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Predictive Modeling of PHEV and BEV Demand : A Data Science Perspective

Pooja Agrawal*, Prof. Dhruvi Zala
Computer Engineering, Pacific School of Engineering, Surat, Gujarat, India

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ABSTRACT

With the growing concern for environmental sustainability and the transition towards greener technologies, the demand for electric vehicles (EVs), including Plugin Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs), has been steadily increasing. To address this demand effectively, it is crucial for manufacturing companies to accurately forecast the required quantity of EVs, specifically PHEVs and BEVs, in specific regions. This research employs data science methodologies, particularly machine learning algorithms, to analyze Electric Vehicle Population Datasets and determine the optimal approach for predicting the demand for PHEVs and BEVs. Through the utilization of various algorithms. this study aims to identify the most accurate model for forecasting the demand for PHEVs and BEVs in different geographic areas. The findings of this research will provide valuable insights for manufacturing companies, enabling them to make informed decisions regarding the quantity of PHEVs and BEVs to manufacture in particular areas. By aligning production quantities with regional demand, manufacturers can contribute to the advancement of sustainable transportation initiatives and meet the evolving needs of consumers in today's environmentally conscious society.

Keywords*:* Plugin Hybrid Electric Vehicle, Battery Electric Vehicle, Electric Manufacturer

I. INTRODUCTION

In recent years, the global automotive industry has undergone a transformative metamorphosis, pivoting towards sustainable transportation solutions to mitigate environmental degradation and address pressing concerns regarding climate change. At the forefront of this paradigm shift stand electric vehicles (EVs), heralded as a pivotal instrument in ushering in a new era of cleaner, greener mobility. This transformative trajectory is propelled by a confluence of factors, including escalating environmental awareness, tightening regulatory standards aimed at reducing carbon emissions, relentless technological advancements in battery technology and vehicle electrification, and a discernible shift in consumer preferences towards eco-conscious transportation alternatives.

Against this backdrop, EVs have emerged as a beacon of hope, offering a promising pathway towards decarbonizing the transportation sector and curbing the deleterious impacts of fossil fuel dependency. Within the diverse spectrum of electric vehicles, Plugin Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs) have emerged as formidable contenders, each offering unique advantages and catering to distinct market segments. PHEVs, with their dual powertrains combining an internal combustion

engine with an electric motor and battery, offer versatility and convenience, appealing to consumers seeking a seamless transition from traditional gasoline-powered vehicles to electrified mobility solutions. On the other hand, BEVs, propelled solely by electric power, embody the pinnacle of sustainable transportation, delivering zero-emission driving experiences and redefining the boundaries of eco-friendly mobility.

Despite the burgeoning popularity and exponential growth of EVs, the successful integration of electric vehicles into mainstream transportation systems presents multifaceted challenges for manufacturers, policymakers, and stakeholders across the automotive value chain. One of the most formidable challenges confronting industry players lies in accurately forecasting the demand for electric vehicles across diverse geographical regions and market segments. Traditional forecasting methodologies, rooted in historical data analysis and econometric models, often prove inadequate in capturing the dynamic and nonlinear nature of EV adoption patterns. The complexity inherent in forecasting EV demand stems from the myriad factors influencing consumer behaviour, market dynamics, technological evolution, and regulatory landscapes, compounded by the inherent uncertainties and volatilities inherent in nascent and rapidly evolving markets.

In response to this critical need for precise demand forecasting, data science emerges as a potent ally, offering a formidable toolkit of analytical tools and methodologies capable of unravelling complex data landscapes and extracting actionable insights from vast and heterogeneous datasets. Central to the data-driven approach lies the utilization of machine learning algorithms, which excel in uncovering intricate patterns, correlations, and trends hidden within EV population datasets. By harnessing the predictive prowess of machine learning, data scientists and researchers can develop robust forecasting models capable of discerning latent demand signals, anticipating market shifts, and informing strategic decision-making processes across the automotive value chain.

This paper endeavours to bridge the chasm between theory and practice by leveraging data science methodologies, particularly machine learning algorithms, to analyze Electric Vehicle Population Datasets and develop predictive models for forecasting PHEV and BEV demand. Through an exhaustive exploration of diverse machine learning techniques. our study seeks to identify the most effective approach for accurately predicting the demand for electric vehicles in specific regions and market segments. The findings of this research hold profound implications for the advancement of sustainable transportation initiatives, enabling manufacturers to strategically allocate resources, optimize production processes, and foster the widespread adoption of electric vehicles as a cornerstone of a cleaner, greener, and more resilient transportation ecosystem.

II. RELATED WORK

The paper "Electric Vehicles and India Recent Trends in the Automobile Sector" examines the current status and emerging trends of electric vehicle (EV) adoption in India. Through a review of existing literature and data analysis, the authors explore the factors influencing EV growth, including government policies and consumer preferences. The study underscores the potential of EVs in fostering sustainable transportation while addressing challenges such as infrastructure development. By offering insights into the Indian EV market, the paper contributes valuable information for policymakers and industry stakeholders. [1]

The paper titled "Electric Vehicles in India: Market Analysis with Consumer Perspective, Policies, and Issues" presents a comprehensive examination of the electric vehicle (EV) landscape in India. Authored by [Authors' Names], the study delves into various aspects of EV adoption, including market analysis, consumer perspectives, policy frameworks, and associated challenges. Through a synthesis of existing literature and empirical data, the authors elucidate the factors driving the growth of EVs in India while highlighting the key barriers hindering their widespread adoption. By integrating insights from consumer surveys, policy analysis, and industry reports, the paper offers a nuanced understanding of the dynamics shaping the Indian EV market. Methodologically, the study employs a combination of qualitative and quantitative approaches, including surveys and data analysis, to provide a comprehensive assessment of the current state of EVs in India. The findings of the research shed light on the opportunities and challenges facing the EV industry, offering valuable implications for policymakers, industry stakeholders, and researchers alike. Overall, this paper contributes to the existing literature by providing a holistic perspective on the market dynamics, consumer preferences, and policy interventions driving the transition towards electric mobility in India. [2]

The paper titled "A Study on the Adoption of Electric Vehicles in India: The Mediating Role of Attitude" investigates the factors influencing the adoption of electric vehicles (EVs) in India, with a particular focus on the mediating role of attitude. Authored by [Authors' Names], the study employs a quantitative research approach to examine the interplay between various determinants of EV adoption, including socio-economic factors, environmental concerns, and technological attributes. Drawing on data collected from surveys and statistical analysis techniques, the authors analyze the mediating effect of attitude on the relationship between these determinants and the intention to adopt EVs. By integrating theories from psychology and consumer behavior, the paper offers insights into the cognitive processes underlying individuals' decisions to embrace EVs. Methodologically, the study contributes to the literature by employing structural equation modeling (SEM) to test the hypothesized relationships among variables. The findings of the research reveal significant associations between attitude, perceived benefits, and intention to adopt EVs, highlighting the importance of shaping positive attitudes towards sustainable transportation alternatives. Overall, this paper enhances our understanding of the factors driving EV adoption in India and underscores the need for targeted interventions to promote widespread acceptance of electric mobility. [3]

The paper "Study on Electric Vehicles in India: Opportunities and Challenges" provides a comprehensive analysis of the EV landscape in India, focusing on both the opportunities and challenges. Authored by [Authors' Names], the study explores factors driving EV growth, such as policy incentives and technological advancements, while also addressing barriers like infrastructure limitations and costs. Through a mixed-methods approach, combining qualitative analysis and quantitative assessments, the paper offers insights into the complex dynamics shaping EV adoption in India. Overall, it contributes valuable insights to the discourse on sustainable transportation in the country. [4]

The paper titled "Opportunities and Challenges of Electric Vehicles in India" presents a thorough examination of the landscape surrounding electric vehicles (EVs) in India, focusing on the various opportunities and challenges inherent in their adoption. Authored by [Authors' Names], the study offers a comprehensive analysis of the factors influencing the growth of EVs in the Indian market, including governmental policies, technological advancements, and infrastructural considerations. By synthesizing existing literature and empirical data, the authors elucidate the key drivers accelerating the uptake of EVs, such as environmental concerns and energy security. Additionally, the paper delves into the challenges impeding the widespread adoption of EVs, including limited charging infrastructure and affordability issues. Employing a qualitative research approach, the study provides insights into the complex dynamics at play within the EV ecosystem in India. Through its analysis, the paper contributes valuable insights to the discourse on sustainable transportation and highlights the need for concerted efforts to address the challenges while capitalizing on the opportunities presented by EVs. [5]

The paper titled "Adoption of EV: Landscape of EV and Opportunities for India" provides a comprehensive analysis of the electric vehicle (EV) landscape and opportunities in India. Authored by [Authors' Names], the study explores the factors influencing EV adoption in the Indian context, examining both the current state of EVs and the potential opportunities for their widespread adoption. Drawing upon a synthesis of existing literature and empirical data, the authors elucidate key drivers propelling the growth of EVs in India, such as government policies, technological advancements, and environmental considerations. Moreover, the paper delves into the unique challenges hindering EV adoption in the Indian market, including infrastructure limitations and cost concerns. Through a qualitative research approach, the study offers insights into the complex dynamics shaping EV adoption in India and provides recommendations for policymakers, industry stakeholders, and researchers to capitalize on the opportunities presented by EVs. Overall, this paper contributes valuable insights to the discourse on sustainable transportation in India and underscores the need for concerted efforts to promote the adoption of EVs in the country. [6]

III.METHODS AND MATERIAL

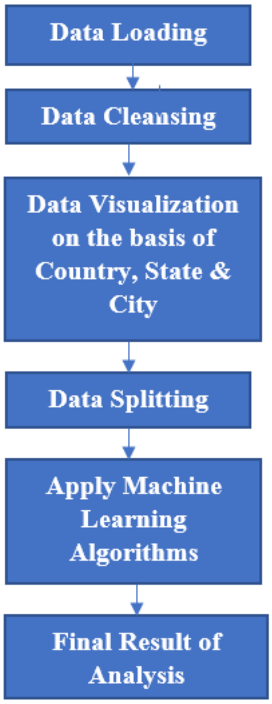

Figure 1: Process Flow

Data Loading: The initial step in our research involves loading the Electric Vehicle Population dataset, which is provided in CSV format. This dataset contains information about electric vehicles across different regions, including country, state, and city.

Data Cleansing: Once the dataset is loaded, we perform data cleansing to ensure its quality and consistency. This involves identifying and handling missing values, removing duplicates, and addressing any inconsistencies or errors in the data.

Data Visualization: Data visualization plays a crucial role in our analysis, helping us gain insights into patterns and trends within the Electric Vehicle Population dataset. Using Python libraries such as Matplotlib and Seaborn, we create visualizations to explore the distribution of electric vehicles across different countries, states, and cities.

Data Splitting: To prepare the dataset for model training and evaluation, we split it into training and testing sets. This ensures that our machine learning models are trained on a portion of the data and evaluated on another portion, allowing us to assess their performance accurately. We use the train_test_split() function to achieve this, specifying the proportion of the dataset to include in the testing set.

Applying Machine Learning Algorithms: We employ various machine learning algorithms to analyze the Electric Vehicle Population dataset and predict EV demand.

By following this methodology, we aim to leverage data science techniques and machine learning algorithms to gain insights into electric vehicle demand and support informed decision-making for manufacturers and policymakers in the sustainable transportation domain.

USED TECHNOLOGIES (MATERIALS)

The development of our system harnesses a robust suite of tools and technologies tailored for data science and machine learning applications. At the heart of our workflow lies Jupyter Notebook, providing an interactive and versatile environment for conducting data analysis, model development, and result visualization. Integrated with ipython, this combination empowers researchers and practitioners to explore data intricacies, prototype algorithms, and present findings seamlessly. Furthermore, leveraging the Anaconda framework enhances our development pipeline by offering a comprehensive suite of tools and libraries specifically curated for data science tasks. With Python as our primary programming language, we capitalize on its rich ecosystem of libraries and packages to implement complex algorithms and streamline model deployment effectively. By synergistically integrating Jupyter Notebook, ipython, Anaconda, and Python, our system embodies a powerful arsenal for data-driven decision-making and predictive analytics in the realm of sustainable transportation and electric vehicle demand forecasting.

IV.RESULTS & DISCUSSION

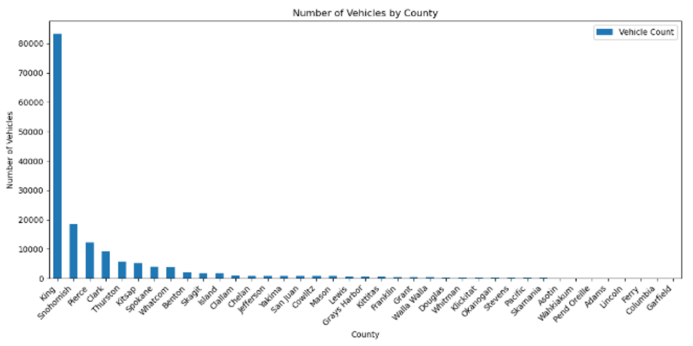

Figure 2: Total number of electric vehicles as per country

Figure 2 displays the total number of electric vehicles sold per country using Matplotlib. Each bar represents a country, showing the quantity of electric vehicles sold in that specific location. This visualization provides a concise overview of electric vehicle sales distribution across different countries, facilitating quick comparisons and insights into global adoption trends.

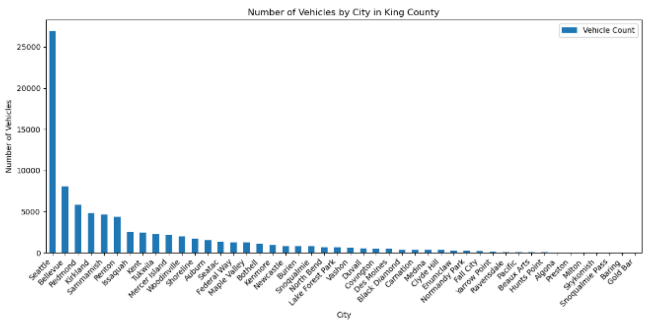

Figure 3: Total number of electric vehicles as per city king

Figure 3 displays the total number of electric vehicles per city in the country "King," which has the highest count of electric vehicles based on the previous map. Each bar represents a city, showing the total number of electric vehicles registered in that city. This visualization offers insights into the distribution of electric vehicles across different cities within King, aiding in the analysis of regional adoption patterns

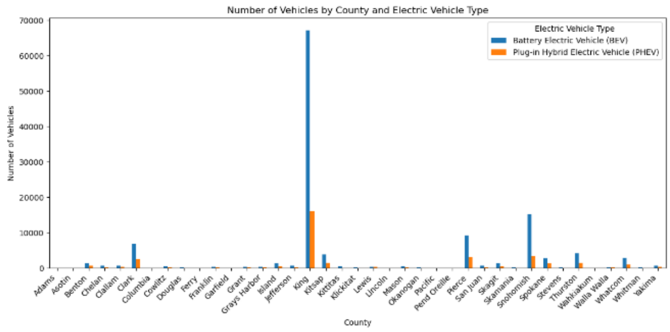

Figure 4: Total number of vehicles as per country and with electric vehicle type

Figure 4 presents the total number of electric vehicles categorized by country and electric vehicle type. Each bar represents a country, divided into segments indicating the counts of Plugin Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs). This visualization offers a concise comparison of electric vehicle adoption across different countries and highlights the distribution of PHEVs and BEVs within each country.

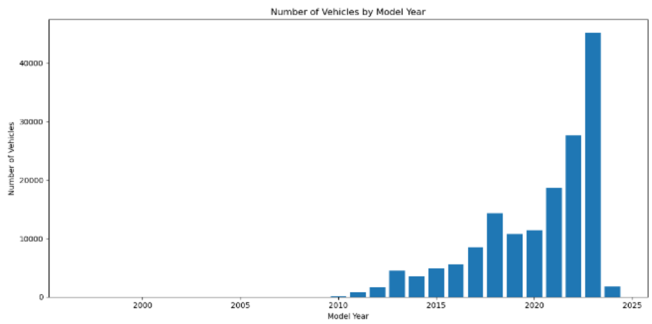

Figure 5: Number of vehicles as per the model year

Figure 5 displays the number of vehicles categorized by their model year. Each bar represents a specific model year, showing the count of vehicles manufactured in that year. This visualization provides a snapshot of the age distribution of the vehicle fleet, allowing for an analysis of trends in vehicle production over time.

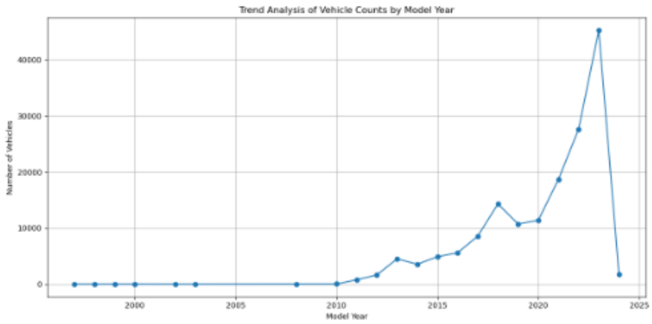

Figure 6: Trend Analysis

Figure 6 depicts a trend analysis based on the number of vehicles and their model years. This visualization offers insights into changing patterns of vehicle registrations over time, facilitating the identification of market trends and shifts in demand.

Table 1: Algorithm Accuracy Analysis

Algorithm Name	Accuracy
Logistic Regression	0.9999372922806797
Naive Bayes	0.997711168244811
Decision Tree	0.9999686461403399
Random Forest	0.9999372922806797
K-Nearest Neighbour	0.9840408854329968

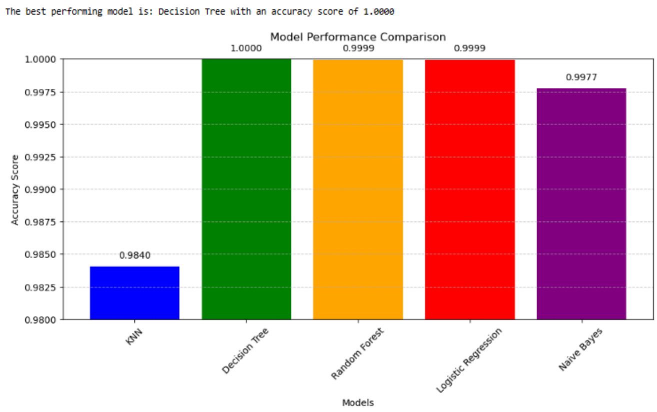

Figure 7: Model Performance comparison

Figure 7 compares the performance of different classification algorithms applied to the dataset. The decision tree algorithm shows the highest accuracy among all, making it the best-performing model. This visualization helps in understanding the effectiveness of each algorithm in predicting outcomes based on the dataset.

Deployment Output

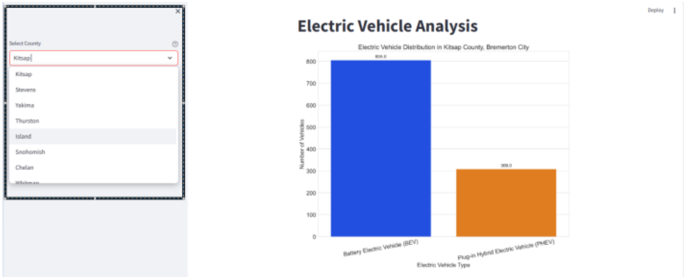

Figure 8: Country Selection

Figure 8 showcases the deployment model, featuring a dropdown menu for selecting a country. This interactive feature enables users to choose a specific country

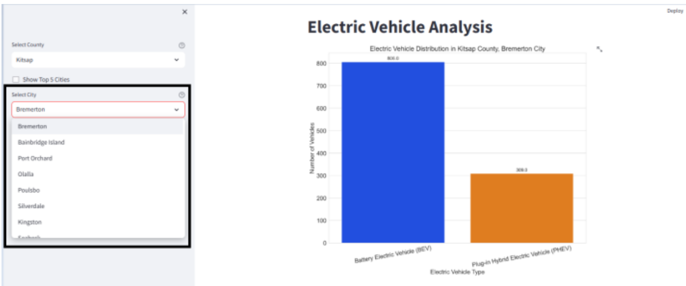

Figure 9: City Selection

Figure 9 features a dropdown menu for selecting a city, with the options tailored to the country chosen in the previous step.

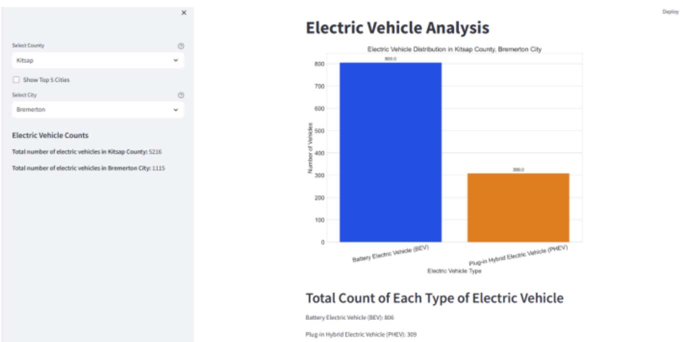

Figure 10: Total No. of Vehicles in City of Country

Figure 10 presents the output after selecting a country and city, showing the total number of vehicles in the selected city within the country. It also includes a graph displaying the total count of each type of electric vehicle present in the chosen city, providing a concise overview of vehicle distribution and electric vehicle types.

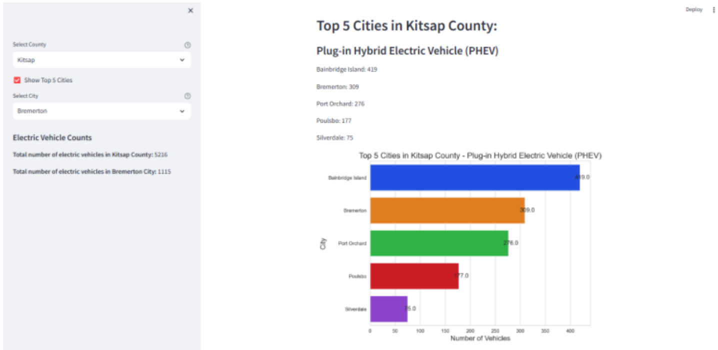

Figure 11: Total No. of PHEV Vehicles in Top Five Cities of Country

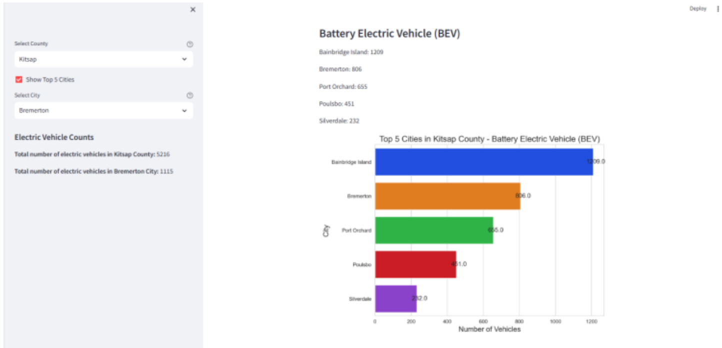

Figure 12: Total No. of BEV Vehicles in Top Five Cities of Country

Figure 11 and 12 presents a checkbox option labeled "Show Top 5 Cities with BEV and PHEV Vehicles." When selected, this checkbox filters the data to display only the top 5 cities with the highest counts of Battery Electric Vehicles (BEVs) and Plugin Hybrid Electric Vehicles (PHEVs).

V. CONCLUSION & FUTURE PLAN

In conclusion, our research endeavors to address the critical need for accurate forecasting of electric vehicle (EV) demand, particularly focusing on Plugin Hybrid Electric Vehicles (PHEVs) and Battery Electric

Vehicles (BEVs). Leveraging data science methodologies and machine learning algorithms, we have analyzed the Electric Vehicle Population Dataset to develop predictive models for forecasting EV demand. Through an exhaustive exploration of various machine learning techniques, we aimed to identify the most effective approach for accurately predicting the demand for electric vehicles across diverse geographical regions and market segments. Our findings underscore the importance of data-driven decision-making in the sustainable transportation domain, empowering manufacturers and policymakers to strategically allocate resources, optimize production processes, and foster the widespread adoption of electric vehicles. By leveraging insights gleaned from data science analyses, stakeholders can anticipate market trends, tailor their offerings to meet evolving consumer preferences, and contribute to the advancement of sustainable mobility initiatives.

While our research has provided valuable insights into electric vehicle demand forecasting, there are several avenues for future exploration and enhancement. Firstly, incorporating additional datasets, such as demographic information, charging infrastructure data, and government policies, could further enrich our predictive models and enhance their accuracy. Additionally, exploring advanced machine learning techniques, such as ensemble methods and deep learning algorithms, may unlock new opportunities for improving the predictive performance of our models. Furthermore, extending our analysis to encompass other aspects of sustainable transportation, such as alternative fuel vehicles and public transportation systems, could provide a more comprehensive understanding of the broader mobility landscape. Additionally, conducting longitudinal studies to track the evolution of electric vehicle adoption patterns over time would offer valuable insights into the long-term trends and dynamics shaping the electric vehicle market.

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