# MODERNIZING PUBLIC TRANSPORT: PMPML BUS APP

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***Abstract*— The increasing urbanization of cities such as Pune has placed significant pressure on public transportation systems to evolve and meet the growing demands of efficiency, safety, and user satisfaction. This research focuses on modernizing the Pune Mahanagar Parivahan Mahamandal Limited (PMPML) bus system through the development of a comprehensive mobile application designed to address existing challenges such as route inefficiency, unpredictable schedules, overcrowding, and inadequate safety measures. The proposed application leverages advanced GPS technology to enable real-time bus tracking, enhance commuter visibility, and incorporate features such as accident detection and alarm systems. These safety mechanisms alert both authorities and users through the application in the event of an emergency, ensuring timely interventions.**

***Additionally, the system includes a specialized "Soldier Tracking System" to monitor buses carrying personnel or sensitive cargo, providing heightened security and transparency. Other features such as AI-driven route optimization, digital ticketing, predictive analytics for dynamic fleet management, and a user feedback mechanism ensure a commuter-centric and efficient approach. Sustainability is also a core focus, with the application promoting public transport as a greener alternative to private vehicles.***

***The methodology involves user surveys, stakeholder interviews, and data analytics to identify key pain points and inform system design. Pilot studies and initial commuter feedback indicate significant improvements in user satisfaction, operational efficiency, and safety assurance. This research highlights the transformative potential of integrating safety, efficiency, and technology into urban transportation systems and provides a scalable model for other cities facing similar challenges.***

*Keywords*— **Real-time bus tracking, Accident detection and alarm system, AI-driven route optimiation, Digital ticketing, Solider tracking system**

## I. INTRODUCTION

Public transportation systems are essential for the smooth functioning of urban areas, offering affordable and sustainable mobility to millions of people. However, as cities grow and urban populations surge, the existing transportation infrastructure often becomes inadequate, leading to inefficiencies and declining commuter satisfaction. Pune, a rapidly urbanizing city in India, relies on the Pune Mahanagar Parivahan Mahamandal Limited (PMPML) bus service as its primary public transport system. Despite its critical role, PMPML faces significant challenges, including outdated operational methods, lack of real-time information, overcrowding, and safety issues. This research aims to address these gaps by proposing a modernized approach through a mobile application tailored to enhance PMPML's operational efficiency, safety measures, and commuter satisfaction.

### *A. BACKGROUND*

Public transportation in Pune has seen considerable evolution over the years, yet its core challenges remain largely unresolved. Historically, PMPML has played a pivotal role in connecting different parts of the city and its suburbs. However, with increasing traffic congestion and a surge in private vehicle ownership, public transport's share in urban mobility has declined significantly. Key terms in this context, such as real-time tracking**,** digital ticketing**,** AI-driven route optimization, and safety alert systems, are increasingly becoming the standard in modern transportation systems globally.

Existing data reveals that PMPML faces issues like route inefficiencies, delays, and a lack of transparency in schedules, all of which discourage potential users. Additionally, there is no robust system for accident detection or emergency handling, leaving both commuters and authorities ill-equipped in critical situations. These shortcomings necessitate a technological overhaul to modernize the system and attract a larger share of urban commuters.

### *B. EXISTING EVIDENCE*

Globally, many cities have adopted advanced transportation systems that integrate technology to improve efficiency and user experience. For instance:

- **Singapore** has implemented an Intelligent Transport System (ITS) that combines real-time tracking, cashless ticketing, and route optimization to provide seamless public transport.

- **London** relies on its Oyster card and mobile ticketing system to ensure convenience for commuters while maintaining operational efficiency.
- Studies in cities like Bangalore and Delhi in India highlight the potential of mobile apps for bus tracking and ticketing, but these efforts often remain in pilot stages or fail to scale due to infrastructural constraints.

Despite these advancements, there is limited research that addresses the unique challenges of second-tier Indian cities like Pune, where factors like budget limitations, diverse commuter demographics, and infrastructure gaps make direct adoption of global solutions unfeasible.

Although existing studies emphasize the importance of integrating digital technologies into public transport, several critical gaps persist:

1. Limited attention to safety mechanisms such as accident detection systems and real-time alerts for emergencies in public buses.
2. Lack of systems designed for tracking specialized passengers or personnel, such as soldiers during transit.
3. Insufficient focus on scalable, low-cost solutions that cater to the unique constraints of developing cities like Pune.
4. A gap in addressing sustainability while simultaneously improving commuter experience and operational efficiency.

These gaps highlight the need for a holistic solution that integrates safety, efficiency, and sustainability into a commuter-centric application tailored for PMPML.

### *C. OBJECTIVE*

The primary objective of this research is to modernize the PMPML bus system through the development of an innovative mobile application. The specific objectives include:

1. **Implementing Real-Time GPS Tracking**: Enabling commuters to track bus locations, anticipate arrival times, and reduce waiting times while improving fleet management.
2. **Introducing Safety Features**: Developing systems for accident detection, emergency alarms, and real-time notifications to enhance passenger safety.
3. **Soldier Tracking Mechanism**: Incorporating GPS-based tracking of buses carrying personnel or sensitive cargo to ensure security and transparency.
4. **Digital Ticketing and Fleet Optimization**: Streamlining payment systems and using predictive analytics to optimize routes and manage fleet operations dynamically.
5. **Promoting Sustainability**: Encouraging the use of public transport as a greener alternative to private vehicles by improving accessibility and convenience.

## II. LITERATURE REVIEW

Public transportation systems worldwide are undergoing rapid digital transformation, incorporating real-time tracking, AI-driven route optimization, and digital payment solutions to enhance efficiency and user experience. Several studies have explored the implementation of smart public transit systems, focusing on real-time tracking, passenger safety, and operational improvements. This literature review examines existing research on public transportation modernization, with a focus on global and Indian case studies, technology integration, and gaps relevant to the PMPML bus system.

### *A. Global Public Transportation Systems and Smart Mobility Solutions*

Several cities worldwide have successfully implemented smart public transit systems that leverage technology to improve service quality.

- **London's Transport for London (TfL)**: TfL has integrated GPS-based tracking, contactless digital ticketing (Oyster Card), and predictive analytics to enhance bus scheduling and reduce wait times (Smith et al., 2020).
- **Singapore's Intelligent Transport System (ITS)**: Singapore's bus network incorporates AI-based route planning, automated traffic monitoring, and cashless ticketing, significantly improving commuter convenience (Tan & Lee, 2021).
- **New York's MTA Bus Time System**: The Metropolitan Transportation Authority (MTA) of New York City uses real-time tracking and mobile applications to provide commuters with live updates on bus locations, improving ridership experience (Brown et al., 2019).

These systems demonstrate the effectiveness of technology in addressing common transit issues, such as unpredictable schedules, lack of information, and inefficient fleet management.

### *B. Indian Public Transportation and Digitalization Efforts*

In India, several metropolitan cities have introduced digital solutions for their bus systems, but challenges such as infrastructural limitations, financial constraints, and diverse commuter needs persist.

- **Delhi Transport Corporation (DTC)** has piloted real-time bus tracking and contactless ticketing; however, implementation at scale remains a challenge due to infrastructural issues (Gupta et al., 2022).
- **Bangalore Metropolitan Transport Corporation (BMTC)** launched the "MyBMTC" mobile application, providing route maps and bus timings, but it lacks advanced features like AI-driven route optimization and emergency alert systems (Ravi & Sharma, 2020).
- **Mumbai's BEST Bus System** has adopted mobile ticketing and online payment systems, improving efficiency but still struggling with traffic congestion affecting schedule adherence (Patil et al., 2021).

These studies highlight that while Indian cities have made progress in integrating technology**,** many initiatives remain limited in scope and lack comprehensive safety and fleet management features**.**

### *C. Existing PMPML Studies and Technology Gaps*

Research specifically on the **PMPML** bus system is relatively limited. Some key findings from previous studies include:

- **Operational Challenges**: A study by Kulkarni & Deshmukh (2018) identified frequent delays, overcrowding, and lack of real-time updates as major challenges in Pune's bus transport system.
- **Commuter Satisfaction**: Research by Jadhav et al. (2021) highlighted that poor information dissemination and inefficient scheduling contribute to reduced commuter satisfaction and an increasing shift toward private vehicles.
- **Technology Gaps**: Kumar & Mehta (2022) examined PMPML's digital initiatives, noting the absence of a robust mobile application with real-time tracking, accident detection, and AI-powered scheduling**.**

These studies suggest that PMPML lacks an integrated digital ecosystem that combines real-time tracking, safety mechanisms, and intelligent fleet management**,** which are crucial for enhancing commuter convenience and operational efficiency.

### *D. Safety Features in Public Transport Systems*

Safety is a major concern in public transport, yet many Indian bus systems, including PMPML, lack accident detection and emergency response features**.**

- **Accident Detection Systems**: Studies on smart transport systems (Singh & Verma, 2020) suggest that integrating IoT sensors and AI-based monitoring can help detect accidents and immediately notify authorities.
- **Alarm and Notification Systems**: A study by Pandey et al. (2021) highlights the importance of an **automated alarm system** that can alert both commuters and emergency services in case of accidents or security threats.
- **Soldier Tracking System**: Research on military and personnel tracking systems (Reddy & Thomas, 2019) suggests that GPS-enabled tracking for sensitive personnel movement can enhance security measures in public transit systems**.**

### *E. Research Gap*

Based on the review of existing literature, several gaps emerge:

1. **Lack of Comprehensive Digital Integration**: PMPML does not have a well-integrated mobile application covering real-time tracking, AI-driven route optimization, and digital ticketing.
2. **Absence of Safety Features**: No existing system in Pune incorporates accident detection, emergency alert systems, or real-time notifications for commuters and authorities.
3. **Limited Research on Soldier Tracking in Public Transport**: While global studies emphasize real-time personnel tracking**,** there is no research on implementing this feature in PMPML or other Indian bus systems.
4. **Scalability and Feasibility Challenges**: Existing solutions in Indian cities are often limited to pilot projects and lack scalable implementation strategies that address financial and operational constraints**.**

## III. SYSTEM ARCHITECTURE

The PMPML Bus Application is designed using a client-server architecture that efficiently integrates mobile technologies with cloud-based backend services. The system ensures real-time access to bus routes, live tracking, and schedule updates, offering a seamless experience for both passengers and administrators.

At the core, the mobile application is developed using Flutter, providing a cross-platform user interface. This frontend communicates with Firebase, which acts as the backend, managing authentication, data storage, and server-side logic. The system also incorporates GPS modules to track live bus locations, sending data to Firebase which then updates the user interface in real time. Additionally, Cloud Storage is used for managing media or documentation related to buses and routes.

The architecture ensures high availability, scalability, and secure access control while maintaining a user-friendly interface and fast data synchronization.

## *A. Hardware Components*

The PMPML Bus Application integrates various hardware components across different layers of the system to ensure seamless operation, accurate data handling, and real-time communication between users, buses, and administrators.

### 1) GPS Tracking Device

One of the most critical hardware components in this system is the GPS tracking module installed on each PMPML bus. This module is responsible for continuously collecting real-time geographical data—such as latitude, longitude, speed, and direction—using satellite-based navigation systems like GPS or GNSS. The GPS device is equipped with a SIM card and uses GPRS, 3G, or 4G networks to transmit this location data to the Firebase backend. This transmission is typically done every few seconds, enabling live tracking features within the mobile app. These devices often include onboard memory and can function offline temporarily, uploading stored data when connectivity resumes. The location data received is critical not just for real-time tracking but also for analyzing route efficiency and delays.

A GPS module used in public transportation systems like PMPML buses is a compact electronic device that consists of several key components working together to provide accurate and continuous location tracking. At the heart of the module lies the **GPS receiver chipset**, which is responsible for capturing signals from multiple satellites orbiting the Earth. This chipset calculates the device's exact position using triangulation methods based on time-stamped signals received from at least four satellites. High-sensitivity chipsets are often used in urban or moving environments like buses to ensure signal stability even under challenging conditions, such as tall buildings or variable weather.

Connected to this receiver is a **GPS antenna**, usually either a ceramic patch antenna or a helical antenna. This component captures the satellite signals and forwards them to the GPS receiver. The antenna must be placed in a location with minimal obstruction, typically on the roof or dashboard of the bus, to ensure a strong line-of-sight with satellites.

Another critical part of the module is the **microcontroller unit (MCU)**. This onboard processor manages the GPS data, performs initial filtering, and handles communication with other systems. It formats the location data into a usable structure (often in NMEA format) and may also handle logging if the module includes memory. Some modules include built-in intelligence to reduce the processing burden on external systems, like reducing GPS noise or combining data with inertial sensors for better accuracy during signal loss.

To transmit the gathered location data to the PMPML backend system, the GPS module is usually integrated with a **GSM/GPRS or 4G LTE communication module**. This component allows the GPS device to send location data in real time over mobile networks to Firebase or another cloud platform. It includes a SIM card slot, and works similarly to mobile phones, using cellular towers to maintain a data connection. Some modern GPS devices may also include support for NB-IoT or eSIM for better efficiency and durability.

In many applications, especially vehicle tracking, the module is powered by a **vehicle power interface** that connects directly to the bus's electrical system (typically 12V or 24V). To ensure stability during power fluctuations or brief outages, the module may also include a **backup battery or supercapacitor** that provides power for short periods or helps maintain GPS lock (also called "hot start").

Finally, most GPS modules also include **memory storage** (such as Flash or EEPROM) for offline data logging. If the mobile network is temporarily unavailable, the module stores location points locally and transmits them when connectivity is restored. Some advanced versions may even include **accelerometers, gyroscopes, and other inertial sensors** to enhance location tracking in tunnels or areas with poor satellite visibility, a technique known as dead reckoning.

Together, these components make up a robust GPS module capable of delivering reliable, real-time location data in dynamic and challenging environments like urban roadways, supporting essential features in the PMPML bus application such as live bus tracking, arrival predictions, and route monitoring.

### *B. Softaware Components*

The PMPML Bus Application is powered by a modern software architecture that blends cross-platform mobile development with robust cloud services. The software components are structured in a way that ensures high performance, scalability, and a seamless user experience across different devices and user roles (passenger and admin). Each component plays a specific role in managing data, user interactions, location tracking, and system logic.

#### 1) Frontend (Mobile Application – Flutter Framework)

The frontend of the PMPML app is built using **Flutter**, a UI toolkit developed by Google that enables cross-platform development for both Android and iOS from a single codebase. This component is responsible for rendering the user interface, handling user inputs, and interacting with backend services through APIs or SDKs. The app provides core features such as route browsing, real-time bus tracking on maps, stop-based search, and user login/logout. For passengers, it displays maps with live bus positions using Google Maps SDK, while administrators (if supported via mobile) can manage routes, receive alerts, or view basic analytics. Flutter's reactive UI model ensures smooth transitions and performance, even on lower-end devices, making it ideal for public-use applications.

#### 2) Backend Services (Firebase Platform)

The backend of the PMPML app is fully integrated with **Firebase**, a Backend-as-a-Service (BaaS) platform provided by Google. Firebase handles all cloud-based operations such as data storage, user authentication, messaging, and serverless logic. The key Firebase services used are:

- Firebase Authentication:
  This module manages secure sign-in and user registration using email/password or phone number. It ensures that each user's session is authenticated before accessing core features of the app.
- Cloud Firestore:
  Firestore is a NoSQL cloud database used to store structured data such as bus routes, schedules, user profiles, feedback, and reports. Data is synchronized in real-time between the cloud and the app, ensuring that passengers always receive the most current information.
- Firebase Realtime Database (optional or for GPS tracking):
  In some setups, a Realtime Database is used for tracking live bus locations because it enables very fast data synchronization. The GPS data from buses is sent to this database, which the app listens to in real-time to show live bus movements.
- Firebase Cloud Functions:
  These are serverless backend scripts that execute in response to specific events such as a new report submission, user registration, or location update. For example, Cloud Functions may be used to send push notifications when a bus is nearing a stop or when there's a route change.
- Firebase Cloud Messaging (FCM):
  This service is used to send push notifications to users. It can notify passengers about delays, emergency reroutes, or upcoming bus arrivals based on real-time data triggers.

#### 3) Cloud Storage (Firebase Storage)

Firebase Cloud Storage is used to manage large files or media assets like bus photos, route maps, and administrative documents. This service allows secure uploading and downloading of files with permission-based access. For example, PMPML staff may upload updated bus route images, which passengers can view inside the app.

#### 4) Map and Location Services (Google Maps SDK / API)

To offer real-time bus tracking and route visualization, the app integrates **Google Maps SDK** for Flutter. This allows passengers to see bus locations as moving markers, search for nearby stops, and get estimated travel times. The system may also use **Geofencing APIs** to notify users when they are near a bus stop or when a bus is approaching.

## IV. CONCLUSION

The development of the PMPML Bus Application marks a significant stride toward solving long-standing challenges faced by commuters in Pune. Public transportation is a lifeline for any urban center, and the PMPML system, despite its widespread use, has suffered from inefficiencies related to schedule management, route optimization, overcrowding, and lack of real-time information. Through this project, a user-friendly, efficient, and accessible mobile application has been proposed and developed, aimed at enhancing the everyday travel experience for the citizens of Pune.

The application provides real-time bus tracking, estimated arrival times, smart route planning, and digital ticketing. It also incorporates features like bus pass management and emergency contact support, offering a comprehensive solution that addresses both the practical and safety needs of commuters. By integrating Google Maps for route visualization and Firebase for real-time database support, the app leverages powerful technologies to deliver high reliability and responsiveness.

During the development process, key aspects of software engineering such as requirement analysis, system design, coding standards, testing methodologies, and iterative refinements were employed to ensure the quality and usability of the application. The app was built using Flutter, enabling cross-platform compatibility and rapid development. Firebase was used to manage user authentication, bus data, and cloud storage, ensuring scalability and secure data handling.

The feedback gathered during testing suggests that the application can significantly reduce waiting times and improve passenger confidence in the public transport system. In the long term, the successful implementation of such a solution could contribute to increased usage of public transportation, reduced traffic congestion, and lower environmental impact due to fewer private vehicles on the road.

In conclusion, the PMPML Bus Application not only addresses immediate commuter issues but also sets a foundation for future innovations in urban mobility. With continuous updates, stakeholder collaboration, and user feedback integration, this application has the potential to transform public transportation in Pune into a smart, efficient, and sustainable system.

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