Towards Sustainable Commuting: Development of a Carpool Ride-Sharing Platform with Real-Time Tracking and Safety Features

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ABSTRACT

This study presents the design and development of a Carpool Ride-Sharing Application aimed at addressing the challenges of urban commuting through a secure, affordable, and sustainable mobility solution. The application connects drivers and passengers traveling along similar routes, enabling shared rides that reduce individual travel costs, alleviate traffic congestion, and minimize environmental impact. Core features include secure user authentication, trip scheduling, real-time GPS tracking, and integrated cashless payments, complemented by safety mechanisms such as driver verification, ride preferences, and reporting tools to enhance trust and reliability. The system leverages location-based services and route optimization algorithms to improve ride-matching efficiency, thereby ensuring timely and convenient travel for users. Developed using the Agile methodology, the project adopted an iterative, user-centric approach that allowed for continuous refinement of features and responsiveness to commuter needs. Evaluation demonstrated that the platform enhances commuting efficiency, increases ride-sharing adoption, and fosters a more sustainable and community-driven approach to transportation. By combining robust functionality with an intuitive interface, the application offers a practical and scalable solution that aligns with global efforts to promote smarter, greener cities and demonstrates the potential of technology-driven carpooling systems to transform daily mobility practices.

Keywords— Carpooling, Ride-Sharing, Mobile Application, Agile Methodology, Urban Mobility, Sustainable Transportation, Firebase, Flutter

INTRODUCTION

Urban areas are experiencing growing pressure on transportation systems due to escalating traffic congestion, longer commuting times, increasing travel costs, and higher carbon emissions, which highlight the urgent need for more sustainable and efficient mobility solutions [1]. Carpooling has been recognized as one of the most effective approaches to address these issues. By allowing multiple passengers to share a single vehicle, carpooling reduces the number of cars on the road, lowers fuel consumption, and decreases greenhouse gas emissions [2]. Studies indicate that even a modest shift toward carpooling adoption can contribute significantly to reducing carbon emissions while improving traffic flow in densely populated cities [2].

Although the benefits of carpooling are clear, adoption levels remain low. Many commuters are discouraged by safety and privacy concerns, a lack of trust in sharing rides with strangers, and the absence of reliable platforms to support organized ride-sharing [3]. Recent research suggests that incentives such as reduced commuting costs, supportive institutional policies, and improved digital platforms can positively influence commuters' willingness to adopt carpooling practices [3].

Technological advancements have also created opportunities to enhance the effectiveness of carpooling systems. Studies on high-capacity ride-sharing demonstrate measurable benefits, including a reduction of traffic congestion by up to five percent and a decrease in emissions by as much as 50 percent [4]. Similarly, dynamic ride-matching algorithms have been shown to reduce passenger waiting times and improve the efficiency of pooled trips [1].

Building on these findings, this project introduces the design and development of a Carpool Ride-Sharing

Application that integrates essential features such as secure user authentication, trip scheduling, real-time GPS tracking, cashless payment systems, driver verification, and user reporting. By leveraging location-based services and route optimization, the platform improves the accuracy of ride-matching while ensuring user convenience and safety. Developed using the Agile methodology, the system supports iterative refinement and scalability. The ultimate goal of this application is to promote sustainable urban mobility, reduce dependence on single-occupancy vehicles, minimize commuting costs, and contribute to environmentally responsible transportation practices.

Related works

Shared mobility platforms such as Uber, Lyft, and BlaBlaCar illustrate the promise and challenges of technology-enabled ride sharing. Uber and Lyft provide on-demand ride-hailing services via mobile apps, with pooled options such as UberPOOL and Lyft Shared Rides aimed at increasing seat occupancy and reducing costs. However, research highlights user resistance stemming from longer wait times, detours, safety hesitations, and unpredictable surge pricing, making them less appealing for cost-conscious, daily commuters [5][6].

Bla Bla Car, in contrast, facilitates long-distance carpooling by allowing drivers to publish planned trips and enabling passengers to book available seats. This structure builds trust through user profiles, ratings, and cost-sharing. BlaBlaCar has demonstrated real environmental benefits, for example, its 2022 impact report estimates a reduction of 1.5 million tonnes of CO_2 emissions, €450 million saved by drivers, and 90 million community connections that showcasing how structured carpooling can scale [7].

Table 1. Comparison of Proposed And existing Ride– sharing System

Aspect	**Carpool Ride-Sharing Application (Proposed)**	**Existing Ride-Sharing Systems (Uber, Lyft, BlaBlaCar)**
Ride Matching	Real-time matching for commuters based on route and timing.	Focused on ride-hailing; limited carpool matching.
Cost Management	Cashless payments with shared cost options.	Individual ride payments; no true cost-sharing.
Safety Features	Driver verification, live tracking, emergency support, and ride preferences.	Basic driver ratings; limited safety features.
Scheduling	Advance trip scheduling with real-time updates.	Mostly on-demand requests; no commuter scheduling.
Environmental Impact	Aims to reduce single-occupancy vehicles and carbon footprint.	Limited focus on sustainability.
Target Audience	Daily commuters, students, and eco-conscious users.	Casual riders seeking on-demand trips.

By comparison, the proposed Carpool Ride-Sharing Application targets daily urban commuting with structured trip scheduling, real-time ride matching, and predictable costs. It emphasizes safety through authentication, GPS tracking, and user reporting. Unlike Uber and Lyft, it avoids dynamic pricing in favour of commuter-

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oriented features. Unlike BlaBlaCar, it supports short-distance, high-frequency trips within cities, making it a more practical and sustainable option for regular commuting.

METHODOLOGY

The development of the Carpool Ride-Sharing Application adopted the Agile methodology, which emphasizes iterative development, adaptability, and continuous user feedback. Agile was selected because of its suitability for mobile and web-based applications where requirements often evolve based on user needs and technological constraints [8]. This iterative approach ensured that the system could be incrementally developed, tested, and refined to align with project objectives.

Planning

The planning phase established the project's scope, objectives, and user requirements. Key functional requirements included user authentication, trip scheduling, GPS integration, and cashless payment. Non-functional requirements emphasized usability, scalability, and data security. Agile user story mapping was used to define and prioritize features, creating a product backlog to guide subsequent sprints [9].

System Design

The Carpool Ride-Sharing Application adopts a layered, modular architecture to ensure scalability, performance, and ease of maintenance. The architecture is structured into three primary tiers as shown in figure below:

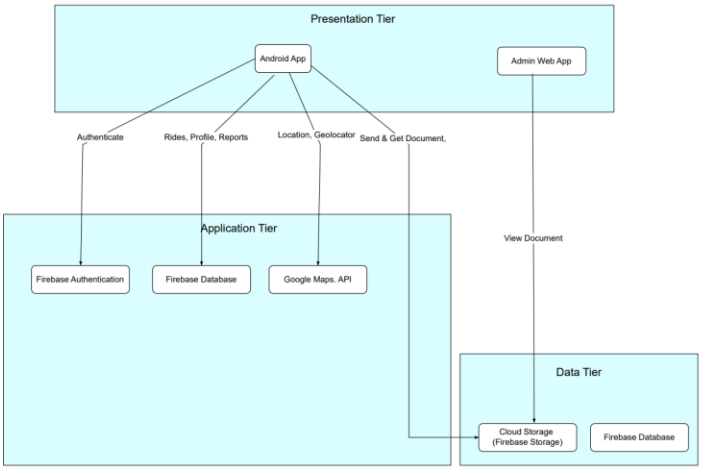

Fig 1.Architecture Design Proposed Application

The Presentation Tier serves as the interface between the system and its users. It includes the Android mobile application, which allows passengers and drivers to authenticate, create profiles, schedule trips, track rides in real time, and manage reports. An additional web-based administrative panel supports system administrators in monitoring activity, verifying drivers, and reviewing safety reports. By focusing on usability and accessibility, this tier ensures that both end users and administrators interact with the system through intuitive and user-friendly interfaces.

The Application Tier forms the core processing layer that links the presentation layer with backend services. It integrates Firebase Authentication for secure user login, a Firebase Database for handling real-time storage and retrieval of ride information, and the Google Maps API for location-based services such as route planning and ride tracking. All business logic, including authentication processes, trip scheduling, ride matching, and notifications, is managed within this tier, ensuring smooth communication between users and the system.

The Data Tier manages persistent storage and ensures secure data handling. It relies on Firebase Cloud Storage to manage documents and uploaded files, while Firebase Database stores structured records such as user

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profiles, trip details, and transaction histories. This design guarantees real-time synchronization of data across devices, providing a consistent experience for all users.

By clearly separating system responsibilities across these tiers, the architecture supports modular development and allows independent scaling of user interfaces, core functionalities, and data storage. This structure also aligns well with Agile development practices, as it enables incremental feature delivery, rapid testing, and iterative refinement without disrupting the entire system.

Development

The development phase was guided by the Agile methodology, where system features were implemented iteratively and tested continuously. One of the core modules developed was the user authentication process, which was implemented using Firebase Authentication integrated with the Flutter mobile application. Figure 2 illustrates the sequence diagram of the registration and login workflow, showing the interactions between the user, the mobile application, and Firebase services.

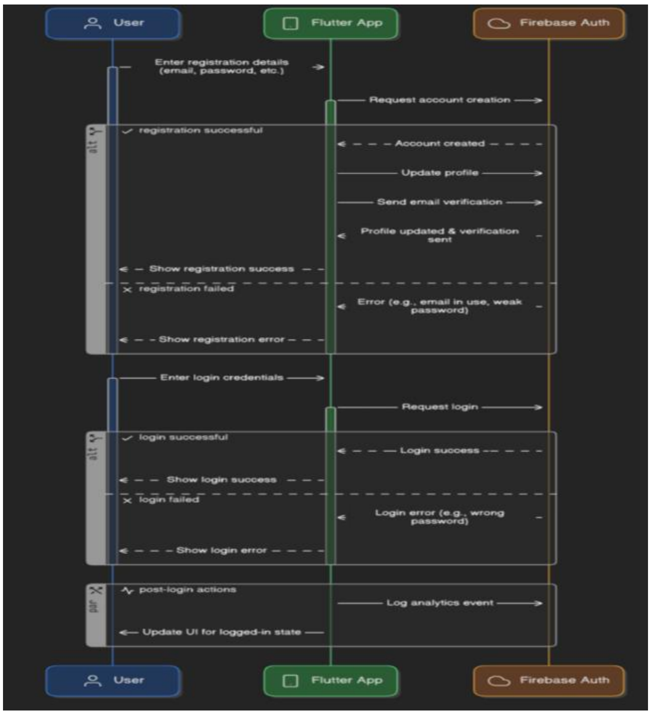

Fig 1. Sequence Diagram Proposed Application

During the registration process, the user begins by entering their credentials such as email, password, and other required details through the mobile interface. The Flutter application then forwards this request to Firebase Authentication, which creates a new account and securely stores the credentials. Following successful account creation, Firebase sends an email verification to the user, and the system updates the user profile within the database. If any errors occur, such as duplicate accounts or invalid input, the error messages are sent back to the application for user notification.

For the login process, the user submits their credentials via the application, which are then validated by Firebase Authentication. If the login attempt is successful, the user gains access to the system, and the interface is updated to reflect the authenticated state. In case of incorrect credentials or other errors, Firebase returns an appropriate error message, which is displayed to the user. Additionally, login events are logged for analytics and monitoring purposes, enabling administrators to track system usage patterns and improve performance.

This structured approach to authentication ensures that the system maintains secure, real-time, and user-friendly access control. By leveraging Firebase Authentication within the Flutter framework, the application achieves both strong security and seamless integration, which aligns with the project's goal of ensuring privacy and reliability in carpooling services.

Evaluation

The evaluation phase of the Carpool Ride-Sharing Application was carried out using black-box testing, a software testing approach that examines the functionality of the system without considering its internal code structure. This method was chosen because it closely reflects how end-users interact with the application, thereby ensuring that the system behaves according to requirements and delivers a consistent user experience.

Table 1. Black Box Test Cases For Proposed Application

ID	Input Condition	Expected Output	Actual Output	Result
TC01	Valid email, valid password, complete profile	Account created successfully, verification email sent	As expected	Pass
TC02	Invalid email format (e.g., user@)	Error message: “Invalid email format”	As expected	Pass
TC03	Password less than 6 characters	Error message: “Password too short”	As expected	Pass
TC04	Valid email and correct password	User successfully logged in	As expected	Pass
TC05	Valid email but incorrect password	Error message: “Invalid credentials”	As expected	Pass
TC06	Valid trip details (origin, destination, time)	Trip scheduled and stored in database	As expected	Pass
TC07	Missing destination field	Error message: “Destination required”	As expected	Pass
TC08	Multiple passengers request same route/time	Passengers matched with available driver	As expected	Pass
TC09	No available driver	Notification: “No drivers available”	As expected	Pass
TC10	Valid card details, sufficient balance	Payment processed successfully	As expected	Pass
TC11	Invalid card number	Error message: “Invalid card details”	As expected	Pass
TC12	Network error during transaction	Error message: “Transaction failed, please retry”	As expected	Pass

By adopting black-box testing, the evaluation ensured that the application satisfied user requirements while maintaining robustness and security. The outcomes of these tests confirmed that the application’s core features operated correctly under different scenarios, supporting the system’s effectiveness as a secure and reliable ride-sharing solution.

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RESULT

The User Interface (UI) of the Carpool Ride-Sharing Application was designed to prioritize usability, consistency, and clarity for both passengers and drivers. Screens from the system are presented in this section to illustrate the implemented functionalities. Each page of the interface was created to address a specific system requirement, ensuring that users can navigate the application efficiently.

Registration and Login

Users need to use email and enter required details for creating account and login.

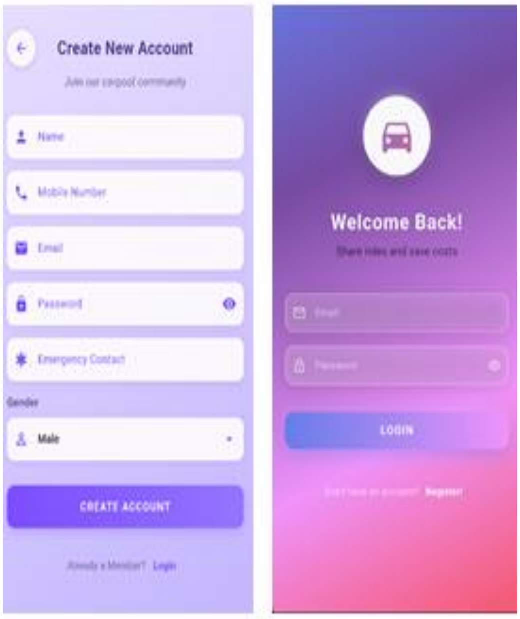

Fig 1. Registration and Login Interface

Find Ride and Offer Ride

User will be able to enter the details required to request for rides and offer rides to others.

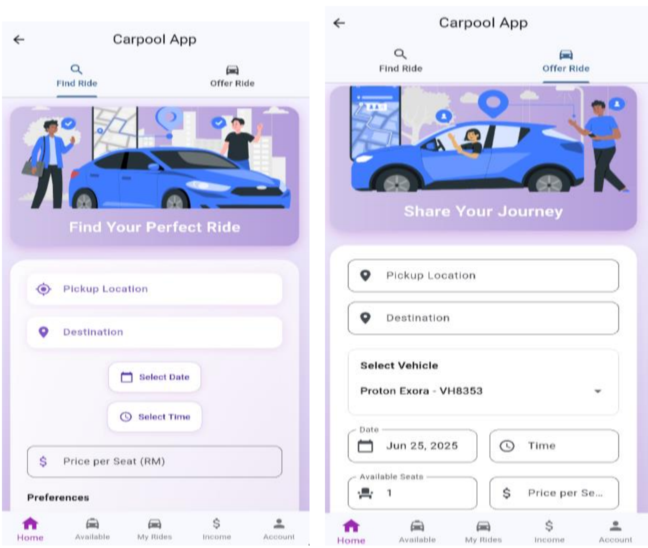

Fig. 1. Homepage Interface

Available Rides

Users can browse through the Ride Offers tab and Ride Requests tab to either book or accept rides.

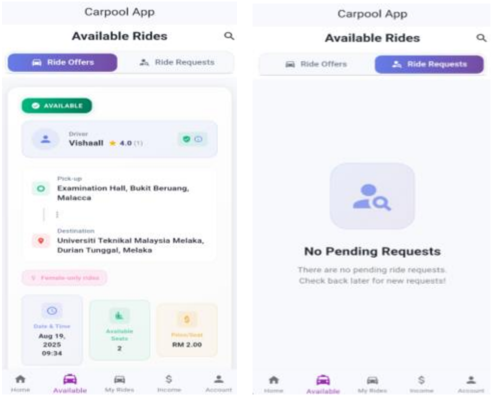

Fig 1. Available Rides Interface

My Rides

User can view, manage and delete their bookings, requests and also ride offered in the My Rides screen. The rides here are categorized based on their status for easier access.

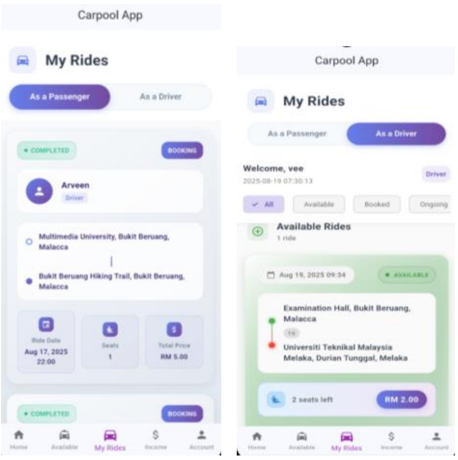

Fig.1. My Rides Interface

Map

GPS permission must be granted by users for location tracking.

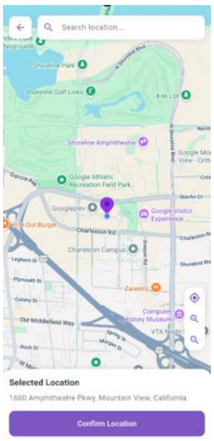

Fig.2. Map Interface

Income Dashboard

User can view the income made by completed rides, ride statistics are also displayed for better tracking.

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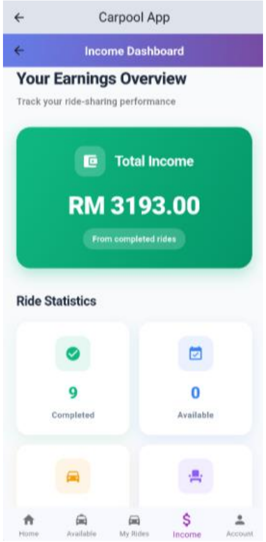

Fig.1. Income Dashboard Interface

Profile Management

Users can view and edit their profile and save changes in the account screen.

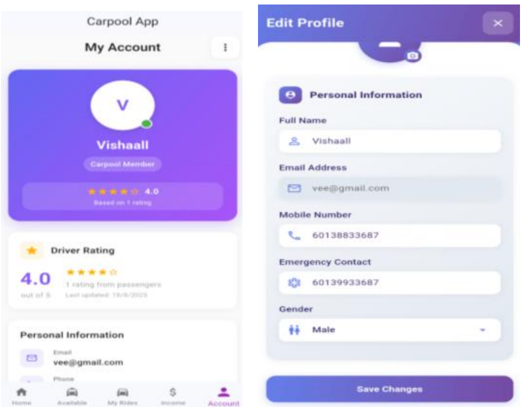

Fig.1. Profile Management Interface

Manage Vehicles

Users can add and delete vehicles.

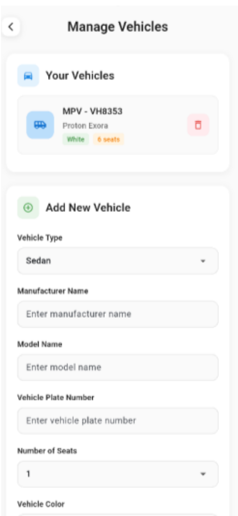

Fig..1. Manage Vehicle Interface

Manage Documents

Users can submit driver licenses to get approval from admin and get access to driver features.

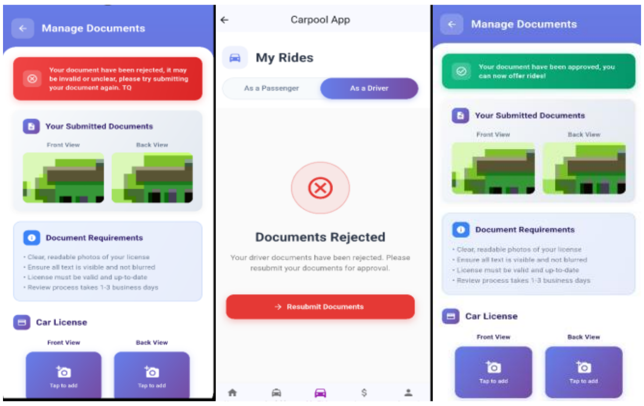

Fig.1. Manage Documents Interface

Report issue

Users can issue a report through the report feature and it will be reviewed and take further action if needed. Admin will keep the report status up to date.

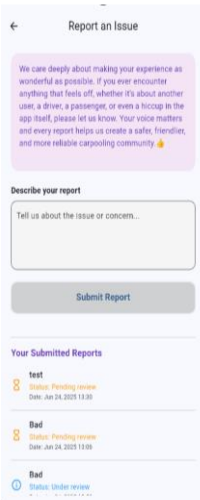

Fig. 2. Report issue Interface

Ride and Booking Details

The page where it will display the details of a booking for the driver and passengers. The journey status also will be updated here. The user will be able to see the passenger and driver information together with a calling feature to communicate.

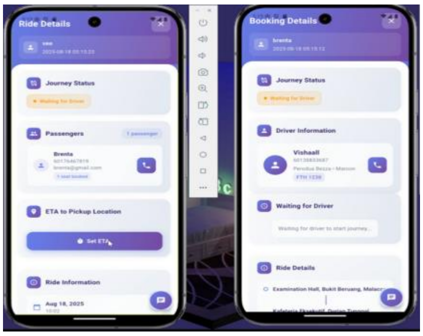

Fig.1. Ride and Booking Details Interface

ETA timer

This timer will be started by the driver when the driver is on the way to the pickup location. The timer will run simultaneously and display for the passengers to see too. This is to give a estimation time of the driver's arrival to the pickup location.

Fig.1.ETA timer Interface

Live Map Tracking

The map will display the live location of the driver, it will be displayed for both the driver and passenger. The map will have markers and route line for the pickup and destination too.

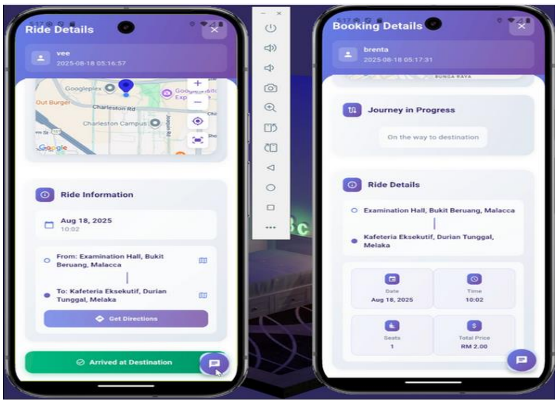

Fig.1. Live Map Tracking Interface

Chat Box

The chat feature works like a group chat which includes the driver and all the passengers of that booking. This will be a better communication system as it includes multiple passengers.

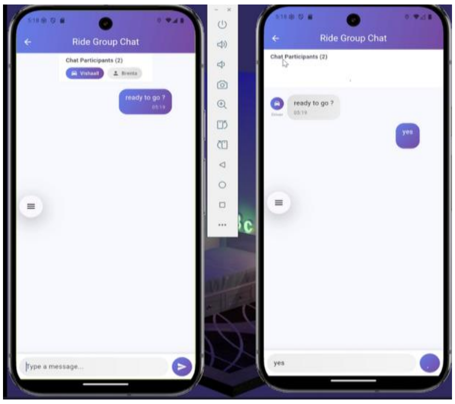

Fig.1. Chat Box Interface

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Payment

The payment process is powered by Stripe. The payment will be made separately by each passenger depending on the number of seats booked respectively. Once each passenger has made payment, it will update the driver

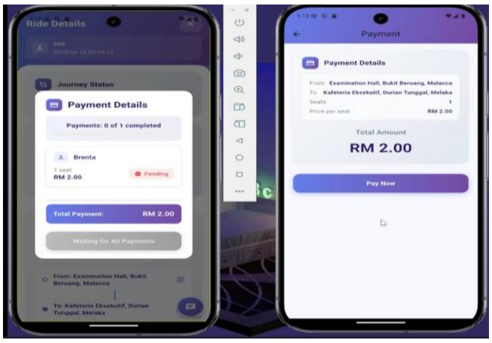


Fig.1. Payment Interface.

Rating

After the ride is completed, the passenger will be able to rate the driver and give feedback. The driver will be able to read his feedback on the account page.

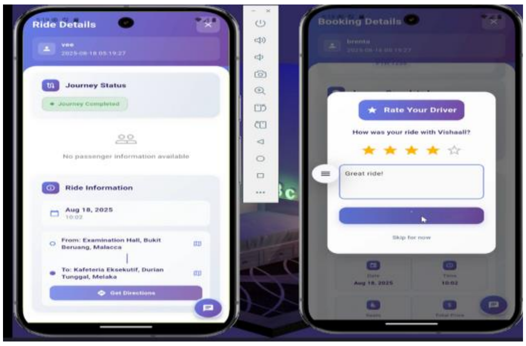


Fig..1. Rating Interface

SOS feature

The SOS feature is one of our safety features, especially for the passengers. There will be a red SOS button, where when the passenger clicks it first it will ask for confirmation on this action. (This confirmation question can be set by the passenger to "Don't ask this again" and be reset too). When the passenger click continues it will provide 2 options of the SOS action. The first option is it will send important information such as SOS messages, current location of the passengers, and ride details to the emergency contact saved by the passenger. Second option is to directly dial 999.

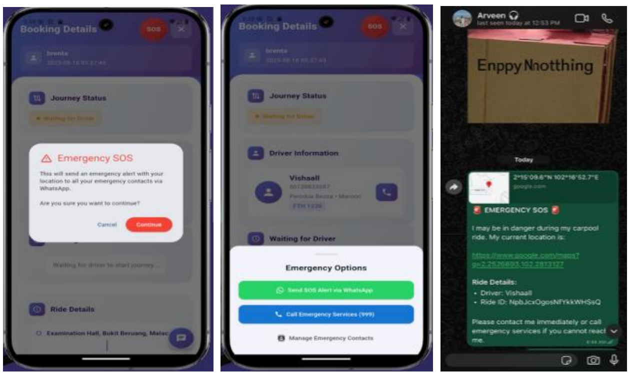


Fig.1.SOS Interface

Admin Login and Register

Admin can register for accounts and login just by using Gmail.

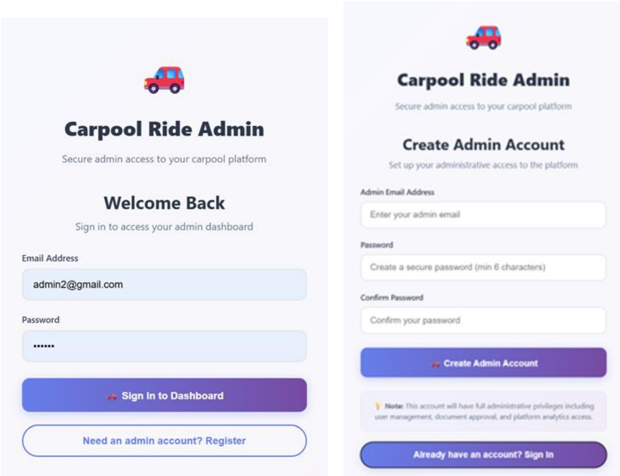


Fig.1. Admin Login and Register Interface

Admin Dashboard

The dashboard is simple and could easily be navigated as all the key features are on the dashboard.

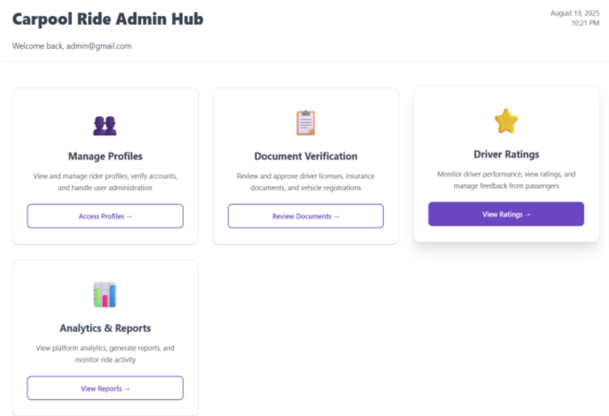
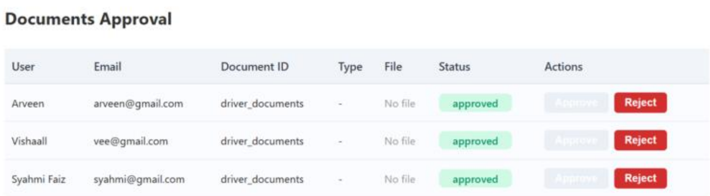


Fig.1.. Admin Dashboard Interface

Documents Approval

Admin can view, verify and approve/reject the document.



Documents Approval

User	Email	Document ID	Type	File	Status	Actions
Arveen	arveen@gmail.com	driver_documents	-	No file	approved	Approve Reject
Vishaall	vee@gmail.com	driver_documents	-	No file	approved	Approve Reject
Syahmi Faiz	syahmi@gmail.com	driver_documents	-	No file	approved	Approve Reject

Fig.1. Documents Approval Interface

Report Management

Admin can review reports and update the status of the report to notify the user. Admin can act if any user is misbehaving.

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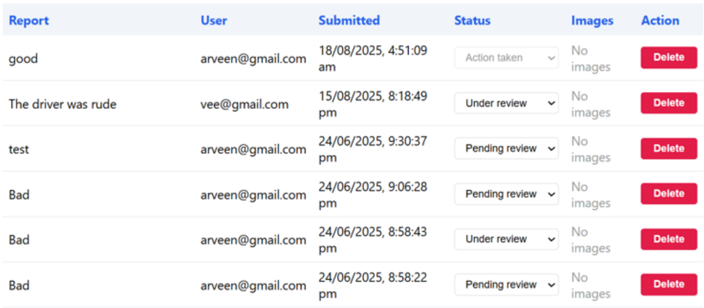

Fig.1. Report Management Interface

Admin Profile Management

Admin can add, update and delete users.

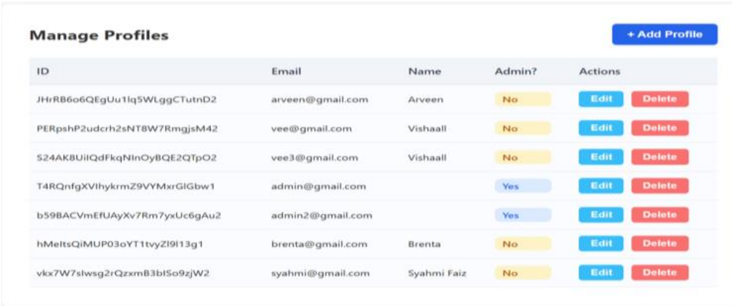

Fig.1. Admin Profile Management Interface

Driver Ratings and Feedback

Admin will be able to monitor driver performance, view ratings with filters, and manage feedback from passengers if necessary.

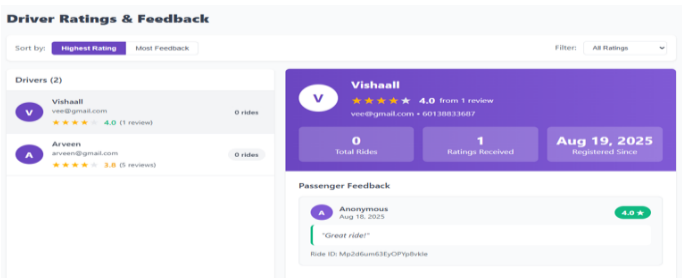

Fig.1. Driver Ratings and Feedback Interface

DISCUSSION: REGULATORY, CULTURAL AND INSTITUTIONAL FACTORS

Although the Carpool Ride-Sharing Application demonstrates strong potential from a technological perspective, adoption of such systems is also influenced by broader contextual factors. A more holistic understanding requires examining the role of regulatory, cultural, and institutional dimensions in shaping commuter behaviors and system scalability.

Regulatory Factors

Public policy and regulations directly affect the feasibility and attractiveness of carpooling. In supportive environments, governments implement incentives such as High Occupancy Vehicle (HOV) lanes, reduced tolls, and parking benefits that encourage shared commuting. Clear guidelines on liability, insurance coverage, and data protection are equally important to reduce legal uncertainties for both drivers and passengers. Conversely, regulatory ambiguity or burdensome restrictions may discourage adoption despite technological readiness.

Cultural Factors

Commuter willingness to engage in carpooling is also tied to cultural attitudes toward sharing and trust. In collectivist cultures, resource-sharing practices are generally more accepted, facilitating faster adoption. In more individualistic settings, however, commuters may hesitate due to concerns over privacy, personal space, or safety when traveling with strangers. Gender considerations are especially critical, as female passengers may prefer gender-matching features or enhanced safety assurances before participating. Addressing these cultural expectations helps normalize carpooling as a viable alternative to single-occupancy commuting.

Institutional Factors

Institutions such as workplaces, universities, and municipal authorities play a pivotal role in embedding carpooling into daily routines. Employers who offer financial incentives, flexible scheduling, or priority parking for carpoolers create a more favorable environment for adoption. Similarly, educational institutions can encourage student-led carpooling initiatives as a means of reducing commuting costs and alleviating parking constraints. Local governments can strengthen these efforts by integrating carpool pick-up points into transport hubs and urban planning strategies.

Implications for the Proposed Platform

The proposed Carpool Ride-Sharing Application can be extended to align with these broader influences. By ensuring compliance with transportation regulations, providing culturally sensitive safety features, and enabling integration with institutional programs, the platform can maximize adoption potential. Such alignment positions the system not only as a technological solution but also as a socially adaptable mobility service that complements policy goals and community values.

Behavioural Drivers and Barriers

User adoption of carpooling is not only shaped by regulatory and institutional contexts but also by individual perceptions and behaviors. Surveys and case studies from previous research reveal that trust, safety, cost savings, and convenience are among the strongest motivators for adoption. Conversely, reluctance often stems from concerns over ride reliability, loss of personal flexibility, and discomfort with traveling alongside strangers. Including user surveys in future iterations of this study would provide empirical insights into how commuters in different contexts perceive carpooling. Such evidence could guide refinements in application features, ensuring they directly address users' behavioral drivers and barriers.

CONCLUSION AND FUTURE DIRECTIONS

This project successfully developed a Carpool Ride-Sharing Application that provides a secure, cost-effective, and environmentally friendly alternative to traditional single-occupancy transport. The system integrates core features such as user authentication, trip scheduling, ride matching, real-time tracking, payment integration, and an admin panel, all built on Firebase services and Google Maps API. The adoption of Agile methodology enabled iterative development, stakeholder feedback, and continuous improvement, while black-box testing validated that all major functionalities performed as expected under diverse scenarios.

The application demonstrates strong potential to reduce commuting costs, traffic congestion, and carbon emissions by promoting shared rides. Compared with existing ride-hailing services like Uber, Lyft, and BlaBlaCar, the proposed solution emphasizes commuter-focused carpooling, enhanced safety, and customizable user preferences. Looking forward, the system can be extended with features such as artificial intelligence–driven ride predictions, dynamic pricing, and stronger security mechanisms to further increase efficiency, user trust, and adoption on a larger scale.

Additionally, future work could expand the platform by conducting user-cantered studies, such as surveys or pilot case studies, to better capture behavioural motivations and hesitations surrounding carpooling adoption. Exploring integration with public transport systems and smart city infrastructure would enable the development of multimodal mobility solutions. By linking carpooling services with bus, train, or micro-mobility networks, the platform can evolve into a more scalable and adaptable component of urban transport ecosystems. This aligns with broader smart city objectives of reducing congestion, lowering emissions, and providing commuters with seamless, flexible, and sustainable mobility options.

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