# CarmaGO

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## Abstract

**This report presents CarmaGO, an innovative web based application designed to empower electric vehicle owners to maximize mobility , usability and profitability of their cars. CarmaGO allows users to choose between personal use and offering their idle electric vehicles as a driverless taxi jobs for possible extra income and increasing the efficiency of urban transportation networks. The web based app provides real-time data, advanced map and location services also offering reliable scheduling algorithms to enable a smooth transition between personal and commercial use, this technology allows users to understand the underutilization of their personal vehicles. CarmaGO aims to transform individual mobility and support a more stable , connected and more flexible urban transportation ecosystem by keeping up with the quick development in electric and driverless AI driven car technologies. CarmaGO systems concept , development and assessment are covered in detail in this paper, also with an examination of its possible effects on users.**

## Acknowledgements

**The journey of bringing CarmaGO to life has been both challenging and rewarding, it is only possible because of the collective efforts and encouragement of many people around me. I am also deeply grateful for lecturers, supervisors , module leaders for accepting this project and providing feedback during the development pushed me to think beyond the obvious and aim higher.**

**I would like to also thank to my friends for their honest opinions on my work, helping me bug testing and giving me ideas to even take this project further.**

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# Introduction

CarmaGO is a forward thinking mobile and web application that aims to revolutionize personal transportation by giving individual user the flexibility and complete control over their driverless cars. Just imagine how magnificent it sounds to simply typing in your destination in our app and having your driverless electric car handle the rest for you. By simply typing in your destination the application will navigate and calculate the safest and fastest route while you enjoy the ride or focus on your other tasks in meantime. The idea for CarmaGO was born out of the increasing demand for a more reliable and more economic transportation as our cities get denser and traffic jams start to become a huge problem. Traditional ways of ride-hailing services still continue to use human drivers, unpredictable times and high pricing. CarmaGO on the other hand adapts into the rapidly advancing world of driverless technology to improve personal transportation to make it smoother, more efficient, budget-friendly and potentially profitable for car owners.

CarmaGO isn't just about traveling in your private driverless car. It also offers an opportunity to monetize your vehicle when it's idle. If your car is not in use at that time and sitting somewhere unattended , you can easily assign taxi jobs to your driverless vehicle this could potentially transform your investment to the driverless car into a potential source of income. This concept builds on the sharing economy model popularized by car sharing services but our app takes it a step further by eliminating the need for a human driver. By doing this CarmaGO hopes to close a market gap by utilizing autonomous technology to provide affordable, on-demand transportation and allowing car owners to make money while their vehicles are not in use. This feature stands out as an essential cost-effective solution in a world where cars are the main transportation type but usually too costly, or another solution for where cars are frequently left unattended for a long period of time.

Moreover, one of CarmaGO's abilities is to let you remotely control and call you're your self-driving car from wherever it is parked. Instead of long walking distances to your car or paying extra money for parking spots,this feature of our application allows you to summon your vehicle with a simple request and the car will drive to you automatically. This flawless experience highlights the app's focus on accessibility and user friendly interfaces, two elements that are important for promoting widespread adoption. On the other hand, CarmaGO could offer newfound independence by simplifying how they get from point A to B for the individuals that have mobility issues.

The core values of CarmaGO are convenience, simple navigation, and route optimization. The system will use algorithms to calculate the most efficient path to reach your destination quickly and safely. Even more you can use the app's remote control features to schedule a pickup time, change routes middle of a trip, and make sure your car is safe and secure. In order to provide a responsive, reliable platform that can manage user requests at scale CarmaGO will technically integrate a number of technologies including HTML/CSS for the front end and Python , Java, (etc) for the back end to make sure that the application is working effectively and efficiently. CarmaGO is also going to be on android mobile devices. To adapt this application to mobile devices, software's like android studio will be used. To make sure that we have a secure accessible database the system might contain MongoDB, Firebase or MySQL.

We will go into greater detail on the design ideas, current research and technological foundations that impact CarmaGO's development in the parts that follow. By investing the state of driverless innovation today. Also we will be going over secure data handling best practices and looking at how comparable services have handled the on demand mobility. This application meets the present issues while remaining adaptable to future developments. This integrated new perspective of travelling makes sures that CarmaGO not only meets the immediate transport needs but also sets the foundation for a future where world becomes fully automated and customized travel will be the new standard.

## Literature Review

Integration of artificial intelligence  to the vehicles have been improving and evolving by a huge amount since the early 2000s. One of the most important self-driving technology competition was held in summer 2002. The company that hosted the Grand Challenge was called Defence Advanced Research Projects Agency (DARPA). The Grand Challenge was a competitive comparison of autonomous cars and there was time limitation and the route was pretty challenging it was leading from Los Angeles to Las Vegas which is approximately 210 miles and it was required to be completed under 10 hours. These contests, played a huge role in the industry and help to set the foundation for advanced sensor integration, machine learning algorithms and robust control systems that guide our modern day autonomous cars. Today companies like Waymo, Tesla and General Motors Cruise have come up as some of the leaders in the field today. The focus of their study is mainly focusing on processing data, radar and video inputs in real time to recognize obstacles on the roads such as road markings, barriers, and traffic patterns.

Even though there are impressive advancements, many challenges still stand in the way of integration of artificial intelligence in the autonomy sector. For example detecting the obstacles on the roads with sensors could be really heavy on the computer side because it requires combination of many data from many sensors. Furthermore, law standards differ across countries and it creates questions about who is responsible in the event of an accident involving a car working fully with artificial intelligence. There is also two types of people in the public ones that are really excited to see the driverless cars and supporting it to happen and the ones that are hesitant to give full control to the artificial intelligence

Literature on driverless cars often focus on their high potential to reduce operational costs by removing the need for a human driver and optimizing the routes for fuel or battery efficiency. Some people believe that this adoption could increase traffic safety, reduce traffic and most importantly create new business opportunities offering their vehicles as a service model. For example people that own cars can rent out their autonomous vehicles when they are not in use. These changes could reshape the labour markets and displace professionals drivers.

There are two or three big companies leading in transportation some of them are Uber , Lyft and Bolt all these apps makes  transportation possible for people need to get from point a to b quickly.

All of these apps connect passengers to the nearest driver through their mobile app with single request from the user. Using these applications makes it easy for customers to travel quickly and reach their destination faster especially in big cities. However these services could be really costly for some people because these services all rely on human drivers, also another which can lead to higher prices is the demand, if there are many people requesting for rides but there are not many drivers the prices will most likely to appear higher, on the other hand if there are not many people looking for rides but there are many drivers, most drivers will not get customers which will result in bad ways. But despite this, apps like Uber etc. have changed the way many people view transportation by providing an app based model.

If we talk about Uber in particular, it stands out for its fast global expansion and expanding their apps to try new ideas, such as Uber Eats they have tested food delivery and it is one of the leading delivery apps in the world as well. They have also tried ideas like helicopter rides and electric scooter rentals, which shows that they are open minded and willing to try new ideas to adapt to the growing technology. Uber have also experimented with some self-driving technology through Uber ATG (Advanced Technologies Group) which later sold. Uber still relies on human drivers around the world. In short Uber has proven that the people appreciate on-demand travel but still they have not eliminated the need for a human drivers or the costs and concerns that come with that.

On the other hand, Tesla has done something similar to CarmaGO, they have created the Tesla Network where owners could let their vehicles offer rides while they are not being used. Although Tesla cars provide a self-driving feature it is not completely driverless and it need a human supervision in most scenarios, especially some regions with legal restrictions. This basically means that Tesla's taxi service is not fully active yet even though most of the car owners rely on the companies self-driving technology.

There are also car sharing services like Zipcar and Turo as one of the most popular ones in the market. Zipcars business idea is that the company places many vehicles around the city spots so that the members can rent them by the hour or day, while Turo allows private owners to list their cars for rent. Both of these businesses help owners offset the cost of car ownership, but still these businesses still rely on human drivers to pickup and drop off vehicles and the cost of gas is something that we can consider since the cars that they use mostly rely on gas as well.

CarmaGO application basically an app that combines and contains all the features that the other apps listed offer. One of the key differences is that our application does not require a driver to be present because it is all automated and this feature will allow the owner to send their driverless car out for taxi jobs if the car not in use. The APP combines the future of electric self-driving vehicles with the todays ride-hailing app. Because there is no driver the car will drive to the customer by itself and this will solve issues like driver unavailability. In conclusion CarmaGO puts all of these ideas together to make one application and fills the gap in the market for the need of cheap safe rides.

The process of developing the app we will be combining several programming languages together to create the perfect application for our users. The aim is to make the interface user-friendly , clear and understandable. And obviously the testing is one of the crucial parts of developing, during this development process, tests of the functions will take place regularly to make sure everything is up and running

The web version of CarmaGO; just like uber our application will offer a website easily accessible from laptops or any web  browser. It will be built using HTML, CSS and JavaScript . HTML will be used to structure the content of the website, creating the pages, including forms for signup and log in pages. CSS will be used to style it and give it visually satisfying design, making the interface modern responsive and easy to use. JavaScript will be essential for adding interactive features such as button animations, user notifications. All of these together will be used to create the Front end of the website. The backend of the app will rely on python because its flexibility. Python will handle user authentication, data processing and the integration of third-party APIs like google maps. It will also be used for real time updates like tracking its location or monitoring its status. CarmaGO will also be developed as a mobile application for Android devices using Kotlin and Java in Android Studio. Making sure that website and the android app works on different size devices is crucial as well, so the website and the app will be usable on many size of devices such as desktops , tables or smartphones.

The most important is the integration of Google Maps, this plays a huge role in the application without this the app would be nothing. CarmaGO will use Google Maps API, Google Maps is one of the best maps to use because of its simple use and its details. By adding this feature users should be able to select destinations and track its progress during the ride. The API will allow the app to calculate the fastest and safest routes using the maps this will improve the user experience and reduce the travel time. For secure data handling MongoDB should be used as a database. MongoDB is really nice and ideal for handling large data like user profiles or ride requests or payment history. MongoDB works perfectly with python so it should be easy to connect them both to the backend, this will make sure that data is received correctly and stored securely.

# Requirements

The development of CarmaGO is guided by a set of requirements and aimed and focused to deliver a practical, user-friendly and technologically robust platform for both electric car owners and passengers without a car. As the beginning CarmaGO must allow users to create account and then log-in. This is followed by registering their personal car to the database with a name, model of the car and a valid address. This platform also allow car owners to view and manage their car fleet and set cars as available for taxi jobs or for personal use with minimal cost. The core key functional requirement is the integration of real-time car location tracking and mapping services. The integration of these services makes it easy for the user to locate, dispatch and monitor their vehicles accurately on a city-wide scale using Google Maps API.

CarmaGO must enable passengers to request rides easily and automatically matching them with the closest available vehicle, providing clear route, ETA and fare calculation. Real time updates are crucial for user experience and they should be able to access and view live changes in car location, status and battery level throughout the entire journey. The system must provide dynamic scheduling, secure data storage and scalability in order to accommodate several users and cars at once. In addition to that web and mobile interfaces are required to work in different types of devices or sizes to ensure accessibility.

**Functional Requirements:**

- User registration, login, and profile management
- Edit account details and support deletion
- Add, edit, and remove electric vehicles from a user account
- Update car status Idle, Working, Charging
- Set vehicles as available for taxi jobs if the car is Idle
- Request rides and match users to the nearest available car
- Allow multiple rides on different cars if the user has multiple cars in their fleet
- Real-time tracking and visualization of vehicles using Google Maps
- Display of ride ETA, route, and battery status during trips
- Account and car management (update details, delete account/car)
- Simulate charging and ride progress, with live updates
- Support for real-time ride notifications: Notify the rider and the car owner when ride is requested
- Ride accept modal : Notify the owner if the ride is requested give and 20 second timer to accept
- Fare estimation and calculation: Automatically calculate fare based on distance using Google Maps API
- Role Flexibility: Allow users to be a car owner or a passenger
- Reverse geocoding: Convert the lat and long variables to display as human readable addresses
- Finance and transactions UI: Provide users with a friendly easy to read ride related income and expenses
- Google Maps Autocomplete integration : Enable easy selection of addresses for car locations
- Multi car fleet management: Allows users to add more then one car if they own multiple cars and display them in dashboard
- Ride History Tracking : Lets both users and car owners to access the ride history to track down how many rides have been completed or cancelled

**Non-Functional Requirements:**

- Web and mobile accessibility with a responsive interface
- Secure storage and transmission of user and vehicle data
- High system availability and reliability for real-time updates

- Fast response times for user actions and ride status changes
- Scalable backend to support increasing user/car numbers
- Data privacy and compliance with relevant standards (e.g., GDPR)
- Error handling and user feedback: All operations provide clear feedback such as success warning and errors to guide user actions
- Support for containerized deployment: Backend supports docker for development, testing and scalable production deployment
- Session management and local storage : User login sessions and state are maintained using secure local storage, this would restore rides and account logged in without breaking the program or needing to log in every refresh.

# Methodology

## 1. Research and Planning

The development of CarmaGO began with a review of existing literature on autonomous vehicles and ride sharing platforms This research part kindly explains the key technological trends, user needs, and gaps in current solutions, informing the project's objectives and feature set. Requirements were gathered through analysis of academic sources, industry reports, and user feedback, ensuring alignment with real-world demands and best practices.

## 2. System Design

A three-tier architecture was chosen to make the system easier to grow, update and manage. The system uses the Docker to help run and connect each part smoothly. There are clear sections for the user interface, the main server logic and the database. This project was made focused on keeping the system safe fast and easy to use from the start

## 3. Incremental Development

The system was developed step by step, adding and testing each big feature separately before putting everything together. The front end was made using HTML5, CSS3 and JavaScript. However on the other hand the backend was fully built using Python Flask, following RESTful API rules and using WebSocket (Socket.IO) for real-time updates. MongoDB was the perfect fit for this system because of its modernity and its ability to easily handle different types of data.

## 4. Testing and Validation

Testing was conducted at multiple levels:

- **Unit Testing:** Individual components and functions were tested to correctness.

- **Integration Testing:** End-to-end workflows were validated to confirm seamless interaction between system components.

- **User Acceptance Testing:** Demo scenarios were used to gather feedback and validate usability.

- **Performance Testing:** Ensured real-time features were quick  and could handle many users.

Also used automated tools and continuous integration to keep the code high quality.

## 5. Deployment and Project Management

Git was used to keep track of the code changes. Docker compose helped with running all the parts of the system easily and made it simple to set up and scale. All the tasks were in a list to keep track of the milestones and to stay organized. Regular check-ins with friends and feedback helped the project to stay on the track and finish the project on time.

## 6. Documentation and Evaluation

As mentioned before detailed documentation was kept throughout the project, covering how the system is built, how the APIs work, the database layout and how to set everything up the final evaluation included :

- **Functional Testing:** Main feature functions such as login, car management, ride requests, and live notifications, were carefully tasted to ensure everything worked well and reliably

- **Performance Evaluation:** Checked the system response times, database efficiency, and real-time update latency under concurrent user loads, with optimizations such as MongoDB indexing and better database connections.

- **Usability and Accessibility:** Reviewed user interface to ensure it was easy to use and accessible to everyone, including clear navigation, good colour contrast, alt text and keyboard support.

- **Security Assessment:** Validation of security measures through code review and testing, including protection against XSS, CSRF, and other vulnerabilities, as well as secure API endpoints and session management.

- **Deployment and DevOps:** Testing of containerization and orchestration using Docker and Docker Compose, with integration of environment-specific configurations and monitoring tools for production readiness.

- **User Feedback:** Collection and analysis of feedback from beta testers such as friends to identify strengths and areas for improvement, such as notification options and payment methods.

- **Comparative Analysis:** Benchmarking against existing ride-hailing platforms to highlight CarmaGO's unique advantages in automation, owner-driver flexibility, and modular architecture.

Lessons learned through the development of this project and the notes and tips were taken for the future to help with further development and possible commercial use. This approach made sure CarmaGO was built to be strong, scalable and focused on users, ready for more updates and real-world launch.

# Design

**1. System Architecture**

CarmaGO uses a three-tier architecture comprising the Presentation Layer (Frontend), Application Layer (Backend), and Data Layer (Database). This setup design ensures scalability, maintainability, and clear separation of concerns. The deployment strategy leverages Docker containers for each major component, orchestrated via Docker Compose for streamlined development and production deployment.

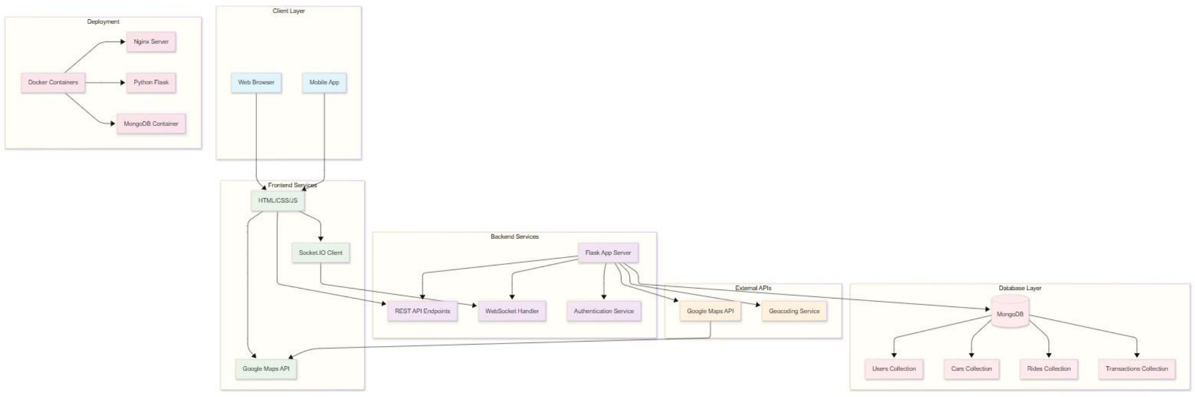
The Presentation Layer, or Frontend, is responsible for all user interactions and visual elements. It is built with using modern web technologies such as HTML5, CSS3, and JavaScript (ES6+), making sure a responsive and intuitive user experience across devices. This layer communicates with the backend exclusively through secure API calls and real-time WebSocket connections, maintaining a clear boundary between client and server logic.

The Application Layer, or Backend, is implemented using Python Flask and handles all the main functions of the app. It shares information throughout  RESTful APIs for all major operations, including user authentication, car management, ride requests, and transaction processing. The backend also manages real-time communication using Flask-SocketIO, enabling instant live updates for ride status, vehicle location, and notifications. By structuring the backend as a set of modular services, CarmaGO can easily be implemented with new features and scale horizontally to handle increased load.

The Data Layer utilizes MongoDB, a NoSQL document-oriented database, to store and manage all persistent data. Collections are designed to efficiently handle user profiles, vehicle information, ride histories, and financial transactions. MongoDB's flexible schema and indexing capabilities support rapid development and high-performance queries, while also enabling future expansion as data requirements evolve.

To ensure robust deployment and operational efficiency, each major component—frontend, backend, and database—is encapsulated within its own Docker container. This approach isolates dependencies, simplifies environment management, and enhances security. Docker Compose is used to make sure all these containers run with harmony , defining service relationships, network configurations, and environment variables in a single configuration file. This not only streamlines local development and testing but also facilitates seamless transition to production environments, whether on-premises or in the cloud.

This architecture gives CarmaGO a strong and a reliable base that can grow and improve over time, making sure it stays easy to manage and ready for future updates.



## 2. Frontend Design

The frontend is built using HTML5, CSS3, and JavaScript (ES6+), with a mobile-first, responsive design philosophy. Key features include:

- Clear HTML structure for accessibility

- Flexible layouts using CSS with Flexbox and Grid for layout

- Interactive elements powered by JavaScript

- Integration with Google Maps JavaScript API for real-time mapping

- Socket.IO client for live updates

Mainly focused on making the app easy to use, with simple navigation and a consistent look. The design works well on all devices desktops, tablets, ad phones so that users can always access it from any device and have a smooth experience

## 3. Backend Design

The backend is implemented using Python Flask, adhering to RESTful API principles for standard CRUD operations.

**Key architectural patterns include:**

- Separate route handlers for authentication, vehicle management, and ride operations

- WebSocket implementation via Flask-SocketIO for real-time communication

- Secure authentication and authorization mechanisms

- Clear error handling and detailed logging

**Core backend modules:**

- app.py: Main application server and route coordination

- auth_routes.py: User authentication and session management

- cars_routes.py: Vehicle management and tracking

- user_model.py: User data management

- car_model.py: Vehicle data models

- db.py: Database connection and configuration

## 4. Database Design

CarmaGO uses MongoDB because it’s flexible, fast and easy to update as the app changes. As a NoSQL, document-oriented database, MongoDB allows for the storage of complex, nested data in a format that closely matches the application's real-world objects. This flexibility is particularly valuable in a system like CarmaGO, where requirements may evolve and new features may necessitate changes to the data model without the overhead of rigid schema migrations.

The database has several main collections:

- **Users:** This collection stores user profiles, authentication credentials, and user-specific preferences. Each document contains essential information such as usernames, email addresses, securely hashed passwords, and metadata related to account creation and activity. The flexible schema allows for the addition of new fields, such as profile images or notification settings, as the platform grows.

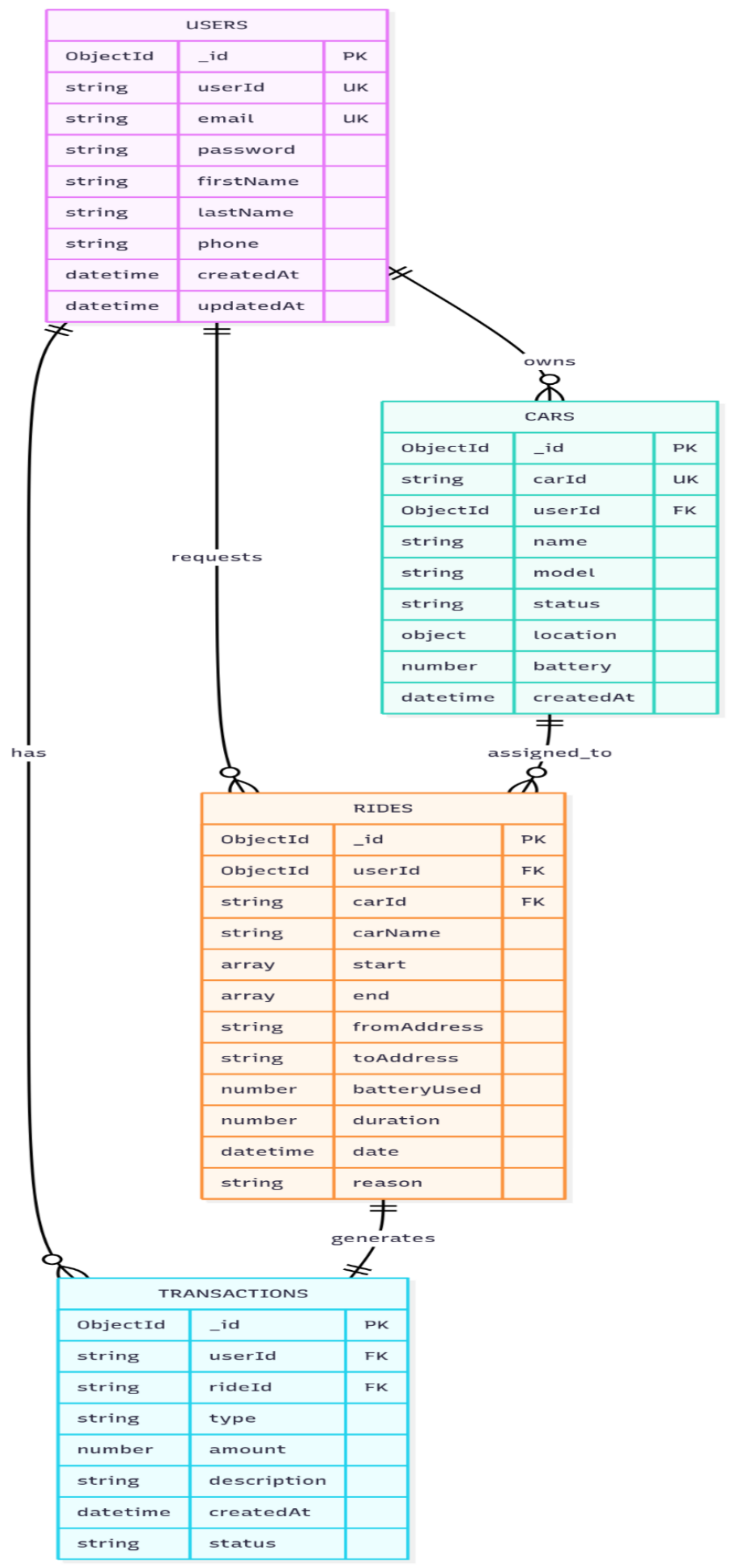
- **Cars:** The Cars collection manages all data related to vehicles registered on the platform. Each entry includes details such as the vehicle's make, model, current status (e.g., Idle, Working, Charging), and real-time location data (latitude, longitude, and address). This structure supports efficient queries for available vehicles, status updates, and location-based services, which are critical for ride matching and fleet management.

- **Rides:** This collection records all ride bookings and their associated transaction details. Each ride document captures information about the rider, the assigned vehicle, pickup and drop-off locations, timestamps for each stage of the ride, fare calculations, and the current status of the ride (e.g., pending, accepted, in_progress, completed, cancelled). The design supports both historical analysis and real-time tracking of ongoing rides.

- **Transactions:** Financial operations are tracked in the Transactions collection. Each document logs payment details, including the user involved, the ride or service associated with the transaction, the amount, payment method, timestamps, and transaction status. This enables comprehensive financial reporting, auditing, and user account management.

By leveraging MongoDB's indexing and aggregation capabilities, CarmaGO ensures fast query performance even as the dataset grows. The database design also supports horizontal scaling, allowing the platform to accommodate increasing numbers of users, vehicles, and transactions without sacrificing reliability or speed. Furthermore, MongoDB's support for replication and backup strategies enhances data durability and disaster recovery, ensuring that critical information remains secure and accessible at all times.

In summary, the use of MongoDB as the backbone of CarmaGO's data layer provides the adaptability, performance, and scalability required for a modern, data-driven mobility platform. This approach not only meets current operational needs but also positions the system for future enhancements and expansion.



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| string | email | UK |
| string | password | |
| string | firstName | |
| string | lastName | |
| string | phone | |
| datetime | createdAt | |
| datetime | updatedAt | |

| CARS | | |
|---|---|---|
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| ObjectId | userId | FK |
| string | name | |
| string | model | |
| string | status | |
| object | location | |
| number | battery | |
| datetime | createdAt | |

| RIDES | | |
|---|---|---|
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| ObjectId | userId | FK |
| string | carId | FK |
| string | carName | |
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| array | end | |
| string | fromAddress | |
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| number | batteryUsed | |
| number | duration | |
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| string | reason | |

| TRANSACTIONS | | |
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| number | amount | |
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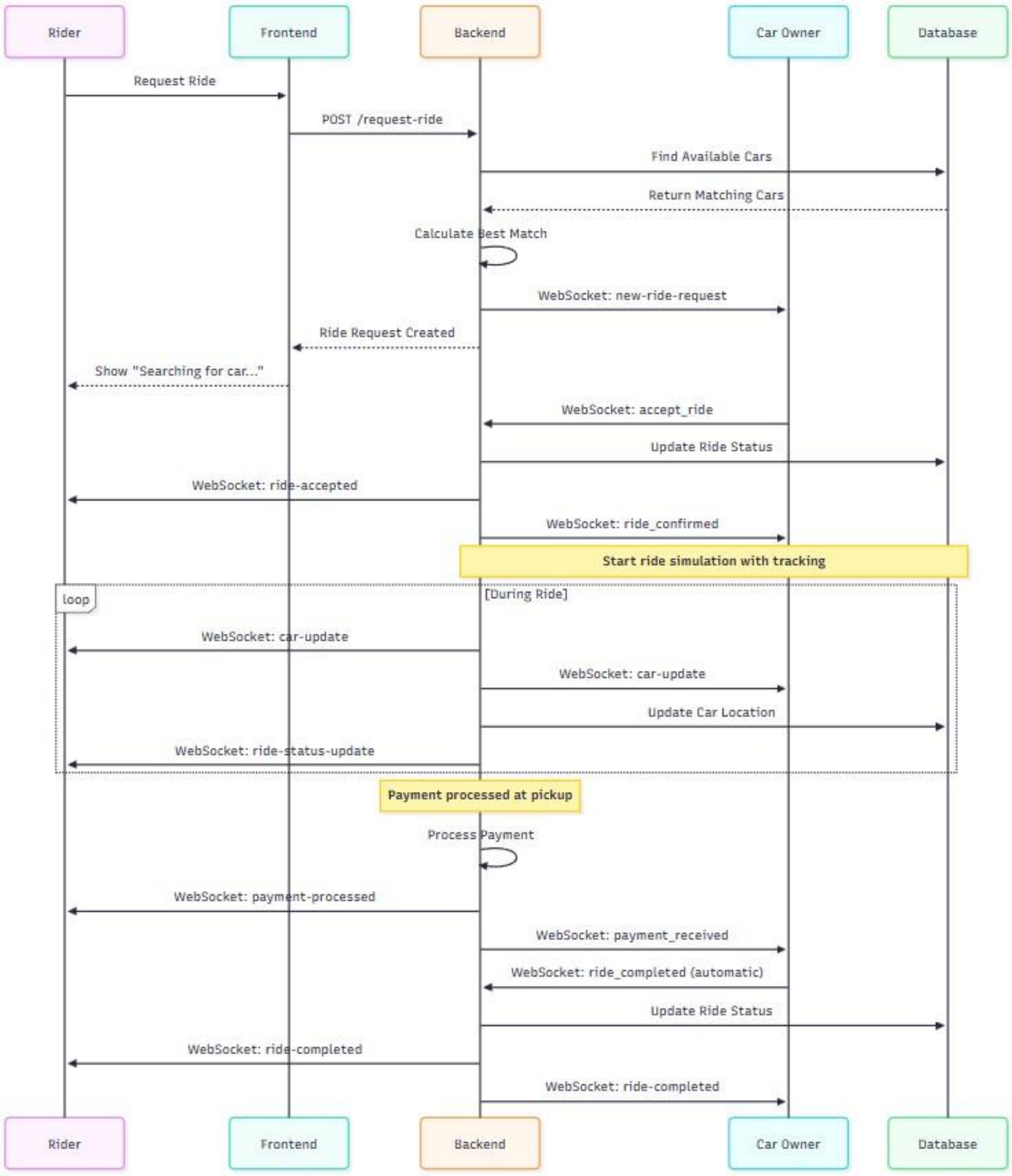
| string | status | |

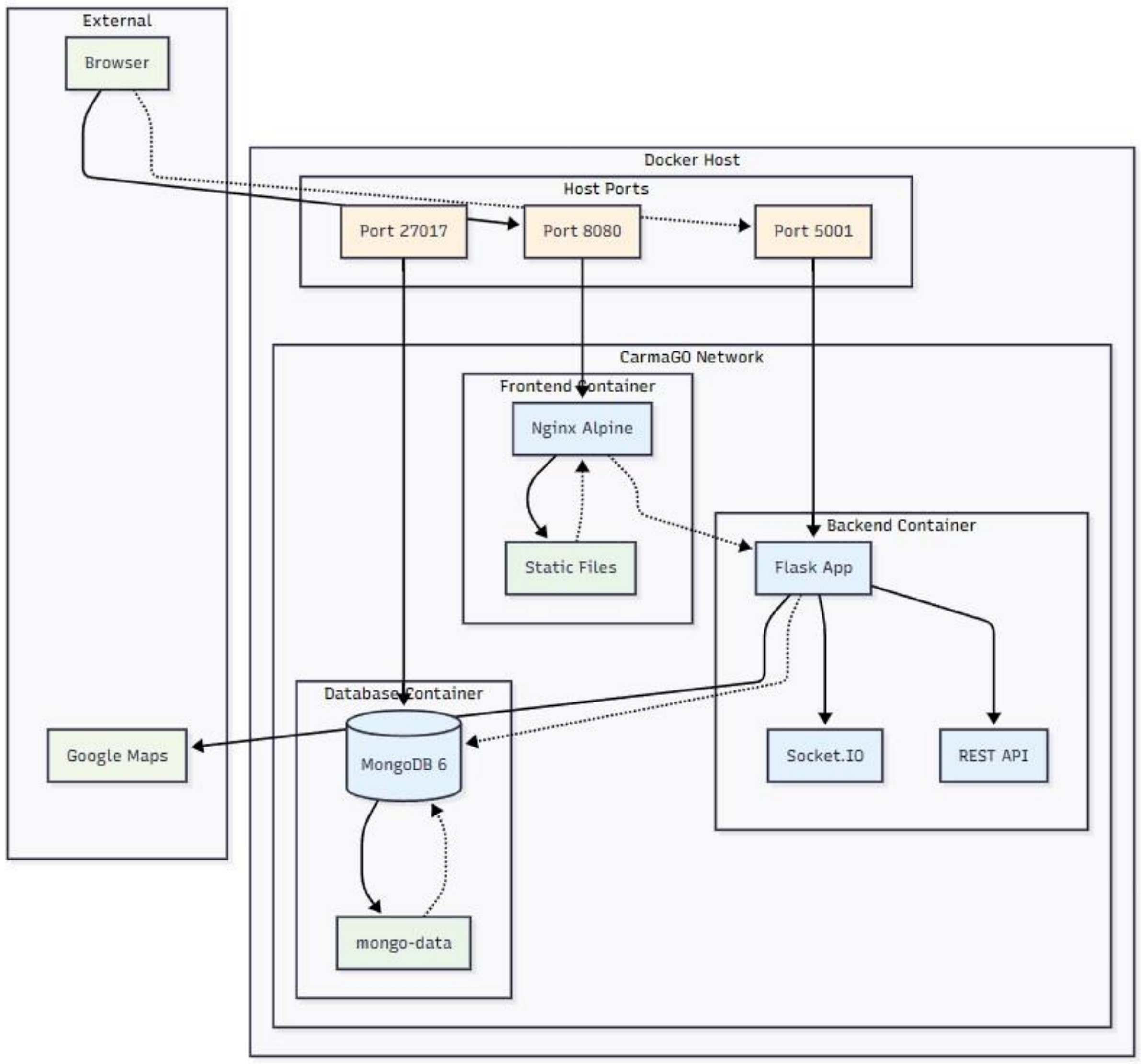
## 5. Real-Time Communication

Socket.IO is used to facilitate live updates for vehicle location, ride status, and notifications. This ensures a responsive user experience and supports concurrent sessions for multiple users.



## 6. Security and Deployment

Security is enforced through password hashing, session-based authentication, CORS configuration, and input validation. Sensitive data is managed via environment variables. The deployment architecture utilizes Docker containers for the frontend, backend, and database, orchestrated with Docker Compose for ease of scaling and maintenance.



# Implementation

## 1. Technology Stack

- Frontend: HTML5, CSS3, JavaScript (ES6+), Socket.IO Client

- Backend: Python 3.11, Flask, Flask-SocketIO, Flask-CORS

- Database: MongoDB 6.0

- APIs: Google Maps JavaScript API, Google Maps Geocoding API

- Deployment: Docker, Docker Compose, Nginx

- Development Tools: Git, VS Code, Browser Developer Tools

## 2. Frontend Implementation

The frontend comprises multiple pages tailored to different user roles and functions:

- Authentication: Registration (signUppage.html), login (logInpage.html), and session management (auth.js)

- Main application: Dashboard (HomePage.html), account management (account.html), ride requests (req-ride.html), vehicle tracking (locate-car.html), and taxi job management (taxi-job.html)

- Styling: Modular CSS for each component, responsive layouts, and consistent navigation (navbar.css)

Key features include real-time map integration, live vehicle tracking, interactive forms, dynamic content updates, toast notifications, and session persistence via local storage.

## 3. Backend Implementation

The backend is structured as a modular Flask application, with clear separation of concerns across authentication, vehicle management, ride operations, and database connectivity. RESTful endpoints provide comprehensive API coverage, while WebSocket events enable real-time updates for location, ride status, and notifications.

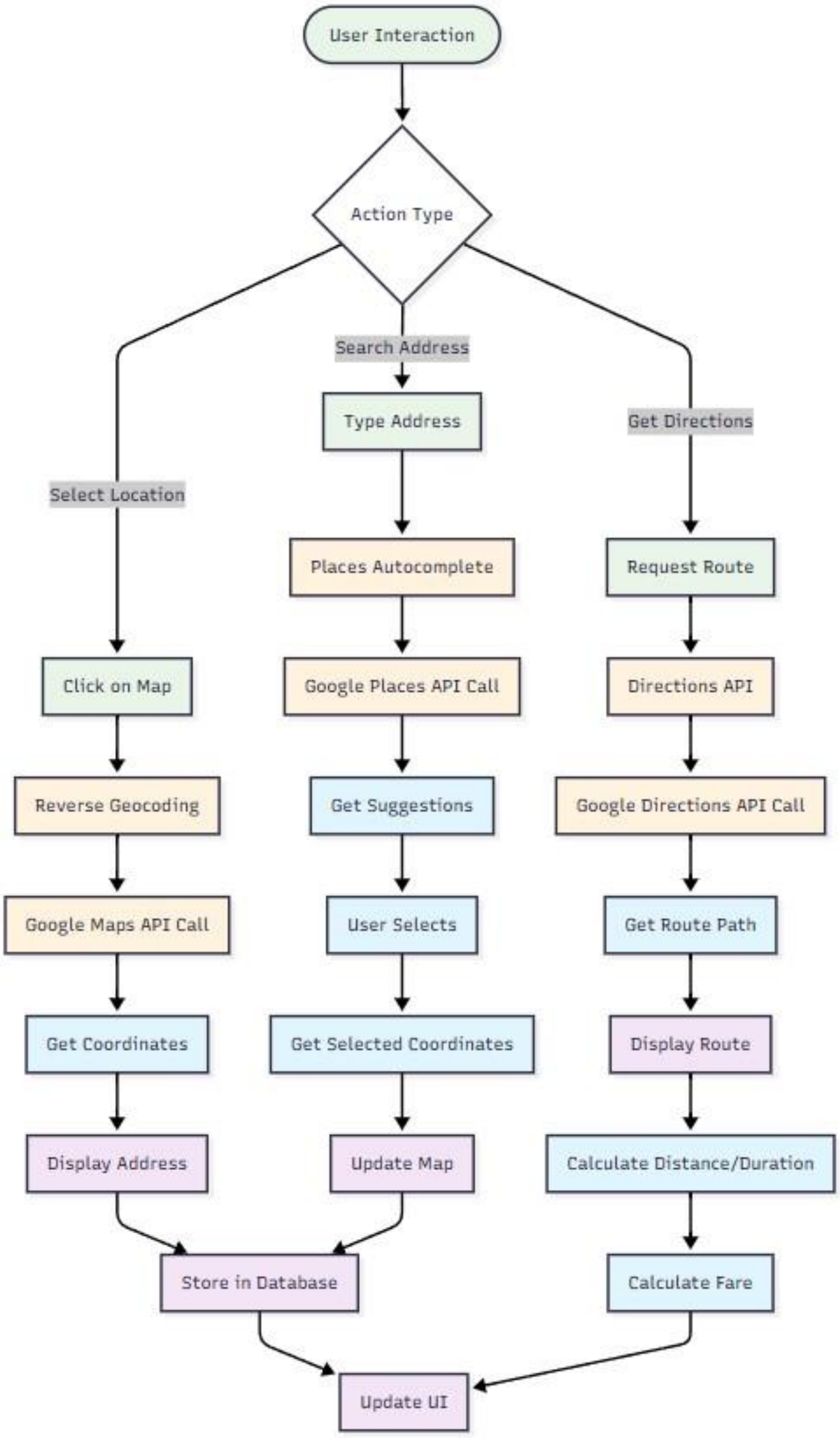
Security is prioritized through password hashing, token-based authentication, and input validation. Error handling and logging are implemented throughout to facilitate debugging and monitoring.

## 4. Database Implementation

MongoDB collections are optimized for both read and write operations, with indexing on frequently queried fields. Data models are designed to support efficient queries for user profiles, vehicle status, ride history, and financial transactions.

## 5. API and External Integration

The backend exposes RESTful endpoints for all core operations, including user registration, authentication, vehicle management, and ride requests. Integration with Google Maps APIs enables geocoding, route optimization, and real-time mapping. Socket.IO events handle live updates for vehicle location and ride status.


User Interaction
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Select Location
Search Address
Get Directions
Type Address
Places Autocomplete
Request Route
Click on Map
Google Places API Call
Directions API
Reverse Geocoding
Get Suggestions
Google Directions API Call
Google Maps API Call
User Selects
Get Route Path
Get Coordinates
Get Selected Coordinates
Display Route
Display Address
Update Map
Calculate Distance/Duration
Store in Database
Calculate Fare
Update UI

### 6. Testing and Validation

Testing is conducted at multiple levels:

- Unit tests for individual components and functions
- Integration tests for end-to-end workflows
- User acceptance testing with demo scenarios
- Performance testing for real-time features

Continuous integration practices are employed to ensure code quality and reliability.

## Project Evaluation

### 1. Functional Testing

All core features were systematically tested to ensure correct operation:

- User authentication and session management
- Vehicle registration, status updates, and tracking
- Ride request, matching, and fare calculation
- Real-time notifications and status updates
- Multi-vehicle management and ride history

### 2. Performance Evaluation

System performance was assessed based on response times, database efficiency, real-time update latency, and scalability. The application consistently delivered API responses under 200ms and WebSocket events within 50ms. MongoDB indexing and connection pooling contributed to stable performance under concurrent user loads.

### 3. Usability and Accessibility

User experience was evaluated through interface design, navigation flow, and accessibility features. The application provides a clean, intuitive interface with responsive layouts, semantic HTML, and keyboard navigation support. Accessibility standards are met through appropriate color contrast, alt text, and screen reader compatibility.

## 4. Security Assessment

Security measures were validated through code review and testing, ensuring protection against common vulnerabilities (XSS, CSRF, SQL injection). Secure API endpoints, password hashing, and session management were confirmed to be effective.

## 5. Deployment and DevOps

Containerization and orchestration were tested using Docker and Docker Compose, enabling seamless deployment and scaling. Environment-specific configurations and monitoring tools were integrated to support production readiness.

## 6. User Feedback

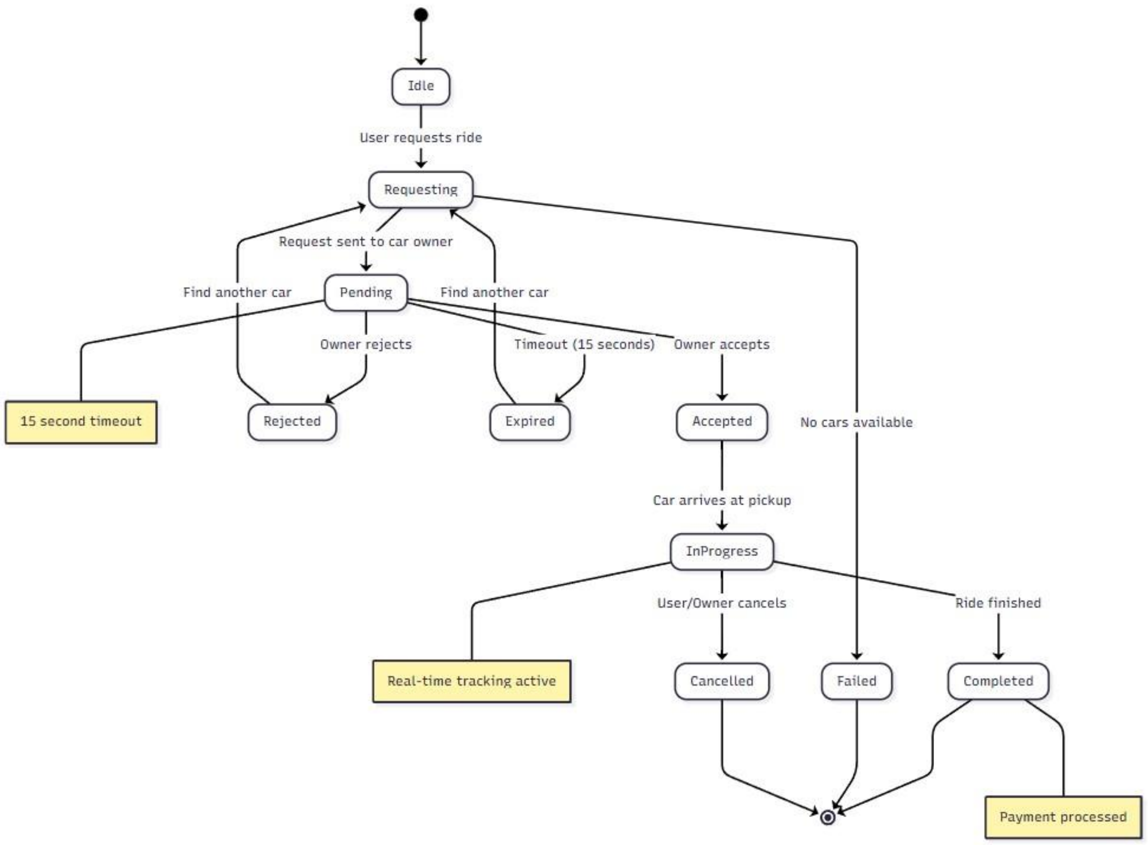
Beta testing with a small user group provided valuable insights into usability, performance, and feature desirability. Users highlighted the intuitive interface, real-time updates, and map integration as key strengths. Suggestions for improvement included enhanced notification options and expanded payment methods.

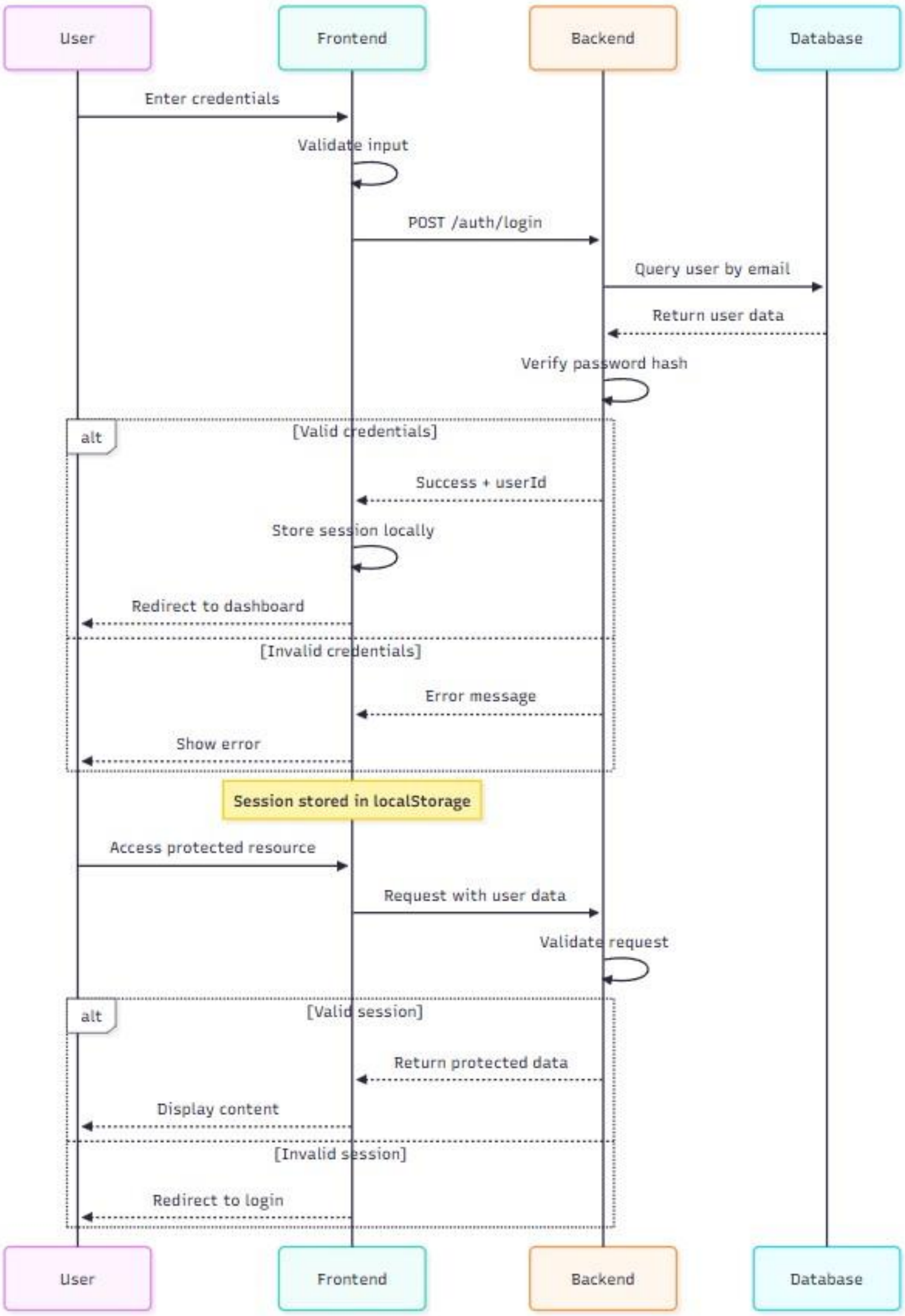
## 7. Comparative Analysis

Compared to existing ride-hailing platforms, CarmaGO offers unique advantages in automation, owner-driver flexibility, and seamless switching between personal and commercial vehicle use. The modular, scalable architecture positions the platform for future growth and integration with emerging technologies.

## 8. Limitations

Current limitations include the simulation of autonomous vehicle operations (no real-world hardware integration), basic fare calculation, and limited scalability for large-scale deployments. Legal and regulatory considerations for AVs are not fully addressed in the current implementation.




User
Frontend
Backend
Database
Enter credentials
Validate input
POST /auth/login
Query user by email
Return user data
Verify password hash
alt
[Valid credentials]
Success + userId
Store session locally
Redirect to dashboard
[Invalid credentials]
Error message
Show error
Session stored in localStorage
Access protected resource
Request with user data
Validate request
alt
[Valid session]
Return protected data
Display content
[Invalid session]
Redirect to login
User
Frontend
Backend
Database

# Further Work and Conclusions

## 1. Future Enhancements

Planned enhancements for CarmaGO include:

- Integration with real autonomous vehicle APIs and control systems
- Advanced AI and machine learning for demand forecasting and dynamic pricing
- Mobile application development for iOS and Android
- Expanded payment options (e.g., Stripe, PayPal, cryptocurrency)
- Multi-language and localization support
- Enhanced fleet management and maintenance tools
- Cloud migration for improved scalability and reliability
- Comprehensive analytics and business intelligence dashboards
- Sustainability features (e.g., carbon tracking, green routing)

## 2. Conclusions

CarmaGO demonstrates the feasibility and potential of autonomous, flexible ride-hailing platforms. The project successfully integrates modern web technologies, real-time communication, and mapping services to deliver a robust, user-centric solution. While the current implementation serves as a proof-of-concept, the modular architecture and comprehensive feature set provide a strong foundation for future development and commercialization.

The project highlights the importance of user experience, security, and scalability in modern mobility solutions. As autonomous vehicles become more prevalent, platforms like CarmaGO will play a critical role in shaping the future of urban transportation.

# Glossary

**API (Application Programming Interface**): Protocols and tools for building and integrating software applications.

**Autonomous Vehicle:** A self-driving car capable of navigating without human intervention.

**Backend:** Server-side logic, data processing, and database operations.

**CORS (Cross-Origin Resource Sharing):** Security feature controlling resource sharing between domains.

**CSS (Cascading Style Sheets):** Language for describing the presentation of HTML documents.

**Database:** Structured collection of data stored electronically.

**Docker:** Platform for containerizing applications and dependencies.

**ETA (Estimated Time of Arrival):** Predicted time for a vehicle to reach its destination.

**Fleet Management:** Administration of multiple vehicles for efficiency and cost-effectiveness.

**Frontend:** Client-side interface and user interaction layer.

**Geocoding:** Converting addresses into geographic coordinates.

**HTML (HyperText Markup Language):** Standard markup language for web pages.

**JavaScript:** Programming language for interactive web applications.

**MongoDB:** NoSQL document database for flexible data storage.

**REST (Representational State Transfer):** Architectural style for web APIs using HTTP methods.

**Real-time Communication:** Instantaneous data exchange between systems.

**Ride-hailing:** Service connecting users with available vehicles via an app or website.

**Socket.IO:** Library for real-time, bidirectional communication between clients and servers.

**Responsive Design:** Web design approach for optimal viewing on various devices.

**V2I (Vehicle-to-Infrastructure):** Communication between vehicles and road infrastructure.

**WebSocket:** Protocol for full-duplex communication channels over a single TCP connection.

## Table of Abbreviations

| ABBREVIATION | FULL FORM |
|---|---|
| **AI** | Artificial Intelligence |
| **API** | Application Programming Interface |
| **CORS** | Cross-Origin Resource Sharing |
| **CSS** | Cascading Style Sheets |
| **DARPA** | Defense Advanced Research Projects Agency |
| **DOM** | Document Object Model |
| **ETA** | Estimated Time of Arrival |
| **GDPR** | General Data Protection Regulation |
| **GPS** | Global Positioning System |
| **HTML** | HyperText Markup Language |
| **HTTP** | HyperText Transfer Protocol |
| **HTTPS** | HyperText Transfer Protocol Secure |
| **JSON** | JavaScript Object Notation |
| **ML** | Machine Learning |
| **NOSQL** | Not Only Structured Query Language |
| **REST** | Representational State Transfer |
| **TCP** | Transmission Control Protocol |
| **UI** | User Interface |
| **UX** | User Experience |
| **V2I** | Vehicle-to-Infrastructure |
| **XSS** | Cross-Site Scripting |

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# Appendix A: First Appendix

## A.1 System Requirements

**Hardware:**

- CPU: Dual-core processor (2.0 GHz or higher)
- RAM: 4GB (8GB recommended)
- Storage: 2GB available disk space
- Network: Broadband internet connection

**Software:**

- Operating System: Windows 10/11, macOS 10.14+, or Linux Ubuntu 18.04+
- Web Browser: Chrome 90+, Firefox 88+, Safari 14+, Edge 90+
- Docker Desktop 4.0+ (for containerized deployment)
- Node.js 16+ (for development)
- Python 3.8+ (for backend development)

## A.2 Installation and Setup Guide

**1. Clone the Repository:**

```
git clone https://github.com/HasanbRG/CarmaGO2.git
cd CarmaGO2
```

**2. Docker Deployment (Recommended):**

```
docker-compose up -d
```

This command starts all services:

- Frontend: http://localhost:8080
- Backend: http://localhost:5001
- MongoDB: localhost:27017

**3. Manual Setup (Development):**

- **Backend:**

```
cd backend
pip install -r requirements.txt
python app.py
```

- **Frontend:**

```
cd frontend
python -m http.server 8080
```

## A.3 API Documentation

**Authentication Endpoints:**

- POST /auth/register - User registration
- POST /auth/login - User authentication
- GET /auth/user - Get current user information
- POST /auth/logout - User logout

**Vehicle Management Endpoints:**

- POST /cars/add - Add new vehicle
- GET /cars/user/<user_id> - Get user's vehicles
- PUT /cars/<car_id>/status - Update vehicle status
- DELETE /cars/<car_id> - Remove vehicle

**Ride Management Endpoints:**

- POST /rides/request - Request a ride

- GET /rides/history/<user_id> - Get ride history

- PUT /rides/<ride_id>/accept - Accept ride request

- PUT /rides/<ride_id>/complete - Complete ride

## A.4 Database Schema

**Users Collection:**

```
{
  "_id": ObjectId,
  "username": String (unique),
  "email": String (unique),
  "password_hash": String,
  "created_at": DateTime,
  "last_login": DateTime,
  "profile": {
    "name": String,
    "phone": String,
    "address": String
  },

  "financial": {
    "balance": Number,
    "total_earnings": Number,
    "total_spent": Number
  }
}
```

**Cars Collection:**

```
{
  "_id": ObjectId,
  "owner_id": ObjectId (ref: Users),
  "name": String,
  "model": String,
  "status": String, // "Idle", "Working", "Charging"
  "location": {
    "lat": Number,
    "lng": Number,
    "address": String,
    "last_updated": DateTime
  },
  "battery_level": Number (0-100),
  "available_for_taxi": Boolean,
  "created_at": DateTime
}
```

**Rides Collection:**

```
{
  "_id": ObjectId,
  "rider_id": ObjectId (ref: Users),
  "car_id": ObjectId (ref: Cars),
  "owner_id": ObjectId (ref: Users),
  "pickup_location": {
    "lat": Number,
    "lng": Number,
    "address": String
  },
  "destination": {
    "lat": Number,
    "lng": Number,
    "address": String
  },
  "status": String, // "pending", "accepted", "in_progress", "completed",
"cancelled"
  "distance": Number, // in kilometers
  "duration": Number, // in minutes
  "fare": Number,
  "created_at": DateTime,
  "accepted_at": DateTime,
  "started_at": DateTime,
  "completed_at": DateTime
}
```

## A.5 Configuration Settings

**Environment Variables:**

- MONGO_URI: MongoDB connection string
- GOOGLE_MAPS_API_KEY: Google Maps API key
- SECRET_KEY: Flask session secret key
- DEBUG: Debug mode (True/False)
- PORT: Application port (default: 5001)

**Docker Configuration:**

The application uses Docker Compose for orchestration with three main services:

- mongo: MongoDB database service
- backend: Python Flask application
- frontend: Nginx web server for static files

## A.6 Testing Procedures

**Unit Testing:**

- User authentication functions
- Vehicle management operations
- Ride request processing
- Database operations

**Integration Testing:**

- API endpoint testing using automated scripts
- Database connection and query testing
- WebSocket communication testing
- Google Maps API integration testing

**User Acceptance Testing:**

- Account creation and login workflow
- Vehicle registration and management
- Ride booking and completion process

- Real-time updates and notifications

## A.7 Deployment Configuration

**Production Deployment Checklist:**

- [ ] Configure HTTPS certificates
- [ ] Set up environment variables
- [ ] Configure database backups
- [ ] Set up monitoring and logging
- [ ] Configure load balancing (if needed)
- [ ] Test all functionality in production environment

**Security Considerations:**

- Implement rate limiting for API endpoints
- Use HTTPS for all communications
- Regularly update dependencies
- Monitor for security vulnerabilities
- Implement proper access controls

## A.8 Troubleshooting Guide

**Common Issues and Solutions:**

**1. Docker Container Won't Start:**

  - Ensure Docker Desktop is running
  - Verify port availability (27017, 5001, 8080)
  - Review Docker logs: docker-compose logs

**2. Database Connection Issues:**

  - Confirm MongoDB container is running
  - Check connection string configuration

- Ensure network connectivity between containers

**3. Google Maps Not Loading:**

- Verify API key configuration
- Check API key permissions and quotas
- Ensure internet connectivity

**4. WebSocket Connection Failures:**

- Check CORS configuration
- Verify Socket.IO client/server versions
- Review network firewall settings

**Performance Optimization Tips:**

- Enable database indexing for frequently queried fields
- Implement caching for static resources
- Optimize image sizes and formats
- Use CDN for global content delivery
- Monitor and optimize database queries