Chapter 2

Literature view

2.1 Introduction

In recent years, with the rapid growth of technology and the strong policy support and promotion by various countries, the electric vehicle (EV) market has grown rapidly. Leading automakers such as Tesla, BYD, and Nissan have created a series of high performance, high tech, long range models that are favored by consumers. In the fierce competition among major automakers, modern electric vehicle technology has developed rapidly, producing a series of mature and innovative high tech products, mainly in the areas of electric vehicle technology, battery technology, motor and control systems, and autonomous driving technology. With the development of these technologies, more and more EV models are emerging. The current market mainly includes “Battery Electric Vehicles (BEV)”, “Plugin Hybrid Electric Vehicles (PHEV)”, “Fuel Cell Electric Vehicles (FCEV)”, and “Hybrid Electric Vehicles (HEV)”. The emergence of an increasing number of models provides consumers with more affordable and diverse choices. In the future, with ongoing technological advancements and the support of global policies. the EV market is bound to continue its steady growth. This study aims to analyze and review historical data on the EV market to predict the future development of various EV models.

2.2 Historical literature on the electric vehicle market

The next discussion focuses on recent literature on growth of the electric vehicle (EV) market. The latest research suggests that a few primary models type will dominate future market trends, and will be determined by technological advances, alterations in environmental policy, and consumer preferences. These developments involve vehicle models that have much bigger batteries, more powerful smart technologies, and newer electric variants. Besides, yes, one would be accelerating from sustainable transportation solutions and infrastructure for charging that includes electric vehicles.

2.2.1 Type of Electric Vehicles

Today there are various types of electric vehicles available on the market, each with its own specifications and benefits. Here's a (relatively) simple overview of these primary types and their principles:

a) Battery Electric Vehicles (BEV)

Advantages:

i. Zero Emissions: Without tailpipe emissions, air quality could improve and pollution could decrease.
ii. Higher Efficiency: Electric motors have higher efficiency than their internal combustion counterpart.
iii. Low Maintenance: They have fewer mechanical parts than gasoline and hence easier and less to maintain.
iv. Just Awesome Ride: Silent & smooth drive.

Disadvantages:

stations, making long trips inconvenient.

Environmental Analysis:

Battery electric vehicles (BEVs) generate minimal environmental pollution, diminishing reliance on fossil fuels and cutting down greenhouse gas emissions. However, the production and disposal of batteries still require attention to environmental impacts.

b) Plugin Hybrid Electric Vehicles (PHEV)

Advantages:

i. Flexibility: Combines electric and internal combustion engine modes, highly adaptable.
ii. Reduced Emissions: Can run entirely on electric power for short trips, reducing tailpipe emissions.
iii. Long Range: The internal combustion engine provides additional range, avoiding battery depletion.

Disadvantages:

i. Complex Design: Requires two sets of power systems, making maintenance more challenging.
ii. High Cost: Generally more expensive than traditional internal combustion vehicles and BEVs.
iii. Increased Weight: Having both an internal combustion engine and a battery increases the vehicle's overall weight.

Environmental Analysis:

Effectively reduces tailpipe emissions on short trips, but relies on the internal combustion engine for long journeys. It is an important step towards zero emission vehicles.

c) Hybrid Electric Vehicles (HEV)

Advantages:

i. Fuel Efficiency and Reduced Emissions: Combines electric motors with internal combustion engines, reducing fuel consumption.
ii. Long Range: Internal combustion engine provides additional driving distance.
iii. Ready to Use: Does not require external charging, suitable for users without charging facilities.

Disadvantages:

i. High Cost: More expensive than traditional internal combustion vehicles.
ii. Complex Design: Requires two sets of power systems.
iii. Battery Life: Battery performance may degrade over time.

Environmental Analysis: HEVs perform well in reducing fuel consumption and emissions but still rely on fossil fuels, placing their environmental impact between traditional vehicles and BEVs.

d) **Fuel Cell Electric Vehicles (FCEV)**

Advantages:

i. Zero Emissions: Only emits water vapor, environmentally friendly.
ii. Long Range: Typically offers a range comparable to internal combustion vehicles.
iii. Quick Refueling: Hydrogen refueling time is short, similar to refueling with gasoline.

Disadvantages:

i. Limited Infrastructure: Insufficient hydrogen stations.
ii. High Cost: Hydrogen fuel cells and storage systems are expensive.
iii. Safety: Hydrogen storage and transportation require high safety standards.

Environmental Analysis: FCEVs do not produce pollutants during operation, only emitting water vapor. However, hydrogen production requires significant energy, especially when sourced from fossil fuels, which produces carbon dioxide. Developing renewable hydrogen production methods is crucial to realizing their environmental potential.

2.3 Important Factors Affecting the Development

In recent years, numerous studies have delved into the development trends of the electric vehicle (EV) market and the factors influencing these trends. Most of these studies focus on identifying the primary factors that shape the development trajectories of various types of EVs. However, there remains a gap in comprehensive research on the overall development trend of the EV market. This study aims to fill that gap by analyzing and synthesizing existing research on EV market trends. It will consider a wide range of factors affecting the development of different EV types and provide a detailed analysis and forecast of the overall trends in the current EV market.

Research on the market development trend forecast of various types of electric vehicles in recent years is as follows:

Authors	**Related Paper**	**Summary**	**Market Analysis Predictions**
Hertzke et al.	Dynamics in the global electric-vehicle market	Explores China's dominance in EV production due to strong policies and advanced manufacturing.	The global market is highly competitive, with China maintaining its dominant position due to scale and policy support.
Muratori et al.	The rise of electric vehicles: 2020 status and future expectations	Provides an overview of BEV growth as the primary zero-emission vehicle and global electrification trends.	BEVs will see steady market growth globally, driven by environmental policies and consumer preferences.
Usman et al.	Recent trends and future prospects in electric vehicle technologies	Reviews the role of HEVs as transitional technologies and PHEVs as flexible urban solutions.	HEVs will maintain steady demand, while PHEVs appeal to urban markets seeking flexible, efficient options.
Joao P. Trovao	Electric Vehicle Efficient Power and Propulsion Systems	It highlights the shift from traditional internal combustion engines to more efficient and eco-friendly propulsion systems like hybrid and all-electric vehicles.	Electrification will grow by 15% by 2030.
A.Olabi et al.	Battery Electric Vehicles: Progress, Power Electronic Converters, Strength (S), Weakness (W), Opportunity (O), and Threats (T)	The document explores the automotive industry's shift from internal combustion engines to electric vehicles (EVs).	Anticipated future trends in the electric vehicle (EV) market will likely prioritize “battery electric vehicles (BEVs)” and “plug-in hybrid electric vehicles (PHEVs)”.
Abdullah Dik	Electric Vehicles: V2G for Rapid, Safe,	This article explores the role of electric vehicles (EVs) in	Future trends in electric vehicles (EV) will likely center around “battery

	and Green EV Penetration	reducing carbon emissions and aiding the integration of renewable energy sources into the power grid.	electric vehicles (BEVs)" and "plug-in hybrid electric vehicles (PHEVs)".
Xiangyang Li	Industrial ripples: Automotive electrification sends through carbon emissions	The research paper discusses the importance of vehicle electrification in addressing climate challenges related to carbon emissions from the transport sector	The study predicts that electric vehicles will dominate the automotive market in the future, with hybrid vehicles acting as an intermediary step.
Conway et al.	A review of current and future powertrain technologies and trends	Examines the rise of FCEVs and powertrain efficiency improvements for long-distance applications.	FCEVs have significant potential in long-distance transport, particularly in markets like Japan.

Table 2.1 Future Trends and Market Analysis of Electrical Vehicles

The Table 2.1 above mentioned historical studies have roughly analyzed and predicted the market trends of some types of electric vehicles (EVs) in some countries and regions, which are specifically reflected in:

Regarding the global electric vehicle market: In the studies such as "Dynamics in the global electric-vehicle market" and "Electric Vehicle Efficient Power and Propulsion Systems", the authors mainly explored the global electrification trend and took China, which occupies a leading position in the electric vehicle market, as the research object, and concluded that the global market is rapidly transitioning to electric travel. Battery electric vehicles (BEVs) are becoming the flagship of zero-emission efforts. Their steady growth is driven by environmental regulations and increasing consumer demand (Muratori et al.), and with strong policy incentives and advanced manufacturing capabilities, their growth will be strongest in regions with sound infrastructure and government incentives, such as Europe, China and the United States (Muratori et al.), among which China leads in production, sales and technology, making electric vehicles more affordable (Hertzke et al.), which is a typical representative of the rapid transition of global electrification trends to electric travel in the future.

Battery and charging innovation: Lithium-ion batteries and solid-state batteries have always been a major issue hindering the development of electric vehicles. Today's innovations in battery and charging technologies have increased battery energy density, reduced manufacturing costs, and significantly reduced charging time (A. Olabi et al.). At the same time, emerging wireless charging and vehicle-to-grid (V2G) integration are reshaping electric vehicle infrastructure, making it more practical and attractive (Hemavathi et al.).

Efficient powertrain: Advances in powertrains are revolutionizing the automotive sector, with many electric drive engines outperforming traditional internal combustion engines, and fuel cell electric vehicles (FCEVs) becoming a viable option for long-distance transportation (Conway et al.).

Sustainability and policy impact: Governments around the world are adopting stricter carbon emission regulations, which will directly promote the growth of the electric vehicle market, and hybrid electric vehicles (HEVs) serve as a transition technology in regions where electric vehicle adoption is slower (Xiangyang Li).

2.4 Classification

Classification is a data mining (machine learning) technique used to predict group membership for data instances. There are several classification techniques that can be used for classification purpose. (Aized and Arshad, 2017).

Machine Learning (ML) is a comprehensive interdisciplinary domain that draws from computer science, statistics, cognitive science, engineering, optimization theory, and various other fields of mathematics and science [1]. Among its numerous applications, data mining stands out as particularly significant [2]. ML techniques are broadly categorized into supervised and unsupervised learning.

In unsupervised machine learning, models make inferences from datasets that consist of input data without labeled responses [3]. Essentially, in unsupervised learning, there is no predefined output for the model to predict.

Supervised machine learning aims to uncover the relationship between input features (independent variables) and a target variable (dependent variable) [4]. These techniques are further divided into two main categories: classification and regression. In regression, the target variable is continuous, while in classification, the target variable takes on discrete class labels [5].

Classification is a machine learning approach used in data mining to predict the group membership of data instances [6]. Despite the variety of available machine learning techniques, classification remains the most widely used [7]. It is particularly popular in planning for future trends and knowledge discovery.

Research in machine learning and data mining has extensively studied classification problems [8]. Figure 1 illustrates a general model for supervised learning through classification techniques.

Despite its popularity, classification faces challenges such as handling missing data. Missing values in datasets can create problems during both training and classification phases. Reasons for missing data include non-entry due to misunderstandings, data deemed irrelevant at the time of entry, removal of data due to inconsistencies with other recorded data, and equipment malfunction [9].

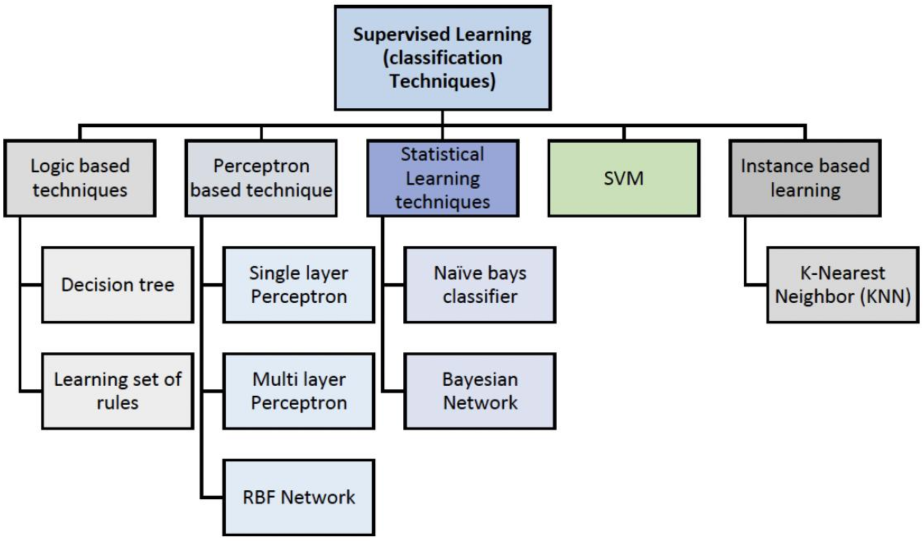

Figure 2.1 Supervised learning classification technique(Shoofi and Awan, 2017)

2.5 Market Trend Analysis and Forecast

Below is market trend analysis and forecasts for various electric vehicle types:

a. Battery Electric Vehicles (BEV)

Key factors affecting growth is Improvements in battery technology, like solid-state batteries, favorable government policies for the electric vehicle sector, and the development of charging infrastructure, including fast and wireless charging, are key factors propelling the electric vehicle market forward. Forecasts for the BEV market in past historical studies are BEVs will dominate the global electric vehicle market. Growth will be strongest in regions with well-established infrastructure and government incentives, such as Europe, China, and the United States (Muratori et al.).

b. Plug-in Hybrid Electric Vehicles (PHEV)

Key factors affecting growth are Urban consumers' demand for electric vehicle range and fuel support, gradual transition from internal combustion engines to fully electric solutions. Market forecast isPHEVs will maintain steady growth, especially in urban markets and regions where charging infrastructure is still developing, and their appeal lies in balancing efficiency and practicality (Usman et al.).

c. **Hybrid Electric Vehicles (HEV)**

Key factors affecting growth are Transition technology for regions not fully ready for electric vehicles, continued use in areas with low access to charging infrastructure. Market forecast is HEVs will gradually decline in favor of BEVs and PHEVs. However, their cost advantages make them remain relevant among cost-sensitive consumers (Xiangyang Li).

d. **Fuel Cell Electric Vehicles (FCEV)**

Key factors affecting growth are Use in long-distance and heavy-duty transportation, government investment in hydrogen infrastructure. Market Forecast: is FCEVs will find a place in specific markets, such as logistics and long-distance transportation, with growth potential in regions that are actively investing in hydrogen technology (Conway et al.).

e. **Charging Infrastructure and V2G Integration**

Key Factors Influencing Growth are Infrastructure development of fast charging networks and standardized protocols, integration with renewable energy systems for sustainability. Market Forecast is Growth in charging infrastructure will directly affect the speed of EV adoption, and investments in V2G technology will accelerate the integration of EVs with renewable energy grids (Hemavathi et al.).

Each type of electric vehicle will have a place in market development, especially BEVs are expected to lead the zero-emission revolution, while PHEVs will fill the gap during the transition period and FCEVs will be instrumental in meeting the specialized needs of long-distance transportation. The construction of battery technology and charging infrastructure will ensure sustainable growth for all electric vehicle types.

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Conclusion:

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2.5.2 summary of factors affecting the future development trend of electric vehicles (EVs)

Here is a comprehensive overview of the factors influencing the future development trends of electric vehicles (EVs), derived from various research studies. including government policies, technological advancements, infrastructure development, environmental considerations, and economic factors.

Technology and infrastructure development

a. Battery technology and charging infrastructure:

i. Solid-state batteries: As the electric vehicle industry progresses, solid-state batteries are anticipated to become increasingly prevalent due to their superior energy density, expedited charging capabilities, and enhanced safety features compared to traditional lithium-ion batteries. These advancements are expected to significantly extend the driving range of electric vehicles and potentially optimize manufacturing costs. (Source: "Challenges, Solutions and Future Trends in Electric Vehicle Technology: A Review").

ii. Lithium-sulfur batteries: Studies on lithium-sulfur batteries indicate that these batteries offer superior energy storage capacity and may surpass current lithium-ion technology, thereby further enhancing the range and efficiency of electric vehicles, which may adversely affect the future development trends of electric vehicles. Quite an impact (source: "Efficient Power and Propulsion System for Electric Vehicles").

iii. Battery Management System (BMS): BMS innovation will further optimize battery life, performance and safety, and improve overall battery performance by more effectively monitoring and managing battery usage (Source: "Electric Vehicles: Battery Management Systems, Charging Stations, Comprehensive review of traction motors").

iv. Fast charging stations: Expanding fast charging networks is essential for shortening charging times and improving the convenience of long-distance travel. Advancements in ultra-fast charging technology are anticipated to further shorten the charging time of electric vehicles in the future. (Source: "Global Electric Vehicle Market Dynamics").

v. Wireless charging: Wireless charging solutions are currently under development and, if successfully developed, will eliminate the need for physical cables and connectors, thereby providing a more convenient and efficient charging option for electric vehicles. This technology can be integrated into parking lots and public areas to support mobile charging (Source: “Special Issue on Advanced Charging Technology for Next Generation Electric Vehicles”).

b. Vehicle-to-network (V2G) technology:

The purpose of V2G integration technology is to enable electric vehicles to supply power to the grid, enhance grid stability, and sell excess power to the grid through electric vehicles during peak power demand periods, allowing electric vehicle owners to monetize battery storage (Source: "Electric Vehicles: V2G enables fast, safe and green electric vehicle penetration”).

c. Smart grid:
   i. Energy management: Smart grids will be instrumental in managing the flow of energy between electric vehicles and the grid. Optimizing the use of renewable energy and ensuring efficient power distribution are top priorities for smart grids (Source: "Electric Vehicles: Technology" , integration, adoption and optimization).
   ii. Renewable energy integration: Combining electric vehicles with renewable energy sources like solar and wind will lead to a reduction in overall carbon emissions and help achieve a low-carbon economy (Source: "Forecasting Consumption and Emissions of Passenger Cars and Light Trucks to 2050").

Market dynamics and policy support

a. Government incentives and policy support:
   i. Government subsidies and tax incentives play a critical role in encouraging the adoption of electric vehicles. To reduce the purchase and operating costs of electric vehicles, governments worldwide are implementing various incentives and policies. These include car purchase subsidies, tax exemptions, and financial support for charging infrastructure development. Improve its market attractiveness (Source: "Global Electric Vehicle Market Dynamics").
   ii. Tighter vehicle emissions regulations and a ban on internal combustion engine vehicles are also speeding up the shift to electric vehicles. For instance, the European Union aims to completely prohibit the discontinuation of new internal combustion engine vehicle sales by 2035. (Source: "Assessment of the Impact of Electric Vehicle Mobility on Power Generation").

b. Economic factors:

i. Although the initial outlay for purchasing an electric vehicle is higher, their reduced operational and reduced maintenance expenses contribute to a lower overall Total Cost of Ownership (TCO) over their lifecycle. In the long run, electric vehicles prove to be more economical than internal combustion engine vehicles. costs (source: "Finding the most suitable vehicle type by integrating economic and environmental aspects through the AHP").
ii. Investment in charging infrastructure, battery production equipment and the integration of renewable energy sources are key to supporting the growing electric vehicle market (Source: “Overview of the future of electric and hydrogen cars and trucks”).

environmental and social impacts

a. Reduce carbon emissions:
   i. The popularization of electric vehicles will significantly reduce greenhouse gas emissions and help achieve the goal of protecting the global climate. For example, the actual benefits of China's popularization of electric vehicles are expected to reduce 54 billion tons of carbon dioxide equivalent by 2060 (Source: "The Feasibility of Carbon Neutrality in the Global and Chinese Transportation Sectors by 2060").
   ii. Research emphasizes considering the entire life cycle carbon emissions of electric vehicles, including manufacturing, use and disposal, to fully understand their impact on the environment (Source: "Assessing Europe's electric vehicle transition: Emissions during the manufacturing and use of electric vehicles").

b. Social and economic impact:
   i. The growing popularity of electric vehicles is anticipated to generate additional employment opportunities in fields like EV manufacturing, battery production, and charging infrastructure development. (Source: "Development of New Energy Vehicles under China's Carbon Peak and Carbon Neutral Strategy").
   ii. Increasing public awareness and acceptance of electric vehicles is critical to their widespread adoption. Educational campaigns and incentive programs can help address consumer concerns and expand the market for electric vehicles (Source: “Towards an Energy Future of Universal Electric Vehicles: Barriers and Opportunities”).

Conclusion:

The outlook for electric vehicles is determined by technological progress, policy support, market demand and environmental issues. The continuous progress of battery technology and charging infrastructure will play a key role in promoting the popularization and sustainable development of electric vehicles. Under the influence of various factors, it is expected that in the future, BEV will lead the zero-emission revolution, while PHEV and FCEV will provide transitional and professional solutions respectively. Continuous advancements in these fields will guarantee the sustainable growth and evolution of the electric vehicle market.

2.6 Methodologies for Ontology Development

A variety of methods have been explored in the literature. Through the analysis and comparison of various research methods, for this study: predicting the trend of the electric vehicle market, time series models such as ARIMA and SARIMA will be used to predict the electric vehicle market.

2.6.1 Sales Forecasting Techniques

ARIMA Model

SARIMA (Seasonal ARIMA) is an extension of ARIMA that accounts for seasonal differences and autoregressive/moving average components. This makes it particularly efficient in capturing seasonal swings in EV sales, such as increased demand. Purchases made during fiscal year-end reductions or new model releases. SARIMA accurately estimates monthly or quarterly sales. Validation with historical information ensures accuracy in detecting supply chain limitations and unanticipated demand surges.

Benefits in terms of the EV market:

By applying ARIMA:

a. Historical sales data are decomposed into trend, seasonal, and residual components.
b. The forecast accuracy can be verified using historical sales records.
c. The model is dynamically adjusted to respond to external influences such as changes in market conditions or policy changes.

ARIMA predicts future sales by modeling the relationship between past observations in a time series. It is denoted as ARIMA(p, d, q), where:

- p: Number of autoregressive terms.
- d: Number of non-seasonal differences.

q: Number of moving average terms.

The general equation of ARIMA is:

$$y_t = c + \emptyset_1 y_{t-1} + \emptyset_2 y_{t-2} + \cdots \emptyset_p y_{t-p} + \epsilon_t + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \cdots + \theta_q \epsilon_{t-q}$$

Where:

- y_t: Predicted value at time ttt.
- $\emptyset$: Coefficients of the autoregressive terms.

- θ_t: Coefficients of the moving average terms.
- ϵ_t: Error term at time ttt. : Error term at time

Steps in ARIMA Application:

a. Stationarity Check: The series is tested for stationarity using methods like the Augmented Dickey-Fuller (ADF) test. If non-stationary, differencing is applied.
b. Model Fitting: Based on parameter tuning (using criteria like AIC/BIC), the model is fitted to the data.
c. Forecasting: Predictions are generated for the future time points.

SARIMA Model

SARIMA: Seasonal ARIMA, besides everything that ARIMA does, includes seasonal differences and seasonal autoregressive/moving average components. This makes it really effective in capturing seasonal fluctuations of EV sales, such as increased purchases during end-of-fiscal-year discounts or new model launches. It also can be used to predict monthly or quarterly sales, thus providing effective forecasts. Validation with historical datasets ensures accuracy for anomalies such as supply chain constraints or unexpected demand surges.

Benefits in the context of the EV market: These models are particularly beneficial to stakeholders, including manufacturers and policymakers, to:

a. Forecast production needs.
b. Identify peak demand periods.
c. Design incentives for low demand seasons.
d. Best-selling vehicle prediction

To identify which types of EVs are poised to lead the market, harnessing machine learning-based classification models is essential. These models classify vehicle models based on their specifications and consumer preferences.

a. Modeling approach:
   i. Input data: Vehicle specifications (e.g., range, battery capacity, cost) and consumer preferences (e.g., affordability, charging speed, environmental impact).

ii. Model development: Using techniques such as logistic regression, random forest, or neural networks, the likelihood of a vehicle becoming a bestseller can be classified.
iii. Validation: Use historical data on sales performance and consumer feedback to improve model accuracy.

b. Applications:
   i. For example, a random forest model can analyze the weight of factors such as price vs. range in consumer purchase decisions.
   ii. Sensitivity analysis can reveal how specification changes (such as battery improvement.
c. Advantages in the context of the EV market: These models enable manufacturers to:
   i. Align product development with consumer priorities.
   ii. Identify market segments with unmet needs.
   iii. Optimize marketing strategies based on predicted high-demand features.

SARIMA introduces seasonal components to ARIMA. The model is denoted as SARIMA(p, d, q)(P, D, Q, s), where:

- P,D,Q: Seasonal autoregressive, differencing, and moving average terms, respectively.
- s: Seasonal period (e.g., 12 for monthly data).

The equation extends ARIMA with seasonal terms:

$$y_t = c + \sum_{i=1}^{p} \emptyset_i y_{t-1} + \sum_{i=1}^{q} \theta_i \epsilon_{t-1} + \sum_{j=1}^{p} \omega_j y_{t-js} + \sum_{j=1}^{p} \Phi_j \epsilon_{t-js} + \epsilon_t$$

Where:

- ω_j, Φ_j: Seasonal autoregressive and moving average coefficients.
- s: Seasonal period.

Seasonality Capture: SARIMA is particularly adept at capturing regular demand cycles, like annual or quarterly trends, making it an excellent choice for modeling EV sales that are influenced by policy changes or economic fluctuations.

2.6.2 Best-Selling Vehicle Type Prediction

Machine learning-based classification algorithms are critical for predicting which EV kinds will dominate the market. These models categorize vehicles based on characteristics and consumer preferences.

a. Modeling Approach:
   i. Input Data: Vehicle specifications (e.g., range, battery size, cost) and consumer preferences (e.g., affordability, charging speed, environmental impact).
   ii. Model Development: Techniques such as logistic regression, random forests, or neural networks can classify the likelihood of a vehicle being a best-seller.
   iii. Validation: Historical data on sales performance and consumer feedback is used to refine model accuracy.
b. Application:
   i. A random forest model helps determine which characteristics, such as price and range, have a greater impact on consumer purchasing decisions.
   ii. Sensitivity analysis can show how changes in specifications, such as battery upgrades, may impact consumer choices.

Supervised machine learning models use methods like logistic regression, random forests, and support vector machines (SVMs) to classify vehicles. The focus is on the mathematical underpinnings.

Logistic Regression

Logistic regression models the probability of a vehicle being a best-seller (P(y=1) based on features like price, range, and battery size:

$$P(y=1)=\frac{1}{1+e^{-(\beta_0+\beta_1x_1+\beta_2x_2+\cdots+\beta_nx_n)}}$$

Where:

- ββ_0: Intercept.
- β_1, $\beta_2, \cdots$, β_n :Coefficients for features x_1, $x_2, \dots, x_n$.

- P(y=1): Probability of the vehicle being a best-seller.

The model estimates coefficients to maximize the likelihood function, fitting the data.

Random Forest

Random forests use an ensemble of decision trees to classify data. For a feature set X, each tree predicts a class label $\hat{y}$. The final prediction is based on majority voting:

$$\hat{y} = Mode(\hat{y}_1, \hat{y}_2, \dots, \hat{y}_m)$$

Where:

- $\hat{y}_i$: Prediction from the iii-th tree.
- m: Total number of trees in the forest.

Advantages for EV Prediction:

- Handles non-linear relationships in data.
- Avoids overfitting by aggregating results.

Support Vector Machines (SVM)

SVM finds a hyperplane that separates classes (e.g., best-seller vs. non-best-seller). For input XXX, the decision boundary is:

$$\boldsymbol{f(X) = \omega^T X + b}$$

Where:

- ω: Weight vector defining the hyperplane orientation.
- b: Bias term.

The goal is to maximize the margin MMM between classes:

$$\boldsymbol{M = \frac{2}{\parallel \omega \parallel}}$$

Kernel Trick: SVM applies kernels like radial basis functions (RBF) to handle non-linear separability.

Conclusion

By integrating these mathematical models, the paper can robustly forecast EV sales trends and predict market dynamics for best-selling vehicles. The ARIMA/SARIMA models provide reliable sales trend forecasts, while classification techniques like logistic regression, random forests, and SVM enable accurate predictions of consumer preferences for vehicle types. These methods collectively strengthen the analysis, aligning with the goals of the study "Electric Vehicle Market Forecast."

2.6.3 Software and Libraries

Python, PowerBI, Scikit-learn, Statsmodels, and Matplotlib/Seaborn for visualization.

2.7 Research Gap

Authors	Publication Date	Result	Research Gap
Sanjib Kumar Shil	10 Nov 2024	Accurate predictions of EV adoption trends in the USA.	Limited to the USA; does not address global or regional variations in EV adoption trends.
Shumo Cui	20 Oct 2024	EVs expected to constitute over 25% of global car stock by 2035.	Lacks specificity about regional market disparities and the factors influencing them.
Irvylle Raimunda Mourão Cavalcante	19 Sep 2024	Dataset covering scenarios up to 2050.	Absence of real-time adaptability for emerging trends and unforeseen disruptions in scenarios.
Fei Teng	31 Oct 2024	Enhanced accuracy in EV sales forecasting.	Lack of detailed data sources or validation methodologies for forecasting accuracy.
Ru Qi Yu	13 Nov 2024	Robust framework for forecasting EV sales in China.	Focused on China only; no comparative analysis with other key EV markets globally.
Ning Mao	14 Oct 2024	Impact analysis of EV penetration on ownership and energy demand.	Limited integration of social or behavioral factors impacting energy demand and vehicle ownership.
Yiying Liu	12 Sep 2024	Predicted development trends in the new energy EV industry.	Insufficient examination of the impact of evolving policy and regulatory frameworks.

Table 2.2 Summary of the specified research papers

The above studies have conducted in-depth discussions on the trend forecast, market analysis and related influencing factors of the electric vehicle (EV) market development, but there are still some gaps that need further research. These gaps are mainly concentrated in the following aspects:

a. Insufficient cross-regional comparative analysis

Although some studies focus on the world (such as Shumo Cui's study), there is a lack of in-depth analysis of market differences and their driving factors in different regions. For example, Ru Qi Yu's study focuses on China and does not compare data with other major markets (such as Europe and North America), and the research scope is not comprehensive enough.

b. Dynamic scenario modeling and real-time adaptability

Irvylle Raimunda Mourão Cavalcante provides trend forecasts covering 2050, but lacks dynamic adaptability in the face of rapidly changing policies, technologies and social trends. In addition, this static analysis cannot reflect the rise of emerging markets or the impact of unexpected events in a timely manner.

c. The interactive impact of social behavior and policy

Ning Mao and Yiying Liu discussed energy demand and industry development trends respectively, but the synergy analysis of social behavior factors (such as consumer preferences and acceptance) and policy/regulatory changes is insufficient. In particular, the impact of the evolution of energy policies and car purchase subsidies on consumer behavior has not been fully considered.

d. Forecasting methods and data verification

Fei Teng's research has improved the accuracy of forecasts, but the verification methods and data source transparency of the forecasting model are still insufficient. This deficiency may limit the generalizability of the model in other regions or situations.

e. Potential impact of future technological development

Current research rarely involves the potential impact of breakthroughs in electric vehicle technology (such as battery technology and new energy drive) on market trends and user acceptance.

Based on the above analysis, the following research directions need to be further explored to fill the key gaps in the current literature:

First, build a model that can comprehensively compare the differences between different regional markets (such as Asia, Europe, and North America), analyze the main factors that cause these differences, and conduct a comprehensive comparative analysis of global and regional markets. For the existing forecasting model, verify its applicability in different regional markets, and improve the transparency of its data sources and methods to achieve cross-regional verification and expansion of the forecasting model.

Secondly, develop an adaptive model that combines real-time data and scenario prediction, which can quickly respond to policy adjustments, new technological breakthroughs, and sudden market changes, achieve dynamic prediction and scenario adaptation, explore how policies (such as subsidies and tax incentives) and social behavior changes (such as environmental awareness and consumption habits) jointly affect the long-term development trend of the electric vehicle market, and build a synergistic model between social behavior and policy. Study how technological advances such as emerging battery technology and intelligent connected vehicles affect policy making and the future pattern of the electric vehicle market, and analyze the long-term impact of technological progress and policy interaction.

These research directions provide more comprehensive theoretical support and practical guidance for the global development and policy making in the field of electric vehicles.

2.8 Conclusion

Reasonableness of ARIMA/SARIMA and Classification Models:

1. **Suitability of Time Series Analysis (ARIMA/SARIMA):**

- Characteristics of EV Data: EV adoption trends and sales data often exhibit seasonality, trends, and irregular fluctuations, making time series models such as ARIMA (Autoregressive Integrated Moving Average) and SARIMA (Seasonal ARIMA) suitable tools for analysis.
- Advantages of ARIMA/SARIMA: These models effectively handle time dependence and seasonal patterns, providing a robust framework for short- to medium-term forecasting, especially in markets with mature patterns.
- Integration of policies and disruptions: By introducing exogenous variables (e.g., economic indicators, policy changes), ARIMA/SARIMA models can incorporate external shocks and address gaps in static, long-term scenario analysis.

2. **Role of Classification Models:**

- Market Segmentation: By dividing the EV market into segments according to sociodemographic, behavioral, or regional characteristics, classification techniques (such as logistic regression, random forests, or support vector machines) can uncover variability that conventional time series models are unable to capture.
- Policy and Consumer Interaction investigation: These models supplement the numerical projections of the ARIMA/SARIMA models by enabling investigation of the effects of various policy tools (such as taxes and subsidies) and consumer preferences on market adoption.

- Scalability and Adaptability: Classification models are well-suited for analyzing new trends in the quickly shifting EV industry because they can adjust to changing datasets.

3. **Combination of ARIMA/SARIMA with Classification Models:**

- Hybrid Approach: The integration of time series models into a classification framework improves the forecasts by jointly considering the historical data trend, consumer behavior, and policy dynamics.
- Improvement in Accuracy with Interpretability: Hybrid models leverage the strengths of both to provide accurate, interpretable, and adaptable forecasts that address the complexity issues noted in the literature.

This therefore will enable a comprehensively founded approach toward improving the research gaps identified earlier through using ARIMA/ SARIMA for time series analysis, classification models on behavioral and policy-driven segments.

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