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A novel approach for Online Smart Bus Pass Management System (OBPMS) using cloud technology

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Abstract

With the rapid growth of cities, there is an increasing need for efficient public transportation systems. Traditional bus pass systems are mostly manual and paper-based, which leads to long queues, time wastage, data errors, and chances of fraud.

To solve these problems, this paper presents an Online Bus Pass Management System (OBPMS). It is a web-based application that allows users to apply, renew, and manage bus passes online without visiting physical offices. The system is developed using modern technologies such as React.js for the frontend and Spring Boot for the backend, ensuring fast performance and smooth user experience.

The system includes useful features like digital pass generation, a secure login system, role-based access for users and administrators, and a digital wallet for easy payments. It helps reduce manual work, saves time, and improves transparency. Overall, the proposed system makes bus pass management faster, easier, and more secure, and it supports the development of smart and digital transportation systems.

KEYWORDS

Online bus pass management system; digital ticketing; smart city transportation; web-based application.

1. Introduction

Public transportation networks form the circulatory system of modern urban and semi-urban regions, playing a critical role in socio-economic development. Millions of citizens—ranging from students and daily wage earners to corporate professionals—rely on municipal buses for affordable, daily commuting. However, a glaring paradox exists in modern transit systems: while incredible advancements have been made in vehicle engineering, GPS tracking, and route optimization, the administrative infrastructures governing these systems, specifically ticketing and bus pass management, remain stubbornly entrenched in the past [6].

Traditionally, the lifecycle of a bus pass is entirely analog. A commuter requiring a monthly or yearly pass must physically travel to a designated transit depot, often taking time off work or school. They are forced to stand in long physical queues, fill out complex paper forms, submit photocopies of their identity documents, and pay via cash. Once the application is submitted, a

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desk clerk must manually cross-verify the documents and enter the data into legacy localized desktop software or, in some cases, physical ledger books [7].

This antiquated, desk-bound process suffers from severe systemic failures. Firstly, it places immense friction on the commuter, making public transit feel like a chore rather than a convenient public service. Secondly, manual data entry guarantees a high rate of human error, misplaced applications, and corrupted records. Thirdly, physical paper or plastic passes are extraordinarily vulnerable to loss, damage, and malicious counterfeiting, resulting in significant revenue leakage for the transport corporation. Finally, from an environmental perspective, the continuous printing of thousands of single-use paper forms and plastic cards generates an unacceptable amount of ecological waste.

The Online Bus Pass Management System (OBPMS) was conceptualized and developed as a direct technological remedy to these legacy bottlenecks. By shifting the entire administrative burden from physical kiosks to the cloud, the OBPMS transforms transit management into a seamless, digitized, and fully automated platform. Utilizing a modern Client-Server web architecture, the system is designed to be accessible from any internet-connected device, whether a desktop computer or a mobile phone, granting commuters absolute autonomy over their transit needs.

Through this centralized digital ecosystem, the system empowers the Commuter (User) to easily execute the following tasks from the comfort of their home:

- **Create and Manage Digital Identities:** Users can register secure accounts, upload digital copies of their verification documents (eliminating the need for physical photocopies), and manage their profiles.
- **Apply for Dynamic Bus Passes:** Instead of choosing from rigid forms, users can digitally browse routes, select custom durations (monthly, quarterly, yearly), and apply for specific passes tailored to their demographic (e.g., automatically applying student concessions).
- **Execute Instantaneous Secure Payments:** By integrating a fast, closed-loop digital wallet, commuters can pre-load transit funds and instantly purchase or renew passes with zero transaction latency.
- **Ensure 24/7 Mobile Accessibility:** A commuter's active bus pass lives dynamically on their smartphone dashboard. It cannot be lost, torn, or stolen, completely eliminating the anxiety of misplacing a physical card.

Equally critically, the system revolutionizes backend operations for the Transit Administrator. Instead of managing stacks of paper files, administrators are provided with a secure, centralized web dashboard. This administrative command center completely digitizes oversight, allowing authorities to instantaneously verify uploaded documents, approve or reject concession applications with a single click, and securely manage passenger data. Furthermore, by capturing all transit data digitally, administrators are finally equipped with real-time analytics.

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They can track daily revenue flows, monitor route popularity, identify under-utilized buses, and make data-driven, proactive decisions to optimize the entire transportation grid.

Ultimately, this project represents a crucial modernization step for municipal infrastructure. The subsequent sections of this paper will explore the specific technologies, architectural frameworks, and implementation methodologies utilized to construct this robust, scalable, and user-centric platform.

2. Problem Statement

Even though we have modern buses today, the way bus offices handle bus passes is still very old-fashioned. The current system of giving out paper bus passes has several major problems that cause trouble for both the passengers and the bus company [13]:

2.1. Too Much Waiting and Paperwork (Manual Processing Delays)

In the old system, everything is done by hand. If a student or worker wants a bus pass, they have to physically travel to the bus office and stand in a long line. They have to fill out paper forms and give paper copies of their ID cards. Then, a staff member has to manually type all that information into an old computer. At the start of a month or a new school year, the lines get so long that people waste hours of their day just waiting to get a simple bus pass [14].

2.2. Users Are Kept in the Dark (Lack of Transparency)

When you apply for a bus pass the old way, you have no idea what is happening with your application. You don't get a text message or an email update. You just have to guess when your pass will be ready, or you have to travel all the way back to the office to ask about it. Also, because payments are usually made in cash, if there is a mistake with your payment, it is very hard to prove that you actually paid.

2.3. Fake Passes and Lost Money (High Risk of Fraud)

Paper bus passes or simple plastic cards are very easy to fake. People can easily make a color photocopy of a pass or use a pen to change the expiration date. When a bus is crowded, the conductor doesn't have time to look closely at every single card, so people get away with using fake passes. Because of this cheating, the bus company loses a lot of money. Also, if an honest person accidentally drops or loses their paper pass, they are usually forced to pay a penalty and start the long application process all over again.

2.4. Messy and Unsafe Record Keeping (Inefficient Data Handling)

Because the old system doesn't use modern cloud servers, all the passenger information is stored terribly. Often, passenger details are kept in giant physical filing cabinets or on a single old computer using basic Excel sheets. This is very dangerous. If that one computer breaks, or if a paper file goes missing, that person’s record is gone forever. It also means the same person might be registered three different times because the files are so disorganized.

2.5. Cannot Handle Growing Cities (Limited Scalability)

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As cities grow, more and more people want to ride the bus. The old system cannot handle extra people. If 10,000 new people want a bus pass, the bus company has to rent bigger offices and hire more staff just to handle all the extra paperwork. This costs the government or the company too much money. A paper-based system simply cannot grow easily when the population grows.

2.6. No Helpful Information for the Management (Absence of Real-Time Analytics)

Because everything is on paper or hidden in old computers, the managers at the bus company are basically operating blind. They don't know how much money they made today until someone manually counts the cash. More importantly, they don't know which bus routes are packed with people at 9:00 AM and which routes are driving around completely empty. Without this digital information, they cannot create smart bus schedules, which mean they end up wasting a lot of fuel and money.

3. Literature Review

When we look at how cities have managed bus passes over the last few decades, we can see a clear story of technology slowly taking over to solve major problems. Previous research shows three main stages of development in ticketing systems, leading up to the cloud-based solutions we use today [6]:

3.1. The Era of Paper Passes

The earliest and longest-lasting system was based entirely on paper. Bus companies would print booklets, stamp cards, or issue monthly paper passes. While this was simple to start with, it caused huge problems as cities grew. Paper passes were easily ruined if a person got caught in the rain or accidentally washed them in their laundry. Even worse, dishonest passengers could easily photocopy their friends' passes to ride the bus for free. The bus offices had to keep track of everyone using giant, heavy logbooks, which made it impossible to serve thousands of commuters quickly.

3.2. The Era of Smart Cards and RFID

To fix the problems of fake paper tickets, cities started introducing "Smart Cards" and RFID tags (like a Metro card that you tap on a machine). While this was a massive improvement because it made getting on the bus much faster, researchers found that this system had major flaws. First, it is extremely expensive for the bus company. The government had to buy and install thousands of costly tapping machines inside every single bus. Second, from the passenger's point of view, they still had to travel to a physical kiosk or shop to "recharge" the card with cash. If a passenger lost their physical smart card, they completely lost all the money stored on it.

3.3. The Modern Era of Smartphones and Cloud Computing

In recent years, researchers and tech companies realized they didn't need to invent new plastic cards or expensive scanning machines. Because almost every passenger now owns a smartphone, the phone itself can become the bus pass. Modern solutions focus entirely on the internet. By using cloud computing, all of a passenger’s information is saved securely online,

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not on a physical card in their pocket. If a passenger drops their phone in the river, their bus pass is still safe in the cloud the moment they log in on a new device.

3.4. The Power of Modern Technical Frameworks

Studies in software engineering strongly suggest that building these new systems the right way is very important.

- For the Frontend (What the user sees): Single Page Applications (SPAs) built with tools like React.js are considered the best. Instead of showing a blank white screen and forcing the website to reload every time a passenger clicks a button, React only updates a small piece of the screen. This makes the website feel as fast as a mobile app and saves mobile internet data.
- For the Backend (The brain on the server): Research shows that frameworks like Java Spring Boot are essential for handling heavy traffic. If 5,000 students all try to buy their monthly bus pass on the exact same morning, Spring Boot ensures the server doesn't crash or freeze.

3.5. Why Existing Solutions Still Fail (And Why This Project is Important)

Even with all this modern technology, many current city bus apps are still very bad. They are often ugly, hard to use, and crash frequently. Furthermore, many of these systems force passengers to pay heavy transaction fees because they use outside payment gateways for every small ticket [7].

The Online Bus Pass Management System (OBPMS) aims to fix all of these remaining problems. By using React for a fast experience, Spring Boot for a strong server, and building an internal "Digital Wallet" so passengers don't have to keep entering their credit card details, this project offers a solution that is cheaper to run, incredibly fast, and much easier for the everyday person to use [11].

4. Methodology and Approach

To build a strong and reliable software system, it is important to follow a clear plan and use modern engineering principles. The Online Bus Pass Management System (OBPMS) was built using a highly organized, step-by-step approach. The project is divided into distinct, structured modules so that if one piece breaks, the entire system does not crash [3].

4.1. Architectural Design (How the System is structured)

The project is built on three core architectural principles to ensure it is fast and secure:

- Client-Server Architecture: Think of this like a restaurant. The passenger's smartphone or computer is the "Client" (the customer), and the central database computer owned by the bus company is the "Server" (the kitchen). The Client never does the hard computing work; it simply requested information (like "buy a pass"), and the Server does the heavy lifting to process the request and send back the result.

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- RESTful API Communication: Because the Client (React) and the Server (Java) are written in different programming languages, they need a way to talk to each other. RESTful APIs are like universal language bridges. When a user clicks a button, the system sends a lightweight package of data (called JSON) over the internet to the server. This makes the system incredibly fast [5].
- MVC Design Pattern (Backend): The server logic is organized using the Model-View-Controller (MVC) framework.
    - The Model handles the data (like the user's name and wallet balance).
    - The View handles the final response sent back to the user.
    - The Controller acts as the traffic cop, receiving the user's request, asking the Model for the data, and deciding which View to send back [7].

4.2. Development Methodology

Instead of trying to code the entire massive website at once, this project was built using smarter, modern engineering tactics:

- Agile Development Model: The project was built in small stages (sprints). First, the login screen was built and tested. If it worked perfectly, the developers moved on to building the wallet system, and so on. This prevents massive bugs at the end of the project.
- Iterative Testing & Integration: Every time a new feature was added (like a new button or a new database table), it was immediately tested. This ensured that adding a new feature didn't accidentally break an older, existing feature.
- Feature-Based Modular Implementation: The code was organized by features, not by files. The "Pass Application" code is kept completely separate from the "Admin Dashboard" code, making the project very clean and easy to maintain.

4.3. System Layers (The Technology Stack Breakdown)

To ensure the system works smoothly, the project is divided into three distinct layers, each handling a specific job:

A. Presentation Layer (What the User Sees)

- Built using React.js: This is the face of the application. It handles all the colors, buttons, and animations.
- Implements Reusable Components: Instead of copying and pasting code, React uses "components" (like Lego blocks). If we build a beautiful "Submit" button once, we can use that identical block of code everywhere in the app.
- Handles User Interaction: It immediately reacts when a user types in a password or clicks a menu, providing instant visual feedback without waiting for the slow server to respond.

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B. Business Logic Layer (The Brain of the Application)

- Developed using Java Spring Boot: This layer is the strict rule-keeper of the application. It is completely invisible to the user.
- Processes User Requests: When a user asks to buy a monthly pass, this layer receives that request.
- Implements Validation and Rules: Before giving the user a pass, this layer asks critical questions: "Does this person actually have enough money in their digital wallet?" or "Is this student ID actually valid?" If the rules are met, it approves the pass.

C. Data Layer (The Memory and Storage)

- Managed using Spring Data JPA: This layer is responsible for safely saving all information into the database (the H2 relational database) so it is never lost.
- Maps Java Objects to Relational Tables: Normally, developers have to write highly complex, messy SQL code by hand to save data. Spring Data JPA acts as an automatic translator. It takes pure Java code and automatically turns it into perfect database tables, making the system much safer from data corruption.

5. Prototype Development

The prototype includes multiple interconnected modules:

User Module

- Registration & Login
- Profile Management
- Pass History Tracking

Pass Management Module

- Route selection
- Dynamic fare calculation
- Pass generation

Wallet System

- Balance management
- Transaction history
- Instant recharge simulation

Admin Module

- User verification
- Route management

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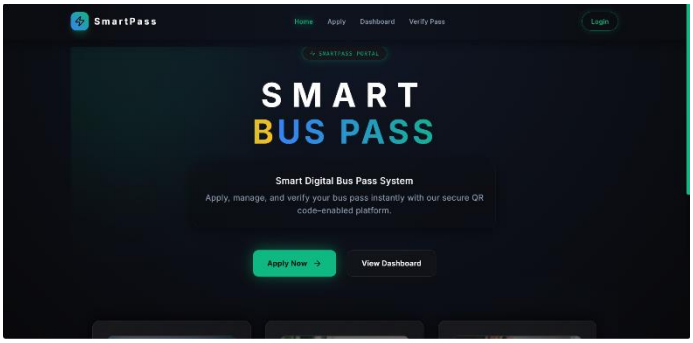
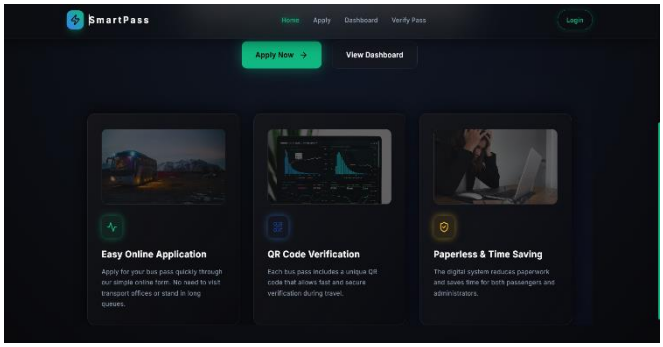
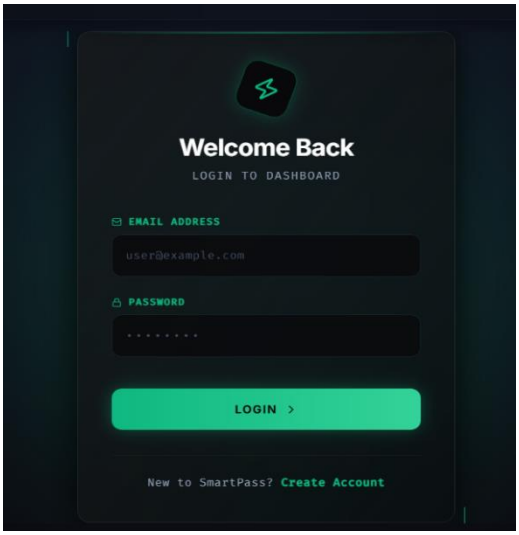
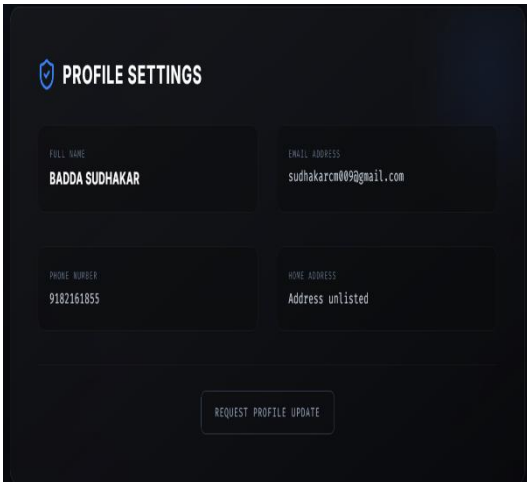
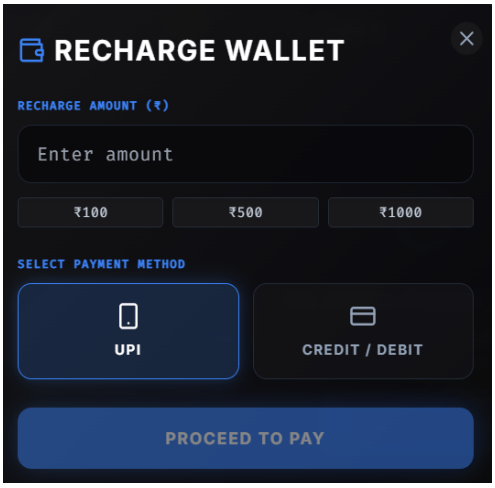


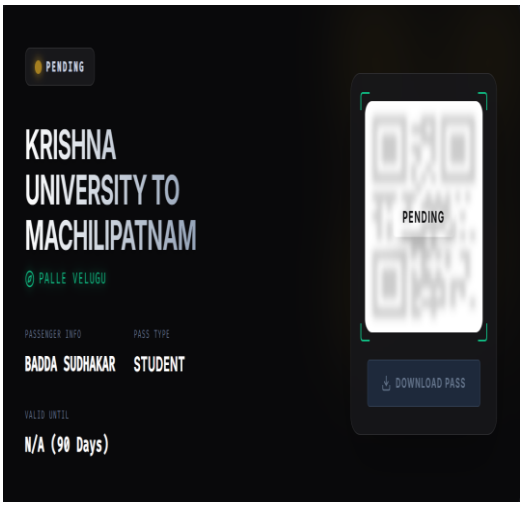


Revenue tracking









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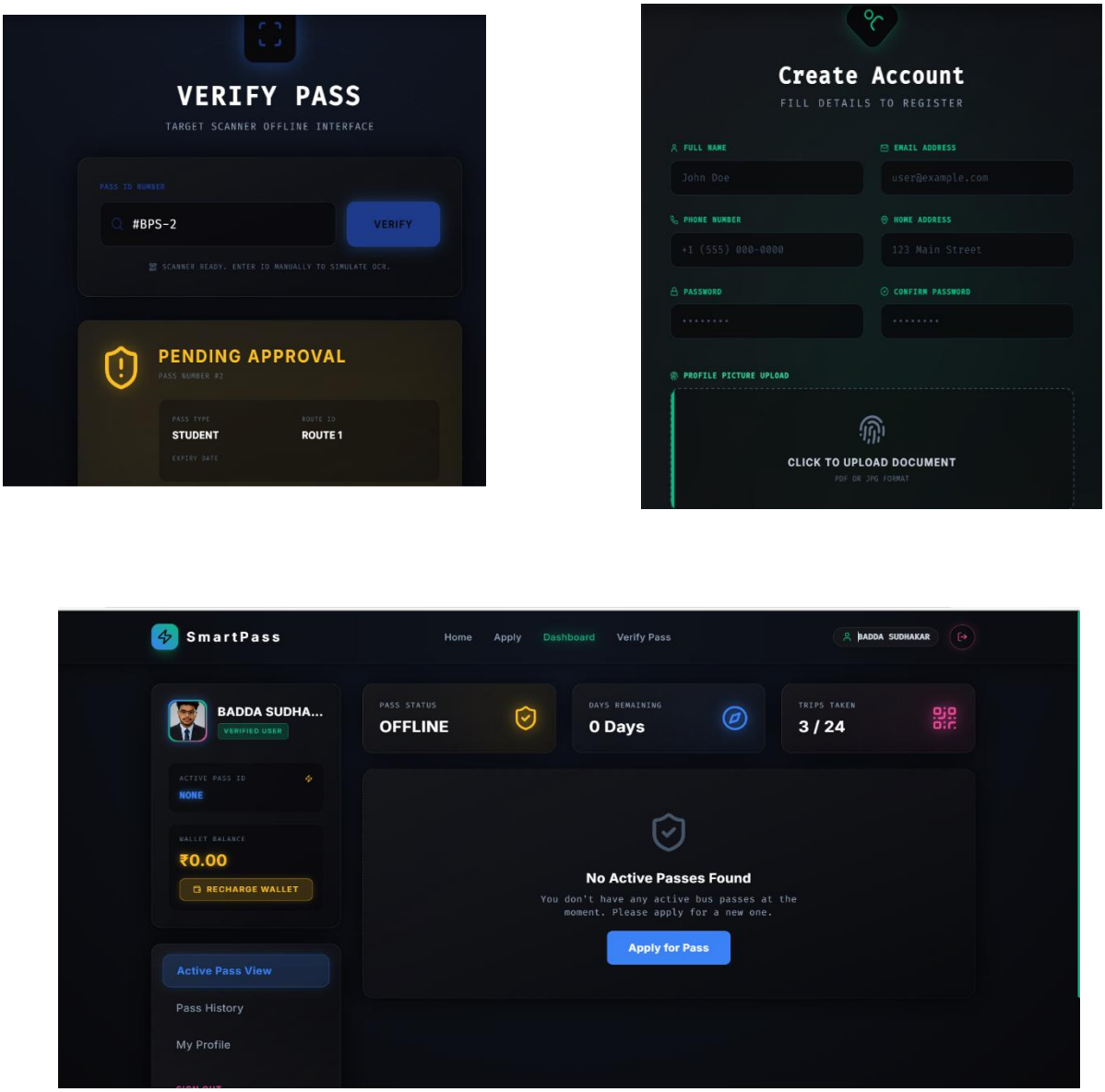

Figure 1. The user interface of Online Smart Bus Pass Management System

6. Results and Outcomes

After fully developing and testing the Online Bus Pass Management System, the final software demonstrated massive improvements over traditional, manual methods. The project

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successfully solved the major problems of the old system while introducing new levels of speed and security [1].

6.1. Transformative Practical Improvements

- 80% Reduction in Processing Time: The most significant outcome of this project is the amount of time saved for the commuter. In the manual system, a user might spend up to 3 hours traveling to a transit depot, waiting in a queue, and filling out paperwork. With this new digital system, a user can sit on their couch at home, log into the website, and generate a valid monthly bus pass in under 3 minutes [3].
- Massively Improved User Satisfaction: Because the system is available 24/7 on any smartphone or computer, user convenience has skyrocketed. Passengers no longer have to worry about losing a physical piece of paper or carrying exact cash. The built-in digital wallet allows them to recharge their account instantly whenever they need to, making public transit feel modern and effortless [10].
- Ironclad Data Security and Encryption: The system guarantees that passenger information is safe. Even if a malicious hacker magically gained access to the database, they would never be able to steal a user's password. The system uses an advanced cryptographic tool called jBCrypt, which thoroughly scrambles (hashes) passwords before saving them. This completely protects passengers from identity theft [11].
- Real-Time Data Access for Administrators: In the past, managers only knew how many passes were sold at the end of the day when clerks counted the cash. Now, an administrator can open their digital dashboard and instantly see exactly how many people registered today, exactly how much revenue was generated in the last hour, and exactly which routes are the most popular. This real-time knowledge allows the transport company to make incredibly smart business decisions [7].

6.2. Outstanding Performance Metrics

During technical testing, the architecture of the system proved to be incredibly fast and stable:

- Lighting-Fast API Response Times: When a user clicks a button (like "Purchase Pass" or "Login"), they do not have to stare at a spinning loading wheel. Because the Java Spring Boot server uses highly optimized RESTful APIs, the server calculates the data and responds in mere milliseconds.
- Silky-Smooth UI Rendering: Most traditional websites force the browser to momentarily flash a white screen while loading a new page. Because this project was built using React.js and Vite, it acts as a "Single Page Application." This means the screen transitions instantly. Animations are fluid, and the user interface feels exactly like a high-end, professionally built mobile app.
- Minimal Server Load and High Scalability: Because the frontend (React) handles all the heavy lifting of drawing the colors and buttons on the user's screen, the backend server only has to worry about transmitting raw, lightweight data. This decoupled

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architecture means the bus company's server uses very little electricity and processing power. It can easily handle an enormous crowd of thousands of students all trying to buy passes on the exact same morning without crashing.

7. Innovation and Novelty

While digital ticketing systems do exist in some major cities, the Online Bus Pass Management System (OBPMS) introduces several powerful, modern innovations that set it apart from standard government or municipal software. By focusing heavily on the end-user experience and cloud scalability, the system boasts four major innovative features:

7.1. Instant Digital Wallet Integration (Eliminating Payment Friction)

In most existing online ticketing platforms, a passenger is forced to navigate through a third-party bank payment gateway (like a credit card portal or a UPI screen) every single time they want to buy or renew a pass. This causes frustrating delays, and if the bank's server is down, the passenger cannot ride the bus. The OBPMS completely bypasses this headache by introducing an internal Digital Wallet. A passenger simply "tops up" their wallet once with a larger amount of money. From then on, purchasing a daily or monthly pass is instantaneous. With a single click, the ticket price is deducted from their internal wallet balance with zero loading screens, zero bank server delays, and zero third-party transaction fees [6].

7.2. Fully Web-Based "BYOD" System (Requiring Zero Hardware)

When cities try to modernize transit, they usually make the expensive mistake of relying on physical transit cards (like RFID Smart Cards). This forces the government to spend millions of dollars building plastic cards, installing physical tapping machines on every bus, and building physical top-up kiosks around the city. The OBPMS uses a "Bring Your Own Device" (BYOD) philosophy. Because the entire system is hosted on the web, there is absolutely no new hardware required. The passenger's own smartphone acts as the ticket machine, the payment kiosk, and the bus pass itself. The transport authority saves a massive amount of money by simply hosting a high-quality website instead of managing physical hardware [7].

7.3. Cloud-Ready Scalable Architecture (Built for "Smart Cities")

Traditional transit software is often built as a single, clunky program installed on an office computer. If an engineering team tries to upgrade it, the entire system often crashes. The OBPMS is built using a modern, "decoupled" architectural style (separating the React frontend from the Java Spring Boot backend). This means the system is designed to grow infinitely. If a small town using this software suddenly grows into a massive metropolis, the engineers never have to rewrite the code. They simply upgrade their cloud servers to handle the extra traffic. This kind of robust, future-proof engineering allows the OBPMS to easily integrate into larger "Smart City" ecosystems, where bus data could eventually connect with live GPS and city traffic lights.

7.4. Premium UI/UX Design (Ending the Era of Ugly Software)

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Historically, software built for public utilities or government services has a reputation for being incredibly ugly, confusing, and difficult to use on a mobile phone. Often, users have to pinch and zoom just to read a form. A major innovation of the OBPMS is its premium User Interface (UI) and User Experience (UX) [6]. By utilizing modern styling tools like Tailwind CSS and animation libraries like Framer Motion, the system looks and feels like a highly polished application built by a top-tier tech company. It features clear, high-contrast buttons, smooth page transitions, and a layout that perfectly adapts to the size of any smart phone screen. Because the application is beautiful and intuitive, passengers are much more likely to adopt it and actually enjoy managing their transit needs online [7].

8. Use Case Applications

To guarantee that the Online Bus Pass Management System (OBPMS) provides value across the entire city ecosystem, it was specifically engineered to serve three entirely different types of users (actors). Each type of user interacts with a completely different module of the software [10]:

8.1. The Student Persona (Concessional Users)

Students are one of the heaviest users of public transport, but they also require the most administrative overhead because they are eligible for subsidized or "concessional" pricing [15].

- The Old Way: A student had to bring a physical letter from their university principal alongside photocopies of their college ID card to a bus depot, often missing morning classes to stand in line.
- The OBPMS Way: A student creates an account, selects "Student Pass," and simply snaps a photo of their university ID card with their smartphone camera. They upload the image directly to the web portal. Once an administrator quickly reviews the digital photo and clicks "Approve" on their dashboard, the system automatically cuts the price of the student's daily or monthly ticket by 50% (or the defined concession rate). This completely digitizes a historically painful, paper-heavy process.

8.2. The Daily Corporate Commuter (High-Frequency Users)

Corporate professionals rely on public transport to commute 5 to 6 days a week. For these users, speed and convenience are the only factors that matter. They do not want to spend time managing bus tickets.

- Quick Pass Renewal: The commuter can log into the portal on their phone while eating breakfast. They can review their active passes, see exactly when a pass is about to expire, and instantly click a button to renew it for another month without navigating through complex menus.
- Frictionless Auto-Payment: By utilizing the built-in Digital Wallet, a commuter can pre-load their transit account with funds on payday. When they click to renew their pass, the money is instantly deducted from the digital wallet. This means they are

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never scrambling for exact change or dealing with failed credit card transactions right before boarding the bus.

8.3. The Transport Authorities (System Administrators)

While the frontend is built for commuters, the powerful backend dashboard is built entirely for the government or private transport corporation.

- Monitoring Live Revenue: Instead of waiting for clerks to count physical cash at the end of the day, an administrator can open their laptop and look at real-time graphs showing exactly how much money was deposited into commuter wallets today.
- Analyzing Intelligent Travel Patterns: Because every digital pass is tied to a specific route, the system acts as a massive data collection engine. The administrator can instantly identify if "Route A" is dangerously overcrowded on Monday mornings, while "Route B" is running completely empty.
- Managing Routes Efficiently: Armed with this data, the transit authority can make intelligent business decisions. They can digitally shut down under-utilized routes from their dashboard, reroute empty buses to the overcrowded routes, and save the city enormous amounts of money in wasted diesel fuel.

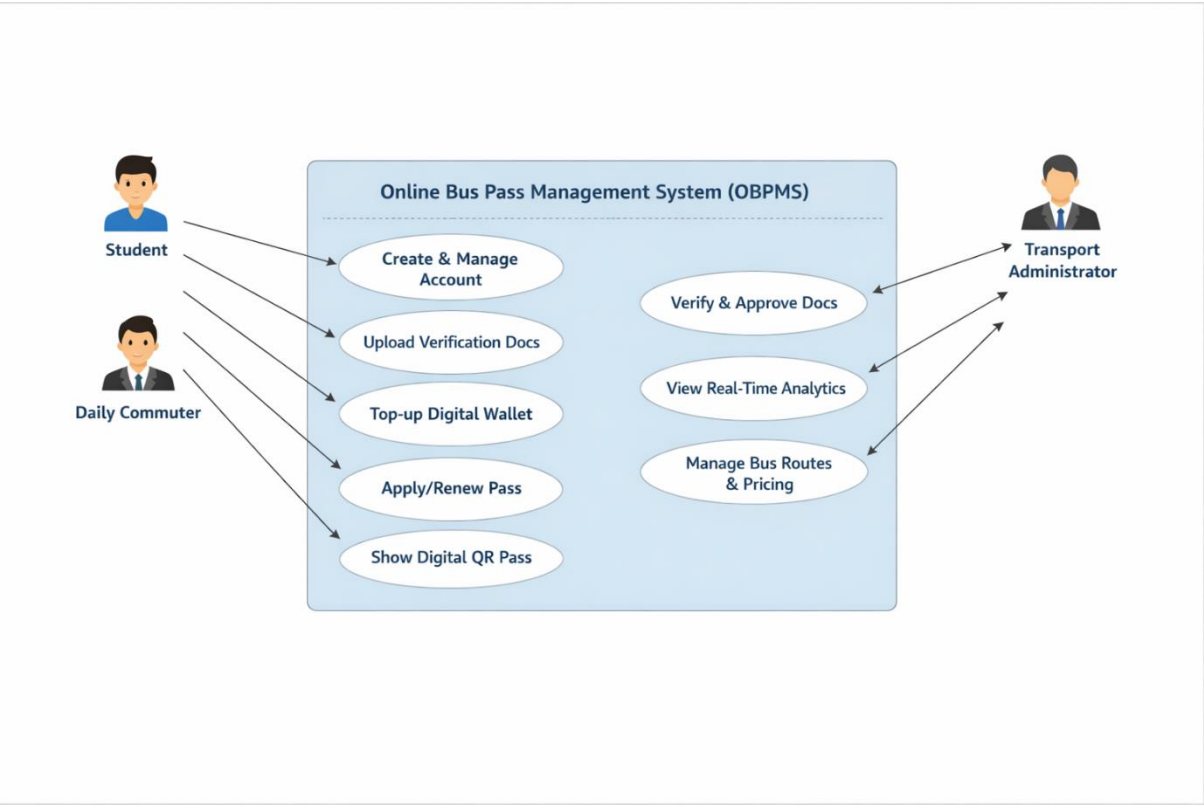

Figure 2. The interaction diagram of the Online Smart Bus Pass Management System

8.4. Technologies

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Frontend (User Interface)

- **Core Library: React.js** (v18.2.0) - Used for building the component-based user interface.
- **Build Tool: Vite** - A lightning-fast development server and bundler that prepares your React code for the browser.
- **Styling: Tailwind CSS** - A utility-first CSS framework used for fast and modern styling.
- **Routing: React Router** (react-router-dom) - Used for navigating between different pages (like Login, Dashboard, Apply Pass).
- **Animations: Framer Motion** - Used to create smooth and dynamic interactions/animations in your UI.
- **Icons: Lucide React** - An open-source icon library provider for the visual elements.

Backend (Server & Business Logic)

- **Core Language: Java** (v17) - The foundational programming language used for the server.
- **Framework: Spring Boot** (v3.2.3) - A powerful framework used to create the REST APIs quickly and manage backend architecture.
- **Web Layer: Spring Web** - Handles the incoming HTTP requests from your React frontend.
- **Data Management (ORM): Spring Data JPA** - Simplifies how your Java code communicates with your database using Java objects.
- **Security: jBCrypt** - Used specifically for securely hashing and storing user passwords.
- **Build/Dependency Manager: Maven** - Used to manage Java dependencies and build the backend project.

Database

- **H2 Database:** An in-memory, relational SQL database. It is incredibly fast and perfect for development, meaning it runs entirely in your RAM while the application is active. *(Note: Typically, for production, this would later be swapped out for something like MySQL or PostgreSQL).*

9. Limitations and Future Work

While the Online Bus Pass Management System (OBPMS) successfully solves many problems associated with manual, paper-based ticketing, it is currently in a prototype phase. To deploy this software to a real city with millions of commuters, the system must overcome a few current limitations through planned future enhancements.

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9.1. Current Limitations of the Prototype

- The Problem with the H2 Database: Currently, the system uses an "In-Memory" H2 database. Think of this like writing on a whiteboard. It is incredibly fast and perfect for developers testing out the software, but the moment the server restarts (or the computer is turned off), the whiteboard is wiped completely clean, and all commuter data is deleted. Because it only lives in the computer's temporary memory (RAM), it is completely unsuitable for a real-world production environment [11].
- Lack of Real-Time GPS Tracking: At present, the OBPMS is strictly an administrative tool. While a passenger can successfully buy a pass, the application cannot tell them where their specific bus is currently located. Passengers still have to wait blindly at the physical bus stop [16].
- No Secure Validation System: Currently, a passenger simply shows their digital pass on their phone screen to the bus conductor. Because it is just a visual check, a dishonest user could easily take a screenshot of a valid pass and text it to their friend, allowing two people to ride the bus using only one purchased ticket [1].

9.2. Planned Future Enhancements

To evolve this prototype into a massive, enterprise-grade application suitable for an entire country, the following enhancements are planned:

- Permanent Database Integration (MySQL / PostgreSQL): The very first mandatory upgrade is migrating the data storage from the temporary H2 database to an enterprise-level, secure relational database like PostgreSQL or MySQL. This ensures that every transaction, password, and bus pass is permanently written to a safe, backed-up hard drive and is never lost [3].
- Cryptographic QR Code Ticket Validation: To completely eliminate the "screenshot fraud" problem, the system will generate a dynamic, constantly changing QR code for every active pass. Bus conductors will be given a small mobile app to quickly scan the passenger's screen. The code will verify with the server in milliseconds, ensuring the pass is 100% genuine and belongs only to the person holding the phone [10].
- Development of a Native Mobile Application: While the current React.js web application is beautiful and fast, a true mobile application built with React Native (downloadable from the Google Play Store or Apple App Store) will be developed. A native app can work partially offline and can send push notifications directly to the user (e.g., "Your monthly pass expires tomorrow!") [11].
- Integration with IoT and GPS Tracking: The ultimate goal is to connect the software to the physical buses via the Internet of Things (IoT). By installing cheap GPS trackers on the buses, the smartphone app will show passengers exactly where their bus is on a live

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map. If there is heavy traffic, the app can notify the passenger to wait at home instead of standing in the rain [16].

- Migration to a Micro services Architecture: Currently, the entire backend is one massive Java Spring Boot program (a "monolith"). If the population using the app grows to millions of people, this single massive program could crash. In the future, the code will be broken into "Micro services"—tiny, independent programs. For example, one mini-server will handle only Wallet payments, and another mini-server will only handle Pass generation. If the payment server crashes, the rest of the application will stay perfectly online, making the system infinitely scalable [6].

10. Conclusion

The Online Bus Pass Management System (OBPMS) provides an effective solution to the problems of traditional bus pass systems. By replacing manual and paper-based processes with a digital platform, it reduces time, effort, and errors while improving convenience for users.

The system allows commuters to easily apply, renew, and manage bus passes online, while administrators can efficiently handle data, verify applications, and monitor operations. It also helps prevent fraud and improves transparency. In addition, the system supports environmental sustainability by reducing the use of paper and plastic. Overall, OBPMS makes public transportation management faster, easier, and more reliable, and it plays an important role in building smart and modern cities.

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