CHAPTER 1

INTRODUCTION

1.1 Brief Introduction

The Carbon-Aware Route Planner (CARP) **is a web-based navigation system designed to encourage sustainable transportation practices. Unlike conventional navigation systems that focus on minimizing travel time or distance, CARP considers** vehicle type, fuel efficiency, emission factors, and traffic conditions **to recommend routes that minimize** carbon emissions**.**

Transportation is a major contributor to greenhouse gas emissions, and cities worldwide are facing environmental challenges due to the rising number of vehicles. CARP bridges the gap by providing an innovative approach to route planning that balances **convenience with environmental responsibility**.

1.2 EXISTING SYSTEM

Current route planning systems such as Google Maps and Waze optimize routes using factors like shortest path, estimated time, or real-time traffic. However, they do not consider carbon emissions or vehicle-specific fuel efficiency.

Limitations of existing systems:

- Focus only on time/distance.
- No personalized eco-routing.
- No carbon emission analytics for users.
- Lack of administrative monitoring for sustainability metrics.

1.3 PROPOSED SYSTEM

The proposed CARP system integrates eco-routing algorithms that combine:

- Vehicle-specific fuel consumption data.
- Carbon emission factors.
- Real-time traffic conditions.
- User preferences (eco-friendly vs faster route).

Key features of the proposed system:

- Suggests eco-friendly routes with reduced emissions.
- Provides an analytics dashboard for emission trends.
- Supports both user and admin modules.
- Scalable backend with modular architecture.

1.4 OBJECTIVE

- To design a **carbon-aware route planning system**
- To integrate **fuel efficiency and emission data** into routing.
- To provide **real-time eco-friendly routes** to users.
- To deliver **analytics and insights** for sustainable decision making
- To encourage **green transportation practices**.

1.5 PROBLEM STATEMENT

With rising pollution levels and increasing fuel costs, there is a strong need for intelligent transportation systems that not only reduce travel time but also minimize environmental impact. Existing navigation systems do not address **sustainable commuting**. CARP solves this by combining navigation with **carbon awareness**, thereby reducing greenhouse gas emissions and promoting eco-friendly travel.

1.6 ADVANTAGES

1.6.1 Improved Accuracy – Provides routes optimized not only for time but also for fuel and emissions.

1.6.2 User-Friendly Design/Interface – Simple and intuitive interface for route suggestions.

1.6.3 Eco-Friendly Routing – Encourages sustainable travel choices.

1.6.4 Time and Cost Saving – Balances eco-friendliness with efficiency.

1.6.5 Real-Time Emission Tracking – Monitors carbon output of each trip.

1.6.6 Analytics and Reporting – Provides insights to users and admins.

1.6.7 Scalable – Can be expanded for future enhancements like public transport integration.

1.6.8 Role-Based Access Control – Admin and user roles with different privileges

CHAPTER 2

REVIEW OF LITERATURE

2.1 INTRODUCTION TO ECO-ROUTING SYSTEM

The Eco-routing systems are designed to provide navigation routes that minimize environmental impact rather than focusing only on travel time or distance. These systems analyze multiple factors such as vehicle type, fuel efficiency, speed patterns, and traffic conditions to determine routes that produce the least carbon emissions. Research in this area has grown significantly with the global emphasis on reducing greenhouse gases and promoting sustainable mobility

2.2 TRADITIONAL VS CARBON-AWARE NAVIGATION

Traditional navigation systems such as Google Maps and Waze primarily focus on optimizing travel time, distance, and traffic flow. While these systems improve user convenience, they neglect the environmental consequences of route choices. On the other hand, carbon-aware navigation incorporates emission models that calculate fuel consumption and greenhouse gas output for each route. This enables users to make informed choices that balance efficiency with sustainability.

2.3 MECHANISM OF CARBON EMISSION CALCULATIONS

Carbon emissions from transportation are influenced by factors such as:

- Vehicle specifications (engine type, fuel type, fuel efficiency).
- Driving conditions (traffic congestion, stop-and-go patterns).
- Route characteristics (distance, slope, number of signals).

Eco-routing algorithms use these variables to estimate emissions for each potential route. The system then recommends the route with the lowest carbon footprint, even if it is not always the fastest in terms of time.

2.4 Role of Carbon-Aware Routing in Sustainability

The transportation sector accounts for nearly one-fourth of global CO_2 emissions. By encouraging eco-friendly routes, carbon-aware navigation systems play an important role in:

- **Reducing carbon footprints** for individuals and organizations.
- **Lowering fuel consumption**, saving costs for users.
- **Supporting government initiatives** on smart cities and sustainable development.
- **Raising environmental awareness** among commuters.

CARP builds on this research by providing a practical, web-based system that combines eco-routing algorithms with an intuitive user interface and an analytics dashboard for monitoring emissions.

Chapter 3

SYSTEM CONFIGURATION

3.1 SOFTWARE COMPONENTS

3.1.1 BACKEND

The backend of CARP is developed using **Node.js with Express framework**. It provides RESTful APIs for handling user authentication, route calculations, analytics, and vehicle management. The modular architecture ensures scalability, allowing new features to be added without affecting existing functionality.

3.1.2 SERVER

The system can be hosted on a **local development server** or deployed on **cloud platforms** such as AWS, Azure, or Heroku. The server manages client requests, interacts with the database, and ensures secure data transfer using middleware and token-based authentication.

3.1.3 DATABASE

CARP uses a **relational database** (MySQL or PostgreSQL) with **Knex.js** as a query builder and migration tool. The database stores structured data such as user details, vehicle information, trips, emission factors, and admin logs. The use of migrations ensures consistency and easy schema management.

3.2 HARDWARE COMPONENTS

The minimum hardware configuration required for development and deployment of CARP is:

- **Processor:** Intel Core i5 or higher
- **RAM:** 8 GB (recommended 16 GB for faster processing)
- **Storage:** 256 GB SSD or higher
- **Operating System:** Windows 10/11, Linux (Ubuntu), or macOS
- **Internet Connectivity:** Required for real-time traffic integration and route API access

CHAPTER 4

MODULE DESCRIPTION

The CARP system is divided into multiple modules, each handling a specific functionality. The modular approach improves maintainability, scalability, and performance of the system.USER MANAGEMENT MODULE

4.1 AUTHENTICATION MODULE

This module manages **user registration, login, and logout**. It uses secure authentication mechanisms such as **JWT (JSON Web Tokens)** to ensure that only authorized users access the system. Passwords are encrypted before storage, improving data security.

Functions:

- User registration with email and password
- Login authentication with token generation
- Secure logout process
- Role-based access (user/admin)

4.2 USER MANAGEMENT MODULE

The user module allows registered users to maintain their profiles and preferences. Each user can add personal details and configure system settings related to route suggestions.

Functions:

- Manage user profile (name, email, preferences)
- View trip history and carbon emissions data
- Update preferences (eco-friendly vs faster route)

4.3 VEHICLE MANAGEMENT MODULE

This module stores and manages details of vehicles owned by users. Since emissions depend heavily on vehicle type and efficiency, this module plays a central role in eco-routing

Functions

- Add, update, or delete vehicle details
- Store fuel type and fuel efficiency
- Link vehicles to trips for emission calculations

4.4ROUTE PANNING MODULE

The core module of CARP, responsible for suggesting **optimized eco-friendly routes**. It considers distance, traffic, vehicle fuel efficiency, and emission factors to compute the most sustainable path.

Functions

- Take input: source and destination
- Fetch route data from APIs
- Compare multiple routes based on emission factors
- Display eco-friendly route along with time and distance

4.5ANALYTICS MODULE

The analytics module provides insights into user and system-wide emission patterns. It helps users understand the environmental benefits of choosing eco-routes.

Functions

- Show carbon emission trends for each user
- Compare eco-routes vs normal routes
- Generate reports for admin monitoring

4.6 ADMIN MODULE

The admin module gives system administrators control over platform activities. Admins can monitor system usage, manage users, and update emission factor data.

Functions

- Manage registered users
- Monitor trips and analytics
- Update emission factor datasets
- View and export reports

CHAPTER 5

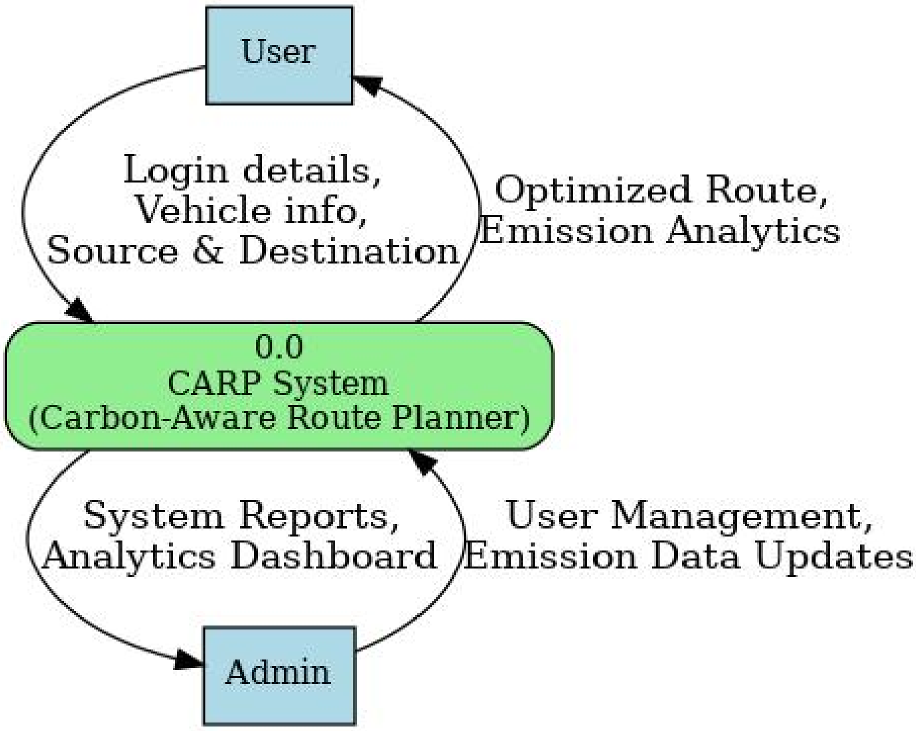
SYSTEM DESIGN

System design defines the overall architecture of the CARP application. It provides a blueprint for how data flows between modules, how users interact with the system, and how the database structures the information.

5.1 Data Flow Diagram-Level0

At Level 0, the CARP system is represented as a single process that interacts with external entities such as **users** and **admins**.

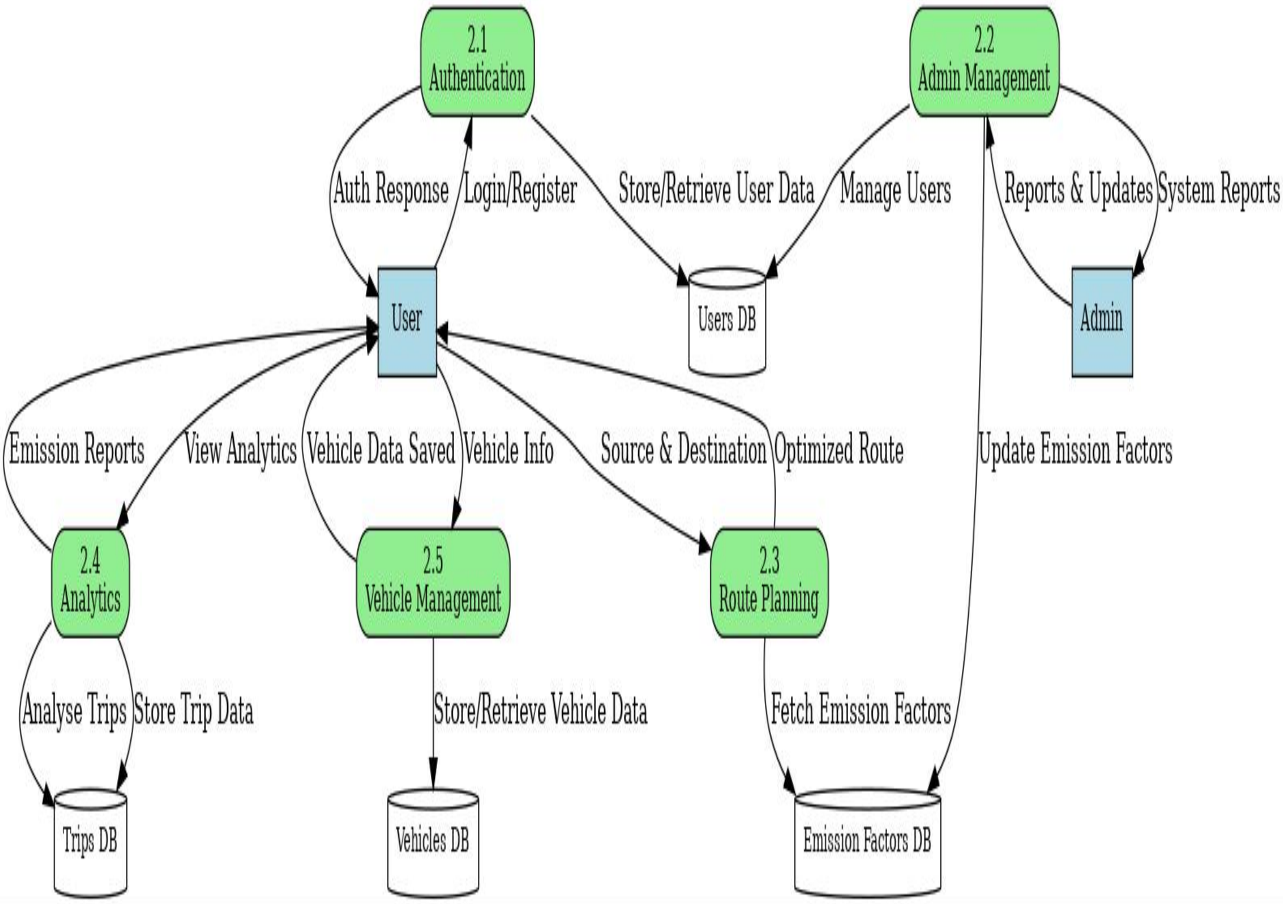
- The user provides inputs such as login details, vehicle information, and trip source/destination.
- The system processes this data and returns results like optimized routes and emission reports.



5.2 Data Flow Diagram – Level 1

At Level 1, the system is divided into sub-processes:

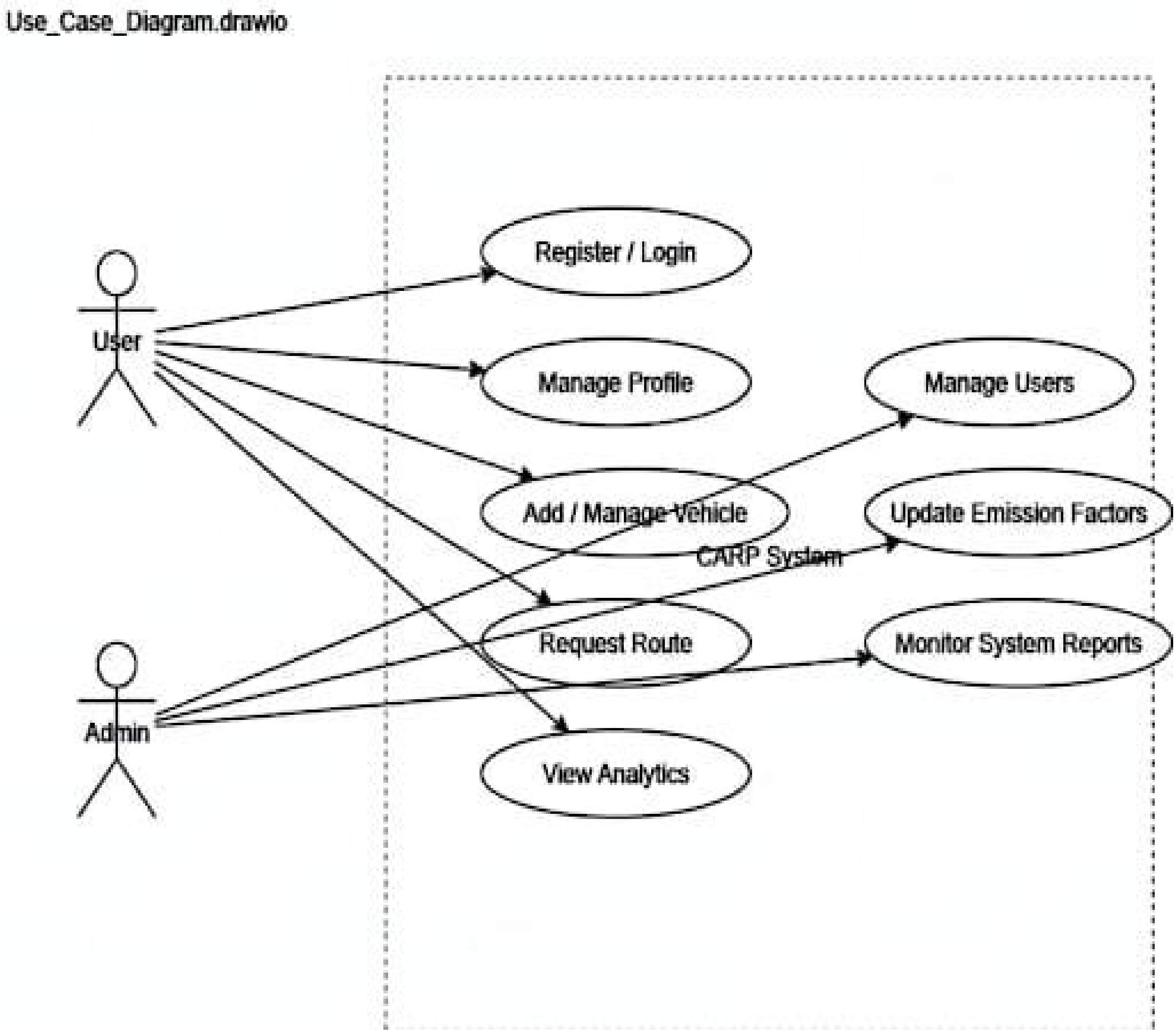
- **Authentication process** (verifies login credentials)
- **Vehicle management process** (stores fuel efficiency and type)
- **Route planning process** (fetches possible routes and calculates emissions)
- **Analytics process** (generates emission reports and dashboards)
- **Admin process** (monitors and manages users & data)



5.3 Use Case Diagram

The Use Case diagram illustrates interactions between **actors** (User, Admin) and the CARP system.

- **User Use Cases:** Register, Login, Manage Profile, Add Vehicle, Request Route, View Analytics
- **Admin Use Cases:** Manage Users, Update Emission Factors, Monitor System Usage



5.4 Entity-Relationship(ER) Diagram

- **Users** table (user_id, name, email, password, role)
- **Vehicles** table (vehicle_id, user_id, type, fuel_efficiency, fuel_type)
- **Trips** table (trip_id, user_id, source, destination, distance, emission)
- **Emission_Factors** table (fuel_type, emission_rate)
- **User_Preferences** table (user_id, preferred_route_type)

Relationships:

- One user → Many vehicles
- One user → Many trips
- One vehicle → Many trips
- Trips use emission factors for calculations

CHAPTER 6

SYSTEM IMPLEMENTATION

System implementation involves translating the design into an operational software system. CARP is implemented using **Node.js with Express**, a **MySQL/PostgreSQL database** (via Knex.js migrations), and RESTful APIs.

TABLE 6.1 USER TABLE

Field Name	Data Type	Constraints	Description
user_id	INT	Primary Key, Auto Increment	Unique ID for each user
name	VARCHAR(100)	NOT NULL	User's full name
email	VARCHAR(150)	UNIQUE, NOT NULL	User's email (login credential)
password	VARCHAR(255)	NOT NULL	Encrypted password
role	VARCHAR(20)	Default: 'user'	Defines access (user/admin)

TABLE 6.2 VEHICLES TABLE

Field Name	Data Type	Constraints	Description
vehicle_id	INT	Primary Key, Auto Increment	Unique ID for each vehicle
user_id	INT	Foreign Key → Users(user_id)	Links vehicle to user
vehicle_type	VARCHAR(50)	NOT NULL	Car, bike, truck, etc.
fuel_type	VARCHAR(30)	NOT NULL	Petrol, diesel, EV, hybrid
fuel_efficiency	DECIMAL(5,2)	NOT NULL	Mileage (km/l or km/kWh)

TABLE 6.3 TRIP TABLE

Field Name	Data Type	Constraints	Description
trip_id	INT	Primary Key, Auto Increment	Unique ID for each trip
user_id	INT	Foreign Key → Users(user_id)	Trip owner
vehicle_id	INT	Foreign Key → Vehicles(vehicle_id)	Vehicle used
source	VARCHAR(150)	NOT NULL	Starting location
destination	VARCHAR(150)	NOT NULL	Destination location
distance	DECIMAL(6,2)	NOT NULL	Distance traveled (km)
emissions	DECIMAL(8,3)	NOT NULL	Carbon emissions (kg CO_2)

TABLE 6.4 EMISSION FACTORS TABLE

Field Name	Data Type	Constraints	Description
fuel_type	VARCHAR(30)	Primary Key	Fuel category
emission_rate	DECIMAL(6,3)	NOT NULL	kg CO_2 per unit fuel

TABLE 6.5 USER PREFERENCES TABLE

Field Name	Data Type	Constraints	Description
user_id	INT	Primary Key, Auto Increment	Unique ID for each user
name	VARCHAR(100)	NOT NULL	User’s full name
email	VARCHAR(150)	UNIQUE, NOT NULL	User’s email (login credential)

OUTPUT SCREENSHOTS

CHAPTER7

SYSTEM TESTING

System testing ensures that the implemented modules of CARP function as expected and meet the defined requirements. Different types of testing have been carried out, including **unit testing, integration testing, validation testing, and user acceptance testing**.

TABLE 7.1 TEST CASES

Test Case ID	Module	Input	Expected Output	Actual Output	Status
TC01	Authentication	Valid email & password	Login successful, dashboard opens	As expected	Pass
TC02	Authentication	Invalid password	Error message “Invalid credentials”	As expected	Pass
TC03	Vehicle Management	Add vehicle (Car, Petrol, 18 km/l)	Vehicle saved successfully	As expected	Pass
TC04	Vehicle Management	Missing vehicle type	Error message “Vehicle type required”	As expected	Pass
TC05	Route Planning	Source=“Bangalore”, Destination=“Mysore”	Optimized eco-route displayed	As expected	Pass
TC06	Route Planning	Invalid location	Error message “Invalid source/destination”	As expected	Pass
TC07	Analytics	Request emissions report	Graph of emissions per trip displayed	As expected	Pass
TC08	Admin Module	Update emission factor for diesel	Updated factor stored in DB	As expected	Pass
TC09	Admin Module	Delete user	User removed from system	As expected	Pass
TC10	Security	Access dashboard without login	Redirect to login page	As expected	Pass

CHAPTER8

RESULTS AND DISCUSSIONS

8.1EXPECTED OUTPUT

The CARP system outputs more than just eco-friendly route suggestions. It also provides users with a **comparison matrix** showing different route options side by side, including travel time, distance, and estimated carbon emissions. This comparative view allows users to **make informed decisions** that balance convenience with sustainability.

Another significant expected output is the **analytics dashboard**, which tracks trip history and cumulative emissions over time. This empowers users to see how their travel choices contribute to overall emission reduction. The ability to visualize one's environmental footprint can serve as a **powerful motivator** for adopting eco-friendly habits.

For administrators, the expected outputs include a **control panel** to manage users, monitor system usage, and update emission datasets. This helps ensure that the system remains **accurate, relevant, and scalable** for broader deployment in smart city ecosystems.

8.2FUTURE ENHANCEMENT

8.2.1 AI-Powered Route Optimization

Future versions of CARP could integrate artificial intelligence and machine learning models to enhance eco-routing accuracy. These models can learn from historical traffic patterns, weather conditions, and fuel consumption data to provide **predictive routing**, ensuring better results even during unexpected situations.

8.2.2 Integration with Public Transport Systems

The system can be expanded to compare eco-friendly private vehicle routes with **public transport options**. This would allow users to evaluate whether switching to metro, bus, or shared mobility reduces their carbon footprint further, promoting **multi-modal sustainable transportation**.

8.2.3 Mobile Application

A dedicated mobile application can enhance accessibility, offering **real-time notifications, GPS tracking, and voice navigation**. With smartphone integration, CARP can reach a wider audience and make sustainable commuting part of everyday life.

8.2.4 Multi-User and Corporate Dashboard

The system can be extended for organizations and logistics companies, allowing them to monitor **fleet-wide carbon emissions**. This feature would help companies reduce costs, comply with environmental regulations, and showcase their commitment to sustainability.

8.2.5 Advanced Analytics and Reporting

Adding advanced analytics tools could help users and administrators generate **predictive forecasts** of emission savings. These insights could also be shared with policymakers to support **data-driven smart city planning**.

8.3 DISCUSSION

The results of CARP highlight the **practical value of combining technology with sustainability goals**. By providing users with both eco-friendly and traditional route options, the system empowers them to actively choose greener alternatives without sacrificing convenience.

Moreover, the project demonstrates how **individual behavioral changes**, when scaled across thousands of users, can significantly reduce carbon emissions in urban transport. CARP thus not only serves as a navigation tool but also as an **awareness platform**, encouraging users to take responsibility for their environmental impact.

From a technical perspective, the modular design ensures scalability, making it possible to integrate CARP into larger **smart city infrastructures**. Future collaborations with government bodies, NGOs, or ride-sharing companies could amplify its impact, making eco-routing a **mainstream practice** in urban mobility

CHAPTER 9

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