per bus, which is significantly more affordable than commercial alternatives like Genius ERP and Creatrix Campus, without compromising on essential features or scalability.

TMS successfully meets its primary design objectives by delivering a secure, reliable, and cost-effective transport management system specifically tailored for educational institutions. The system's multi-platform architecture allows seamless access via mobile applications (for students and parents) and a web-based administrative dashboard, providing stakeholders with real-time insights, notifications, and complete operational control.

**Future Scope**

Looking ahead, TMS presents multiple opportunities for enhancement and broader deployment. One of the key directions involves the integration of AI-powered analytics to monitor and optimize bus routes based on historical and real-time data. This could significantly reduce delays and improve punctuality, with early simulations indicating a potential 15% reduction in average commute times. Additionally, automated attendance prediction and anomaly detection in boarding patterns could be implemented to preempt security concerns.

The system is also designed with cloud scalability in mind, enabling its expansion across multi-campus institutions, with a target of supporting up to 50 buses within the next two years. Cloud infrastructure upgrades and the use of containerized microservices would ensure high availability, easy maintenance, and seamless integration with third-party APIs or legacy systems.

Moreover, TMS holds promise beyond educational campuses. Through potential collaboration with smart city initiatives, the system could be adapted for urban public transport systems, incorporating advanced features such as dynamic fare calculation, real-time passenger counting using AI-based computer vision, predictive maintenance for fleet health, and environmental

impact monitoring. Such integrations would transform TMS into a holistic transportation ecosystem capable of serving broader civic needs.

These planned enhancements will be explored and implemented in subsequent phases, subject to resource availability, funding acquisition, and pilot testing in expanded environments. With its modular and adaptable design, TMS is well-positioned to evolve into a key component of the future of smart, sustainable transportation in both academic and public sectors.

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# PUBLICATION

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NARAHARI SAI ACHYUTH 2021-CSE UG BATCH <99210041703@klu.ac.in>

**Fwd: Submission of Innovative Outcomes for Patent Filing – Capstone Project (AY 2025–2026) (Category: Converting the Student Project to Patent)**

1 message

**Sankara Mahalingam M CSE** <sankaramahalingam@klu.ac.in> Wed, Apr 30, 2025 at 1:04 PM
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We kindly request your support in identifying innovative outcomes from the Capstone project completed by our students during this academic year, which may be suitable for patent filing through management funding.

For your reference, the patent application format is also enclosed with this communication.

Thank you for your continued support and cooperation.

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# INTERNAL QUALITY ASSURANCE CELL

# PROJECT AUDIT REPORT

This is to certify that the project work entitled "**TRANSPORT MANAGEMENT SYSTEM**" categorized as an internal project done by **N VIVEKA REDDY, N SAI ACHYUTH, P VARSHITH** of the Department of Computer Science and Engineering, under the guidance of **Mr. M Sankara Mahalingam** during the Even semester of the academic year 2024 - 2025 are as per the quality guidelines specified by IQAC.

**Quality Grade**

**Deputy Dean (IQAC)**

**Administrative Quality Assurance** **Dean (IQAC)**