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CARBONCAST: CO₂ Emission Prediction and Recommendation for Logistics using ML

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ABSTRACT: CarbonCast is an intelligent sustainability-focused system designed to predict and reduce CO₂ emissions in road logistics. It addresses the growing environmental impact of transportation by providing accurate, data-driven emission insights instead of relying on traditional static estimation methods. By analyzing key trip-related factors such as distance, vehicle type, fuel usage, and cargo load, the system delivers reliable emission forecasts tailored to real-world conditions. Beyond prediction, CarbonCast offers practical recommendations to improve fuel efficiency and minimize environmental impact. With its interactive interface and sustainability tracking capabilities, CarbonCast provides a scalable and effective solution for greener and more responsible logistics operations.

I. INTRODUCTION

CarbonCast addresses the growing need to reduce carbon emissions in road transportation through intelligent monitoring and decision support. Transport activities contribute significantly to greenhouse gas emissions, yet many organizations lack accurate and dynamic emission tracking systems. Existing estimation methods often rely on generalized emission factors that fail to reflect real-time trip conditions and operational variations. CarbonCast provides an automated solution that analyzes trip-related parameters to generate reliable emission predictions and sustainability insights. In addition to forecasting emissions, the system offers practical recommendations to improve fuel efficiency and minimize environmental impact through optimized route and load planning. It enables emission analysis, trip comparison, and sustainability tracking through an intuitive web-based interface. The system focuses on emission prediction and reduction strategies but does not include full fleet automation or direct real-time sensor integration.

II. EXISTING SYSTEM

Current emission estimation systems in the transportation sector primarily rely on fixed emission factors and standardized calculation methods. These approaches use generalized assumptions based on average fuel consumption and vehicle categories, without considering real-time operational variations. As a result, they often fail to reflect actual trip-specific conditions such as load capacity, route characteristics, fuel type, and driving patterns. Many traditional tools also lack interactive analysis features and do not provide actionable recommendations for emission reduction. In addition, emission tracking is frequently performed manually or through static reports, limiting continuous monitoring and informed decision-making. This creates a significant gap between estimated emissions and real-world environmental impact within logistics operations.

III. PROPOSED SYSTEM

CarbonCast enables users to estimate carbon emissions generated from transportation activities by analyzing important trip-related parameters. Users can enter details such as travel distance, vehicle type, fuel category, and cargo load, which are then processed by the system to produce a reliable emission estimate. By considering these operational factors, the platform provides a more realistic view of the environmental impact associated with each trip. This allows organizations to better understand how different transportation conditions influence carbon emissions.

In addition to emission estimation, the system also supports emission monitoring and performance analysis.

CarbonCast maintains records of previous trips, allowing users to review historical emission data and compare results across multiple transportation activities. These insights help identify patterns in emission levels and encourage more sustainable operational planning. Through clear visualization and organized data tracking, the platform helps users make informed decisions aimed at reducing environmental impact.

- **Emission Prediction Module** – Processes key trip parameters such as distance, vehicle type, fuel type, and cargo load to generate reliable CO₂ emission estimates based on real operational conditions.
- **Recommendation Module** – Provides practical suggestions to reduce emissions, including improved load planning and fuel-efficient operational adjustments.
- **Emission Analysis and Tracking Module** – Allows users to view emission results, compare trip data, and monitor sustainability performance through an interactive dashboard with stored trip history.

IV. METHODOLOGY

i. Data Collection

In this stage, the system gathers the necessary data required for CO₂ emission prediction. Trip-related parameters such as distance, vehicle type, fuel type, cargo weight, and terrain conditions are collected. These factors significantly influence emission levels and therefore form the primary inputs for the prediction process. The system also captures real-time user inputs through the web interface, ensuring that emission estimates are generated based on actual transportation conditions.

ii. Data Preprocessing

After collecting the required inputs, the data is prepared for model processing. Missing or inconsistent values are handled to improve data reliability. Categorical variables such as fuel type and terrain conditions are converted into numerical representations suitable for machine learning algorithms. The processed dataset is then structured into a format that allows the prediction model to accurately interpret the input parameters.

iii. Model Training

In this stage, the prepared dataset is used to train the prediction model. A LightGBM regression algorithm is applied to learn the relationship between trip parameters and their corresponding CO₂ emission values. The model analyzes patterns within the data to generate accurate emission estimates. Once the training process is completed and the model achieves satisfactory performance, it is saved and prepared for deployment.

iv. Emission Prediction

During system operation, user-provided trip details are processed and passed to the trained machine learning model. The model evaluates the input parameters and calculates the estimated CO₂ emission value for the given trip. This stage forms the core functionality of the system, enabling users to understand the environmental impact associated with specific transportation activities.

v. Recommendation and Result Presentation

In an interactive interface. Based on the predicted values and input characteristics, the platform provides practical recommendations aimed at reducing emissions, such as improving load planning or adopting more efficient operational practices. The results are displayed clearly so that users can easily interpret the environmental impact and make informed decisions.

V. SYSTEM ARCHITECTURE

CarbonCast follows a modular system architecture that integrates the machine learning pipeline, backend services, and frontend interface to enable efficient CO₂ emission prediction. The machine learning layer processes emission datasets and trip-specific parameters such as distance, vehicle type, fuel type, terrain, and cargo weight. The data undergoes preprocessing steps including cleaning, handling missing values, and numerical encoding before being used to train a LightGBM regression model. The trained model is exported as a .pkl file and deployed in the backend. The backend, developed using FastAPI, handles communication between the frontend and the trained model by receiving user inputs, performing emission predictions, and generating optimization

recommendations. The frontend, built using React, provides an interactive interface where users enter trip details and view the predicted CO₂ emissions along with practical suggestions to reduce environmental impact.

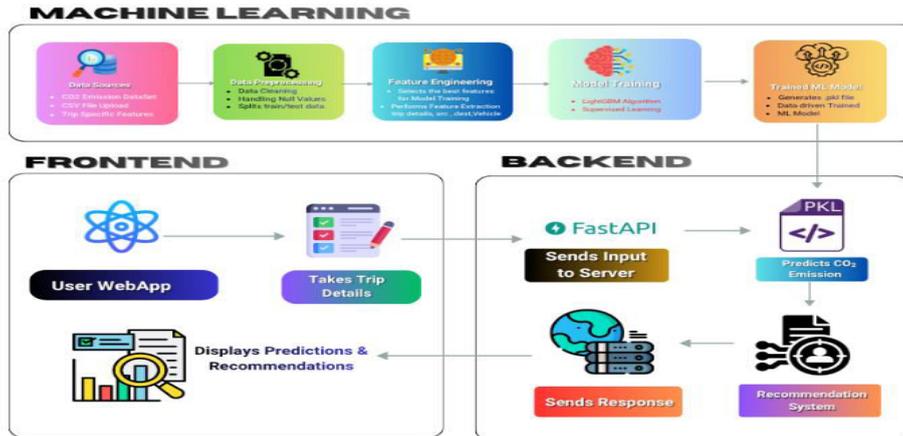


Fig : 7.1 Landing Page

VI. RESULTS AND OUTPUT

STEP 1 : Run the project using the development environment. You can see UI as shown in the image.

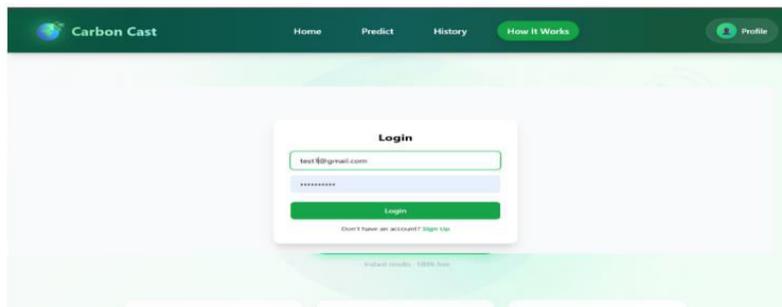


Fig : 7.2 Login page

STEP 2 : Create an account using your mail id and password. Or if you are an existing user login, in to the application using the credentials that you have used while creating your account.

STEP 3 : After logging into the application, click on the “Predict”.The system redirects to the Emission Prediction form, as shown in the image.



Fig : 7.3 Input Page

STEP 4: After clicking “Generate Prediction”, the system displays the emission results. It also provides environmental impact details and recommendations.

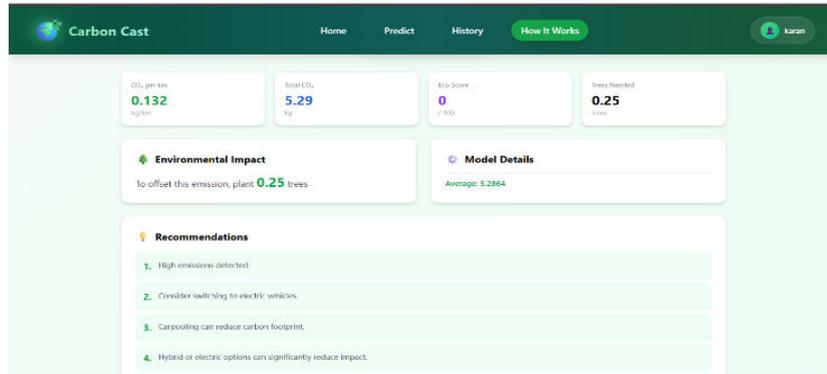


Fig : 7.5 Prediction

STEP 5 : Users can access their previous emission records by clicking on the “History” tab in the navigation bar. The system displays overall statistics, emission trends, vehicle-wise analysis, and detailed trip records in one place.

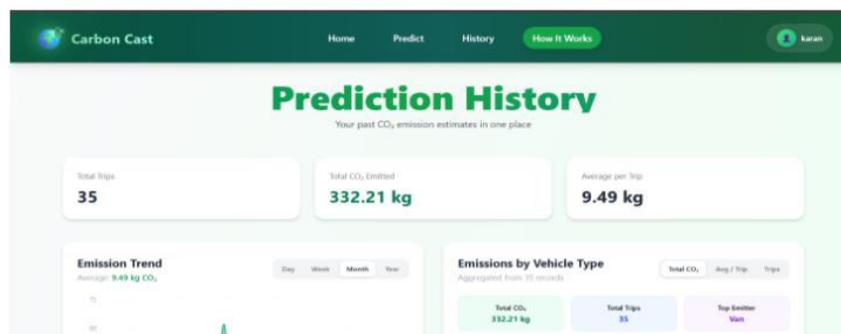


Fig : 7.6.1 History Dashboard

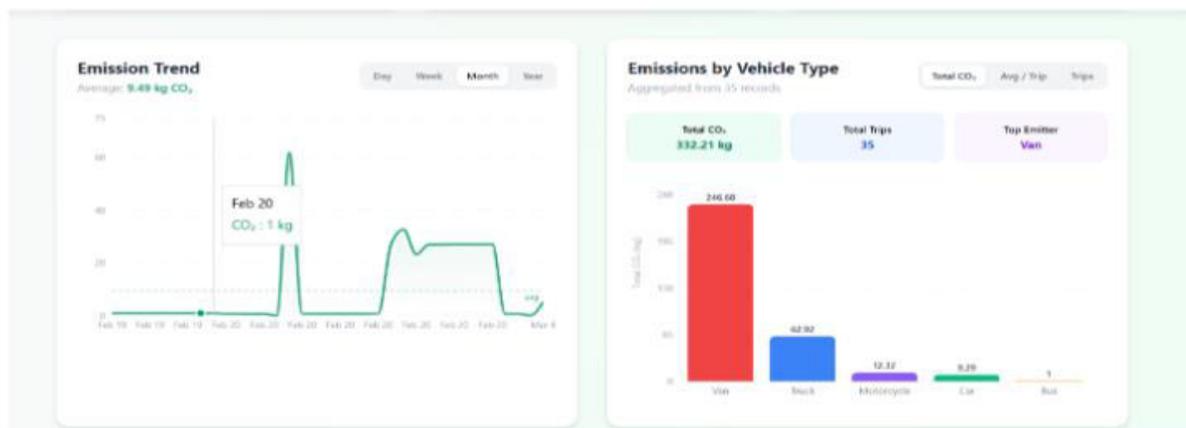


Fig : 7.6.2 Emission Trends and Vehicle-wise Analysis

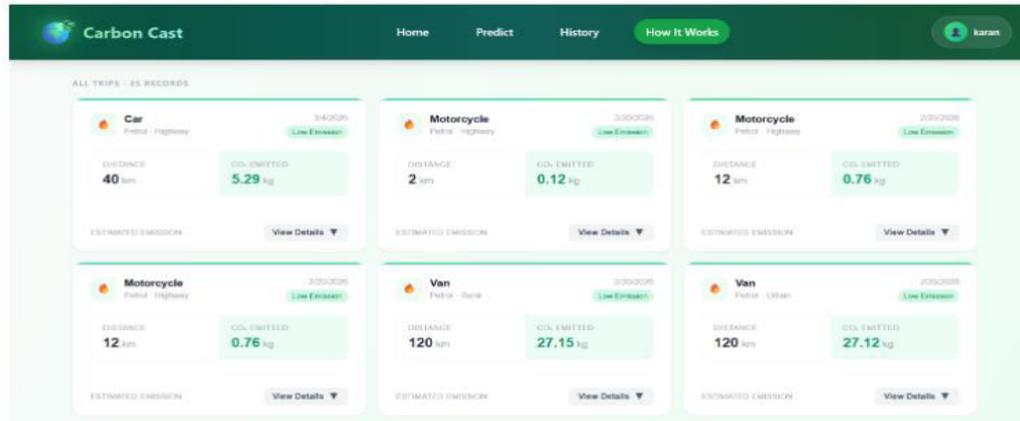


Fig : 7.6.3 Previous Trip Records

VII. CONCLUSION

CarbonCast addresses the challenge of accurately estimating CO₂ emissions in transportation by using a data-driven machine learning approach. Unlike traditional methods that rely on fixed emission factors, the system considers trip-specific parameters such as distance, vehicle type, fuel type, terrain, and cargo weight to generate more realistic emission predictions. This approach improves emission visibility and allows organizations to better understand the environmental impact of their transportation activities.

The system demonstrates the practical use of machine learning for sustainability-focused applications. A LightGBM regression model is used to analyze trip data and produce reliable emission estimates. The backend, implemented using FastAPI, manages communication between the prediction model and the user interface, while the React-based frontend provides a simple platform for entering trip details and viewing results. The recommendation component further enhances the system by suggesting possible ways to reduce carbon emissions.

Overall, CarbonCast contributes to promoting environmentally responsible transportation practices by combining predictive analytics with an accessible web-based platform. By providing emission insights and optimization suggestions, the system supports better operational planning and encourages more sustainable decision-making in logistics activities.

VIII. FUTURE SCOPE

1. Deep Learning Integration:

Future versions of CarbonCast can integrate advanced deep learning models to enhance prediction accuracy. Models such as Neural Networks and ensemble learning techniques can capture more complex relationships between trip parameters and CO₂ emissions.

2. Real-Time IoT and GPS Integration:

CarbonCast can be extended by integrating IoT sensors and GPS tracking systems in vehicles. Real-time data such as fuel consumption, engine performance, speed, and route deviations can be directly collected and analyzed. This would eliminate manual data entry and enable highly accurate live emission monitoring.

3. Smart Route Optimization:

An advanced route optimization module can be developed to suggest low-emission routes automatically. By integrating mapping APIs and traffic analysis, the system can compare multiple route options and recommend the most eco-friendly path. This feature would not only reduce emissions but also improve fuel efficiency and delivery time management.

4. Mobile Application Development:

Developing Android and iOS applications will increase accessibility and usability. Fleet managers and drivers can enter trip details, monitor emissions, and receive recommendations directly from mobile devices. Mobile integration will enhance convenience, real-time monitoring.

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