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Revolutionizing Electric Vehicle Adoption: A Holistic Integration of Marketing Strategies and Analytical Insights

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Highlights

- ARIMA, SARIMA, and ETS models inform marketing strategies in the study.
- The study offers a comprehensive Electric Vehicle (EV) promotion perspective.
- The FEV sales rate in Türkiye is expected to increase by 58.2% in the next five-year period.

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Abstract

This study explores the synergies between marketing strategies, analytical insights, and consumer education in propelling electric vehicle (EV) adoption. We uncover intricate sales patterns in Türkiye's EV sales data using advanced statistical models such as Autoregressive Integrated Moving Average (ARIMA), Seasonal ARIMA (SARIMA), and Error, Trend, and Seasonality (ETS). Türkiye's fully electric vehicle (FEV) sales value was estimated in the next five-year period using the ARIMA (4,1,4) model. According to the research results, the FEV sales rate in Türkiye is expected to increase by an average value of 58.2% in the next five-year period, and the annual sales amount, excluding Tesla, will be 17459. Findings underscore the efficacy of aligning marketing strategies with analytical insights, demonstrating the significance of education in shaping positive consumer attitudes. Education-driven marketing emphasizing economic benefits, reduced emissions, and technological advancements is a potent catalyst in overcoming adoption barriers. Digital campaigns, experiential marketing, and sustainability messaging, validated by our analysis, play pivotal roles in influencing consumer behavior. Strategic partnerships with energy companies address infrastructure challenges, while incentive-based marketing, personalized strategies, and after-sales support foster a sense of community and loyalty. This research contributes a holistic framework for marketers, policymakers, and stakeholders to navigate the evolving landscape of EV adoption successfully, providing actionable insights and paving the way for future research directions in sustainable transportation.

1. INTRODUCTION

The advent of EVs marks a pivotal transition in the automotive industry, reflecting a growing commitment to sustainability, innovation, and the mitigation of the impacts of climate change. As the world grapples with escalating environmental concerns, such as air pollution and global warming, the importance of EVs has never been more pronounced. By their operation, EVs offer a cleaner alternative to their internal combustion engine (ICE) counterparts, primarily by reducing the emissions of pollutants and greenhouse gases. This is crucial in urban areas, where air quality has been a persistent public health issue. EVs emit no tailpipe pollutants, creating cleaner air and a healthier environment [1-3]. Moreover, the significance of EVs extends beyond environmental benefits. They are at the forefront of automotive technological advancements, incorporating sophisticated features such as regenerative braking, advanced battery storage, and highly efficient electric motors. These innovations enhance the driving experience and improve vehicle efficiency and performance. The reliance on electricity as a fuel source also diversifies energy portfolios, reducing dependence on fossil fuels and enhancing energy security. With the ongoing improvements in battery technology, the range of EVs is steadily increasing, making them more viable for a wider range of consumers [4,5]. The economic implications of EVs are equally noteworthy. The transition towards EVs

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fosters new industries and job opportunities, particularly in battery manufacturing, electric powertrain production, and charging infrastructure development. This transition supports economic growth and competitiveness while aligning with global efforts to transition towards low-carbon economies. Additionally, for consumers, EVs offer potential cost savings in the long term, given their lower operating and maintenance costs compared to traditional vehicles [6-8]. Furthermore, EVs are critical in the global effort to combat climate change. The transportation sector is a significant contributor to global greenhouse gas emissions, and the widespread adoption of EVs represents a tangible action towards reducing these emissions. As countries worldwide commit to reducing their carbon footprints and adhering to international agreements like the Paris Accord, EVs' promotion and adoption become integral to these efforts [9, 10]. The importance of EVs is also reflected in the policy measures being adopted by governments worldwide. Incentives for EV purchase, investments in charging infrastructure and regulations favoring clean transportation are becoming more common. These policies not only encourage the adoption of EVs but also signal a strong commitment to sustainable development and environmental stewardship [11,12]. The rise of EVs is a testament to the convergence of environmental sustainability, technological innovation, and economic pragmatism. EVs offer a promising path to reduce environmental impacts, enhance energy diversity, spur economic development, and contribute to the global effort against climate change. As technology advances and societal acceptance grows, EVs stand poised to play an increasingly central role in the transportation scenery of the future. The marketing of EVs embodies a multifaceted strategy that transcends traditional automotive marketing, encapsulating the essence of environmental sustainability, technological innovation, and a transition toward a new era of mobility. As the global consciousness leans towards mitigating climate change and reducing carbon footprints, the marketing narratives around EVs have become increasingly compelling and diverse, aimed at appealing to a broad spectrum of consumers with varying priorities and values [13,14]. At the core of EV marketing is the emphasis on environmental benefits. Brands often highlight the zero-emission nature of EVs, underscoring their role in reducing air pollution and combating climate change. This message resonates strongly with environmentally conscious consumers who are motivated by the desire to make sustainable lifestyle choices. The portrayal of EVs as a key component of a greener future is a powerful tool in marketing campaigns, aligning the product with broader societal goals and values [15-18]. Technological innovation is another cornerstone of EVs marketing. Manufacturers spotlight the cutting-edge features of EVs, such as advanced battery technology, regenerative braking systems, and sophisticated digital interfaces, to appeal to tech-savvy consumers. The narrative often extends to integrating EVs with smart home systems, renewable energy sources, and the broader Internet of Things ecosystem, painting a picture of a connected and efficient future of mobility. By focusing on the innovative aspects, marketers can differentiate EVs from traditional vehicles and attract consumers interested in the latest technological advancements [19-21]. The marketing strategies for EVs also leverage the total cost of ownership (TCO) angle. Despite the higher upfront cost of EVs compared to ICE vehicles, marketers highlight the long-term savings that can be realized through lower operating and maintenance costs and various government incentives and tax benefits. This economic argument is tailored to pragmatic consumers concerned with the financial aspects of vehicle ownership and looking for cost-effective transportation solutions [22-25]. Furthermore, the branding and positioning of EVs often reflect a lifestyle choice beyond mere transportation. Marketing campaigns frequently depict EVs as part of a modern, active, responsible lifestyle, appealing to consumers' aspirations and identity. This lifestyle marketing approach effectively creates a community around EV brands, fostering a sense of belonging among consumers with similar values and interests [26-28]. Customer experience and engagement are pivotal in the marketing of EVs. Many manufacturers have adopted direct sales models or innovative retail experiences that offer consumers a more personalized and informative buying process. Test drives, interactive showrooms, and immersive online platforms educate consumers about EVs, addressing common concerns such as range anxiety and charging infrastructure. Marketers aim to build confidence in the technology by enhancing consumer engagement and easing the transition to electric mobility [29-31]. Social media and content marketing play significant roles in the EV marketing ecosystem. Brands utilize these platforms to share stories, testimonials, and educational content that demystify EVs and showcase their real-world performance and benefits. Influencer partnerships and community-driven initiatives further amplify the message, leveraging social proof and peer influence to encourage consideration and adoption of EVs [32-35]. Marketing of EVs is a complex and evolving area that integrates environmental advocacy, technological enthusiasm, economic considerations, lifestyle aspirations, and customer engagement. Through compelling narratives, innovative marketing strategies, and a focus on the consumer experience, EV manufacturers and brands are navigating the challenges and opportunities of introducing a new era of transportation to a diverse and increasingly receptive global audience. Despite their numerous benefits, consumers' hesitations and the spread of misinformation about EVs represent significant barriers to widespread adoption. These concerns often stem from outdated information, misconceptions, and a lack of clear, accessible information about the technology and its implications for everyday use. Understanding these hesitations and misinformation sources is crucial for addressing them effectively and facilitating a smoother transition to electric mobility [36, 37]. One of the primary hesitations concerns range anxiety, the fear that an EVs will not have sufficient battery capacity to reach a destination or a charging station. This anxiety is often exacerbated by misconceptions about the actual range capabilities of modern EVs, which have significantly improved over the years. However, the persistent narrative of limited range continues to deter potential buyers despite the average daily commute being well within the range of most current EV models [38,39]. Charging infrastructure is another area of concern for consumers. The perceived scarcity of charging stations and the fear of long charging times contribute to hesitating to adopt EVs. While the infrastructure for EV charging is rapidly expanding and technology advancements are reducing charging times, the misconception that charging an EV is inconvenient and time-consuming persists, overshadowing the progress made in this area [40, 41]. The initial cost of EVs also serves as a deterrent for many consumers. The upfront purchase price of EVs can be higher than that of comparable ICE vehicles, leading to the perception that EVs are not economically feasible for the average consumer. This viewpoint often overlooks the long-term savings associated with lower operating and maintenance costs and various incentives and rebates offered by governments and local authorities to offset the initial purchase price [42,43]. Another source of hesitation is the concern about battery life and replacement costs. There is a common misconception that EV batteries degrade quickly and that replacing them is prohibitively expensive. While battery technology has limitations, advancements have significantly increased the lifespan and durability of EV batteries, with many manufacturers offering substantial warranties to alleviate these concerns [44,45]. Misinformation about EVs can also stem from a lack of familiarity with the technology. Consumers may have misconceptions about EVs' performance, safety, and capabilities compared to traditional vehicles. Fictions such as EVs not being as powerful or safe as gasoline vehicles persist despite evidence to the contrary. This lack of understanding can lead to skepticism and reluctance to consider an EV for their next vehicle purchase [46,47]. The environmental impact of EVs is another area where misinformation is prevalent. Critics often point to the environmental costs associated with battery production and the sourcing of electricity from fossil fuels as negating the environmental benefits of EVs. While these concerns are not entirely unfounded, they do not account for the overall reduction in carbon emissions over the vehicle's lifetime and the increasing share of renewable energy sources in the electricity mix [48,49]. Social and cultural factors also influence the hesitations and misinformation surrounding EVs. Traditional views of car ownership and brand loyalty, combined with resistance to change, can influence consumer attitudes toward EVs. Additionally, misinformation can spread through social media, forums, and word of mouth, perpetuating fiction and inaccuracies about EVs [50,51]. Hesitations and misinformation about EVs stem from various factors, including range anxiety, concerns about charging infrastructure and times, perceptions of high initial costs and battery replacement issues, misconceptions about performance and safety, environmental impact concerns, and cultural resistance to change. Addressing these issues requires concerted efforts from manufacturers, policymakers, and the EV community to provide clear, accurate information and demonstrate electric mobility's tangible benefits. By dispelling fiction and highlighting the advancements in EV technology, it is possible to overcome these barriers and encourage more consumers to embrace EVs.

In the transformative landscape of the automotive industry, the adoption of Electric Vehicles (EVs) stands out as a critical avenue toward sustainable transportation. As environmental concerns intensify, understanding the intricate dynamics of EV adoption becomes paramount. This study explores the multifaceted realm of EV marketing, consumer behavior, and the integration of analytical insights to propel adoption. Central to this inquiry are pivotal questions that guide our investigation. How can marketing strategies be aligned with analytical insights to enhance EV adoption? What role does education play in shaping consumer attitudes towards EVs? How do factors such as social media, experiential marketing, and sustainability messaging influence the adoption of Electric Vehicles?

The primary objective is to comprehensively examine the integration of marketing strategies with analytical insights, emphasizing the effectiveness of education in shaping consumer behavior. The study aims to elucidate the impact of various marketing approaches, from digital campaigns to strategic partnerships, and assess their alignment with analytical models to drive positive attitudes and widespread EV adoption. This research endeavors to bridge gaps in the current literature by offering a holistic understanding of the interplay between marketing strategies, analytical insights, and consumer education in the context of EV adoption. Significantly, the study strives to provide actionable insights for marketers, policymakers, and industry stakeholders to successfully navigate the dynamic landscape of electric mobility.

The research design adopts a multifaceted approach. Leveraging time series analysis, we apply ARIMA, SARIMA, and ETS models to Türkiye's EV sales data, offering a detailed understanding of sales patterns. Complementing this, qualitative assessments delve into the impact of educational marketing, social media, and sustainability messaging on consumer behavior. Advanced statistical models, including ARIMA, SARIMA, and ETS, are employed to unravel Türkiye's EV sales patterns. These models facilitate a nuanced interpretation of sales trends, capturing periodic and seasonal variations. Qualitative analysis involves an in-depth exploration of the impact of educational marketing, social media campaigns, and sustainability messaging on consumer perceptions and behavior. The paper unfolds structured, commencing with this introduction to establish the research's context, questions, and objectives. Subsequent sections delve into a comprehensive literature review detailing the current state of knowledge in EV marketing and adoption. The methodology section provides insights into the tools and approaches adopted for data analysis. Findings are presented and discussed in the subsequent sections, leading to a conclusion that synthesizes key insights, highlights limitations, and suggests avenues for future research. This structured approach ensures a coherent and informative exploration of the intricate dynamics of Electric Vehicle adoption.

2. THE ADOPTION OF ELECTRIC VEHICLES

The adoption of Electric Vehicles (EVs) is influenced by many economic, technological, environmental, social, and policy factors. These factors are critical for stakeholders in the automotive industry, policymakers, and consumers as they transition from traditional ICE vehicles to electric mobility solutions [52,53].

Cost as a Pivotal Factor: The initial purchase price of EVs, though decreasing, remains higher than comparable gasoline vehicles, posing a potential deterrent for buyers. However, TCO, including fuel costs, maintenance, and potential tax incentives, often favors EVs in the long run. Consumer perceptions of value for money, influenced by these economic considerations, play a crucial role in adopting EVs [16,25].

Technological Progress: Advancements in battery technology, electric drivetrains, and charging infrastructure significantly impact EV adoption. Battery capacity and efficiency improvements address range anxiety, making EVs more appealing. Similarly, advancements in charging technology, including faster charging times and more convenient solutions, enhance the practicality of EVs for everyday use [5, 54].

Environmental Awareness: Growing awareness of environmental issues, particularly climate change and air pollution, drives interest in cleaner transportation options. With their potential for zero tailpipe emissions, EVs appeal to environmentally conscious consumers. Considering EVs' entire lifecycle environmental impact, including battery production and electricity generation, also factors into the adoption equation [55,56].

Government Policies: Government policies are critical in shaping the EV market. Incentives such as tax rebates, grants, and subsidies can make EVs more financially attractive. Infrastructure investments, including public charging networks and regulations like zero-emission vehicle mandates, create a supportive environment for EV adoption. However, the absence of supportive policies or regulatory barriers can hinder EV market growth [57,58].

Sociocultural Influences: Social norms, cultural attitudes, and consumer awareness influence EV adoption. Peer influence, media portrayal, and societal trends can sway consumer attitudes toward EVs. The perceived fashionability, innovation, or social responsibility associated with EVs significantly affects their adoption. The role of early adopters and influencers in shaping public perceptions is crucial [59, 60].

Charging Infrastructure: The availability and accessibility of charging infrastructure are vital for practical EV ownership. Concerns about the availability of charging stations, particularly for long-distance travel, can inhibit adoption. Developing a widespread, reliable, and convenient charging infrastructure is essential for encouraging EV uptake [61-63].

Range Anxiety and Misinformation: Concerns about the driving range of EVs and the fear of running out of charge (range anxiety) remain significant barriers to adoption. Misinformation and a lack of understanding about EV technology, performance, and benefits can impede adoption. Educational initiatives and transparent communication from manufacturers and governments are crucial in dispelling fiction and building consumer confidence in EVs [64].

Variety of EV Models: The variety of EV models available in the market affects consumer choice and adoption. A broader range of models, covering various vehicle segments and price points, can cater to a broader audience and meet diverse consumer needs, thereby driving adoption. The impact of EV marketing strategies on consumer behavior is profound and multifaceted, shaping perceptions, influencing attitudes, and ultimately driving the decision-making process regarding the adoption of electric mobility [65-67].

Role of Marketing in Adoption: As the automotive industry undergoes a significant transformation towards sustainability and technological innovation, the role of marketing in guiding consumer behavior becomes critical. Effective marketing strategies play a pivotal role in raising awareness about EVs and their benefits. Through various channels, including digital media, television, print, and outdoor advertising, marketers can reach a broad audience, introducing the concept of electric mobility and its environmental, economic, and technological advantages [68].

Marketing Strategies' Impact on Consumer Behavior: Marketing strategies significantly influence consumer perceptions and attitudes toward EVs. By highlighting key attributes such as zero emissions, low operating costs, high performance, and innovative technology, marketing campaigns can create a positive image of EVs. This, in turn, can lead to more favorable attitudes toward EVs, making consumers more inclined to consider them viable alternatives to traditional ICE vehicles [69-71].

Addressing Consumer Hesitations: One of the primary objectives of EV marketing strategies is to address and mitigate consumer hesitations and concerns, such as range anxiety, charging infrastructure availability, and initial cost. By providing clear, factual information and showcasing real-world use cases, marketers can alleviate these concerns and build consumer confidence in the feasibility and practicality of EV ownership [50,70,72].

Influencing Preferences and Purchase Intentions: Marketing strategies can influence consumer preferences and purchase intentions by emphasizing the alignment of EVs with consumer values, such as environmental responsibility, innovation, and modernity. Marketers can appeal to specific consumer groups through targeted messaging and segmentation, shaping preferences and strengthening purchase intentions [73,74].

Interactive and Experiential Marketing: Interactive and experiential marketing strategies, such as test drives, virtual reality experiences, and interactive digital platforms, allow consumers to engage with EVs tangibly. These experiences can be instrumental in changing consumer behavior, providing a direct, hands-on understanding of EV features and capabilities, dispelling fiction, and reinforcing positive perceptions [69].

Fostering Brand Loyalty: Effective marketing can foster brand loyalty and turn EV owners into advocates for electric mobility. Satisfied customers are more likely to share their positive experiences, contributing to word-of-mouth marketing and influencing potential buyers' behavior. Building a community around a brand or product can amplify this effect, creating a network of advocates who actively promote EV adoption [75,76].

Combating Misinformation: Misinformation about EVs poses a significant challenge to their adoption, affecting consumer perception and behavior. Combatting this misinformation through accurate, accessible, and persuasive information is crucial for transitioning consumer perceptions, fostering positive attitudes towards electric mobility, and accelerating the transition towards a more sustainable transportation future.

3. THE EXPANDING EV MARKET

3.1. Electric Vehicles in the Automotive Market

As global environmental concerns due to climate change intensify, the transportation sector, a major contributor to greenhouse gas emissions, is undergoing significant developments. Accelerated infrastructure works and research and development studies for EVs have paved the way for the commercial spread of these vehicles. The global market share of EVs is expected to rise from 2% in 2016 to a projected 22% by 2030, with global sales reaching 4.5 million units in 2020, accounting for approximately 5% of the global light vehicle market. Projections suggest a substantial increase in EV sales, reaching 10 million units by 2025, 28 million units by 2030, and 56 million units by 2050 [77].

The Chinese electric car market experienced a remarkable growth rate of 72% in 2017, solidifying China's dominant position in the industry. Presently, China holds an impressive 94% share of global electric vehicle sales, surpassing the combined market share of the United States and the European Union. The global ranking of the electric vehicle market and industry by country places China at the forefront, followed by Japan, Germany, the USA, Korea, France, India, and Italy, as shown in Table 1 [78-81].

Table 1. *Ranking of the electric vehicle market and industry by country [81]*

Ranking	Electric Vehicle Market	Electric Vehicle Industry
1	Norway	China
2	China	Japan
3	Switzerland	Germany
4	Sweden	USA
5	Holland	Korea
6	USA	France
7	France	India
8	UK	Italy

3.2. Market Share of Electric Vehicles in Türkiye

The market share of electric vehicles in the Turkish automobile market remains minimal due to the absence of infrastructure, legal rules, incentives, and policies. Gasoline cars continue to dominate, but electric vehicles have seen a substantial surge in the market. Notably, the sales of electric vehicles skyrocketed by an impressive 862.8%, contributing to a rise in their overall market share from 1% to 5.9%. Electric and hybrid vehicles combined now account for 16.4% of the entire market, indicating an increasing acceptance of electric automobiles in Türkiye.

The surge in electric vehicle sales holds environmental significance, as these vehicles emit fewer carbon emissions, contributing to improved air quality and the global effort to combat climate change. Simultaneously, the rise in electric vehicles enhances energy autonomy, as these cars, powered by local energy resources, reduce dependency on energy imports. The sales numbers for 100% electric brands in the Turkish market reveal notable trends. Renault Zoe remains the top-selling vehicle, while BMW achieved the most sales among all brands. Opel, offering electric models such as Corsa and Mokka, achieved a substantial sales milestone. Despite not disclosing sales statistics, Tesla's initiation of sales and marketing operations in Türkiye is noteworthy [82]. Consistent availability of automobiles responding to high customer demand contributes to sustained market growth. During the first half of the year, the number of electric cars sold surpassed the combined total of the previous year and was about five times higher than the number sold in the previous year's first half. Projections suggest a significant growth in the Turkish electric car market for 2024.

Table 2 illustrates the sales of electric vehicles in Türkiye from 2016 to 2023, excluding Tesla sales. The data reveals a consistent upward trend in electric vehicle sales year over year. In 2023, electric car sales experienced a remarkable increase of 844%, totaling 72,179 sales. The first month of 2024 continued this trend with 3,973 electric cars sold [82,83].

Table 2. *Sales of electric vehicles in Türkiye from 2016 to 2023 (excluding Tesla sales) [82]*

Type	2016	2017	2018	2019	2020	2021	2022	2023
FEV	44	77	155	222	1579	2846	8210	10166
Plug-in HEV	83	27	39	39	170	456	1045	2567
HEV	867	4424	3837	10976	16941	20915	19126	35348
Total	994	4528	4031	11237	18690	24217	28381	48081

This surge in sales indicates a shifting landscape in the Turkish automobile market, with electric vehicles gaining prominence. The analysis of the FEV data between 2016 and 2023 shows a clear trajectory of increasing sales and suggests a continued upward trend in the Turkish electric car market. The data in Table 2 and additional information from Turkish Electric and Hybrid Vehicles Association (*Türkiye Elektrikli ve Hibrid Araçlar Derneği – TEHAD*) 2024 and Automotive Distributors and Mobility Association (*Otomotiv Distribütörleri ve Mobilite Derneği – ODMD*) 2023 indicate a robust growth trajectory, projecting significant expansion in the Turkish electric car market in 2024.

3.3. Effective Marketing Strategies for EVs

Effective marketing strategies for Electric Vehicles (EVs) are crucial for accelerating adoption and transitioning to sustainable mobility. These strategies must address EVs' unique characteristics, evolving market dynamics, and diverse consumer concerns. Combining traditional and innovative methods, a multifaceted approach is necessary to educate, engage, and persuade consumers [71,84,85]. Educational marketing is foundational due to prevalent misinformation and lack of awareness about EVs. Providing clear, accurate information about their benefits and functionalities is crucial. This highlights environmental benefits, economic advantages, convenience, and technological innovations. By demystifying EVs and addressing common misconceptions, educational marketing significantly reduces barriers to adoption [71,86,87].

Digital and social media campaigns leverage online platforms for targeted outreach. Marketers reach diverse audiences through social media campaigns, interactive websites, and engaging content. These platforms disseminate narratives, testimonials, virtual test drives, and comparisons, fostering two-way communication and community building [88-90]. Experiential marketing allows consumers to experience EVs firsthand through events and test drives. These experiences dispel doubts about performance and usability, particularly addressing range anxiety and charging concerns [91,92].

Partnerships and collaborations enhance EV marketing by developing charging infrastructure and promotional campaigns. Strategic collaborations with energy companies, governments, and influencers broaden consumer appeal [93-95]. Incentive-based marketing highlights incentives like tax credits and rebates to make EVs financially attractive. Communicating economic benefits and long-term cost savings influences purchasing decisions [86,95,96]. Customization and personalization create a personal connection with EVs by offering tailored options and personalized experiences. Personalized marketing based on consumer data increases message relevance [97,98]. Sustainability and corporate responsibility resonate with environmentally conscious consumers. Marketing campaigns emphasizing EVs' role in combating climate change and contributing to a sustainable future foster a positive brand image [99,100]. After-sales support and community building contribute to positive word-of-mouth marketing. Providing excellent support and fostering community among EV owners creates brand advocates [101,102]. Effective communication strategies for electric car marketing must inform, engage, and inspire consumers, addressing common misconceptions and resonating with diverse values and needs. Clear and transparent information provides factual data to address concerns and build trust [103,104]. Storytelling emotionally connects with consumers, sharing success stories and positive impacts of EV ownership [105-107]. Leveraging social proof through testimonials and endorsements influences consumer behavior [108,109].

Educational content and thought leadership establish brand authority and provide reliable information [110,111]. Interactive and engaging formats utilize technology to simulate EV experiences and generate excitement [112,113]. Focused messaging on key benefits tailors messages to align with audience priorities [114,115]. Utilization of multiple channels ensures comprehensive outreach through various platforms [116,117]. Community engagement and involvement foster brand advocacy and influence behavior [57,118,119]. Responsive and supportive communication builds trust and loyalty by addressing inquiries and feedback promptly [120,121]. In conclusion, effective marketing and communication strategies for EVs must be diverse, informative, engaging, and supportive to drive adoption and transition to electric mobility.

4. MATERIALS AND METHODS

This study employs a comprehensive methodology to analyze Türkiye's EV sales data from 2016 to 2023, utilizing advanced time series forecasting techniques, specifically Autoregressive Integrated Moving Average (ARIMA), Seasonal ARIMA (SARIMA), and the Error, Trend, Seasonality (ETS) model.

4.1. Data Collection and Description

The primary dataset comprises monthly FEV sales data in Türkiye from 2016 to 2023. The data provide insights into the country's temporal evolution of electric vehicle adoption. The dataset also includes relevant external factors, such as economic indicators and environmental policies, that may influence EV sales.

4.2. Time Series Analysis Using ARIMA and SARIMA

ARIMA Modeling: The ARIMA methodology is employed to model the stationary time series of FEV sales. The four main stages of ARIMA model construction—Model Definition, Parameter Estimation and Selection, Model Validation, and Model Utilization—are meticulously followed. An iterative process involves analyzing the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) to establish the appropriate ARIMA model. The criteria for model selection encompass Mean Absolute Percent Error (MAPE), Akaike Information Criterion (AIC), Hannan-Quinn, Schwarz Criterion, and Theil equality coefficient.

SARIMA Modeling: Building upon ARIMA, the SARIMA model is implemented to capture and forecast seasonality within the FEV sales data. The process involves extending the ARIMA model to include seasonal components. The chosen SARIMA model is assessed based on statistical measures such as Standard Error of Regression, AIC, BIC, Hannan-Quinn, and MAPE. The Generalized Dickey-Fuller (ADF) test ensures the time series' stationarity.

4.3. ETS Modeling

The ETS model, encompassing Error, Trend, and Seasonality components, forecasts future values using the series' inherent patterns. The Exponential Smoothing class is utilized to define the ETS model.

4.4. Forecasting and Comparison

In the forecasting phase, the ARIMA (4,1,4) model is applied to estimate Türkiye's FEV sales for the next five years (2024-2028). Furthermore, the SARIMA (1,0,1)(0,1,1)96 model is compared with other models and evaluated based on its predictive performance. Error bars in Figure represent the range of uncertainty, indicating potential variations in FEV sales due to future marketing methods.

5. RESULTS

5.1. ARIMA and SARIMA

In the study, ARIMA and SARIMA methodologies are used to analyze Türkiye's electric vehicle sales data from 2016 to 2023. A time series is a collection of data points recorded and observed sequentially over time. The ARIMA method is a commonly employed technique for modeling stationary time series. The strategy, coined by George Box and Gwilym Jenkins, is alternatively referred to as the Box-Jenkins (BJ) method. ARIMA models are time series models focusing on analyzing and predicting univariate data with high accuracy. The Box-Jenkins process for constructing ARIMA models consists of the following stages: The four main stages of the process are: (1) Model Definition, (2) Parameter Estimation and Selection, (3) Model Validation, and (4) Model Utilization.

	DATE	FEV	Month	Year
DATE				
2016-01-01	2016-01-01	16	1	2016
2016-02-01	2016-02-01	18	2	2016
2016-03-01	2016-03-01	21	3	2016
2016-04-01	2016-04-01	25	4	2016
2016-05-01	2016-05-01	27	5	2016
...	...	...	...	...
2023-08-01	2023-08-01	10101	8	2023
2023-09-01	2023-09-01	10152	9	2023
2023-10-01	2023-10-01	10160	10	2023
2023-11-01	2023-11-01	10164	11	2023
2023-12-01	2023-12-01	10166	12	2023

Figure 1. *Monthly FEV sales between 2016 to 2023*

The dataset includes a chart (Figure 1) showing monthly FEV sales data from 2016-2023. Additionally, electricity consumption forecasts after 2023 will be created using time series forecasting methods such as ARIMA and SARIMA. These models demonstrate their effectiveness in predicting future values using historical data. In order to estimate ARIMA models, the forms of the ACF and PACF are utilized to assess the stationarity of variables and determine the appropriate lag length for the ARIMA model. The partial PACF is utilized to ascertain the optimal lag order for the autoregressive (AR) model. The quantity of non-zero connections in the PACF dictates the appropriate inclusion of AR delays. The ACF correlogram is employed to ascertain the appropriate number of MA lags. Non-zero correlations suggest the inclusion of lags. If the ACF reaches its maximum value at a specific delay q and then abruptly decreases and resets, it indicates a good fit for the moving average (MA(q)) model. Conversely, the PACF reaches its highest value at a specific delay p. It abruptly stops, indicating a good fit for the AR model with order p. If the values of ACF and PACF satisfy all k requirements. It is appropriate to use the ARMA (p,q) model. In certain instances, when the ACF and PACF functions are inadequate, additional criteria such as BIC (Bayes Information Criterion) and AIC are employed to ascertain the values of the p and q coefficients in the model series. In particular research, a natural logarithmic transformation can convert exponential and linear growth. The statistical measures of Mean Absolute Percentage Error (MAPE) and the equality coefficient were employed to ascertain the most appropriate approach for the model. The model selected had a Theil equality coefficient value below one and the lowest MAPE, Akaike Criterion, Hannan-Quinn, and Schwarz Criterion values compared to the other models [122, 123].

Models exhibiting MAPE values below 10% are categorized as highly proficient, models ranging from 10-20% are classed as proficient, models with values between 20-50% are considered satisfactory, and models over 50% are labeled as inaccurate and defective. When the Theil Inequality Coefficient is zero, the model's optimal predictive capability is signified. However, this value should be as little as feasible, preferably less than 1. The initial step in doing a time series analysis involved testing the stationarity of the series [124]. The data were rendered stationary using the application of the ADF test, a unit root test type [125-127].

Several model trials have been conducted to ascertain the suitable model for prediction. The most suitable model for describing the series has been examined among the available possibilities. The model was selected based on its Theil equality coefficient value below one and its lowest MAPE, Akaike Criterion, Hannan-Quinn, and Schwarz Criterion values compared to other models. The computed values for the tested models are provided below [124, 128, 129].

The Standard Error of Regression for ARIMA (1,1,1) is 0.052835. The AIC is -2.846896, the Schwarz Criterion (SBC) is -2.714282, and the Hannan-Quinn is -2.849174. The MAPE is 92.09574, and Theil's U is 0.987916. The Standard Error of Regression for ARIMA (2,1,2) is 0.049967. The AIC is -2.906258. The Schwarz Criterion (SBC) is -2.654920. The Hannan-Quinn criterion is -2.789811. The MAPE is 92.82670, and Theil's U is 0.990749. The Standard Error of Regression for ARIMA (3,1,2) is 0.053650. The AIC is -2.866809, the Schwarz Criterion (SBC) is -2.674833, and the Hannan-Quinn is -2.809724. The MAPE is 92.33305, and Theil's U is 0.956860. Figure 2 shows the spectrum analysis graph. The spectral analysis graph is utilized to identify periodic or seasonal components in the data, providing insights into how the data varies over time. Figure 2 displays the time series graph of annual electricity use statistics.

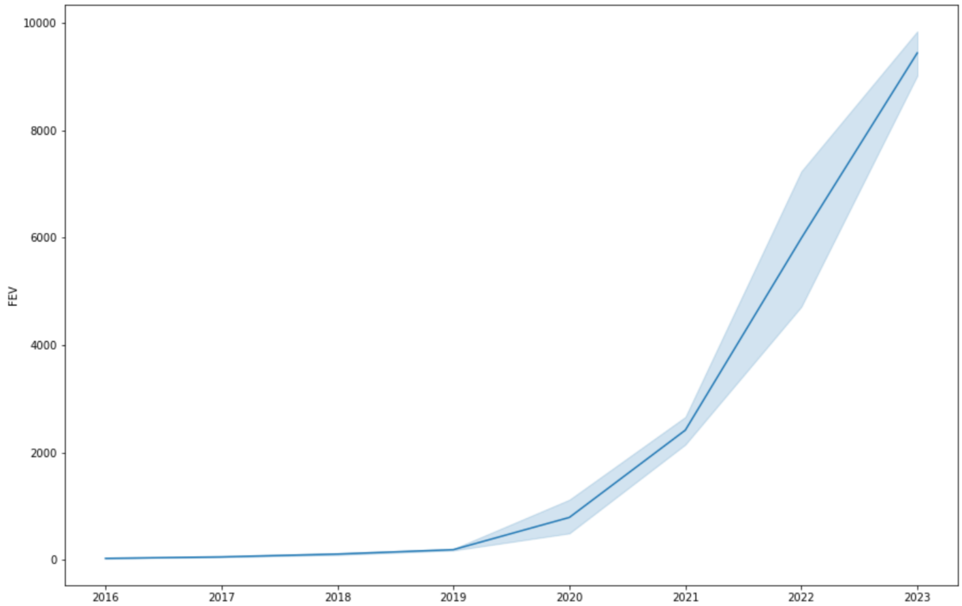


Figure 2. *Spectral analyses graph of the FEV sales data*

5.2. ETS Model

ETS model is an abbreviation for "Error, Trend, Seasonality" components and is a forecasting method used to analyze time series data. The ETS model predicts future values using the series' error, trend, and seasonality components. Considering these three components, the model produces a smoothed version of the data, which is used to predict the future behavior of the time series. ETS models are mainly used when seasonality and trends exist in time series data. This model is an effective tool for analyzing and forecasting time series data by providing flexibility to different trend and seasonality structures. This study defines an ETS model using the Exponential Smoothing class. Figure 3 shows the seasonal results of the ETS model.

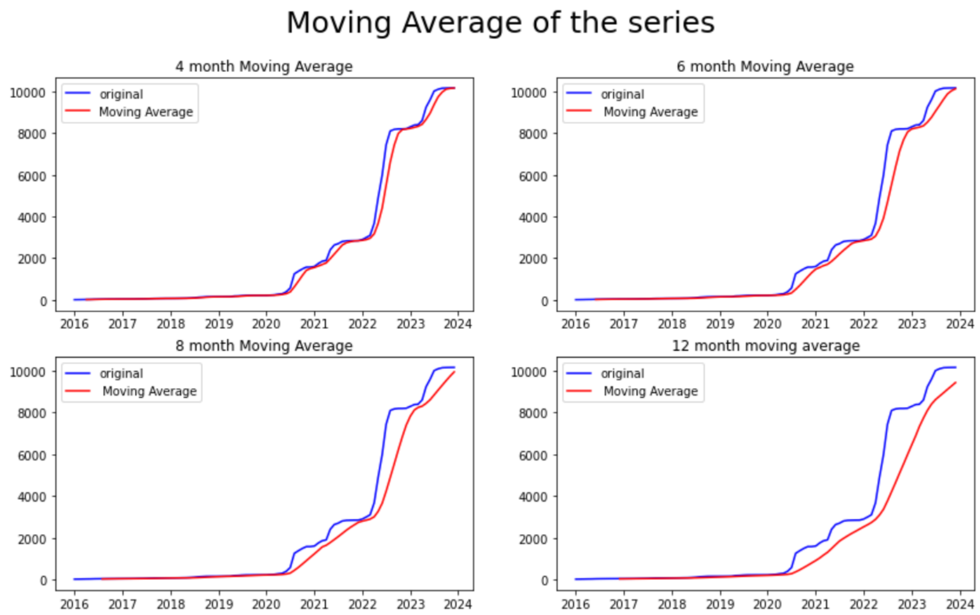


Figure 3. *Seasonal moving average of the series*

Figure 4 also illustrates the results of the ETS model applied to an FEV sales time series data set. The components in the graph provide significant output about the performance and suitability of the model. A statistically augmented Dickey–Fuller (ADF) test was applied for further clarification. ADF tests the null hypothesis that a unit root exists in a time series sample. The alternative hypothesis varies depending on the test version but is usually stationarity or trend-stationarity. Here, since the p-value is more significant than 0.05, we cannot reject the null hypothesis, and we can say that the data is not stationary. ACF chart was prepared to examine this analysis more deeply. ACF is a bar chart of the correlation coefficients between the series and its lags.

According to ADF results and FEV sales data, we can clearly state the following;

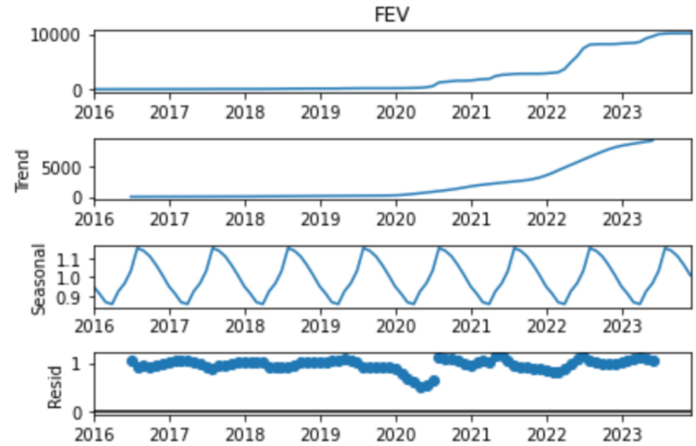
- Electricity consumption is increasing every year (along with the number of electric vehicles).
- We can see monthly seasonality. Electricity demand is high in July and August (as electric vehicle usage and sales volume increase).

A series is considered to be a combination or combination of these four components. All series have a level and noise. The trend and seasonality components are optional. It is helpful to think of the components being combined additively or multiplicatively.

Additive Model (additive)
The additive model suggests that the components are grouped as follows:

y(t) = Level + Trend + Seasonality + Noise.

The additive model is linear, where the same amount consistently changes over time. A linear trend is a straight line. A linear seasonality has the same frequency (cycle width) and amplitude (cycle height).



DATE	FEV	seasonal	trend	resid
2016-01-01	16.0	0.951899	NaN	NaN
2016-02-01	18.0	0.910172	NaN	NaN
2016-03-01	21.0	0.866167	NaN	NaN
2016-04-01	25.0	0.855510	NaN	NaN
2016-05-01	27.0	0.924173	NaN	NaN
2016-06-01	33.0	0.967858	NaN	NaN
2016-07-01	36.0	1.034720	32.916667	1.056972
2016-08-01	38.0	1.157314	35.208333	0.932582
2016-09-01	40.0	1.142740	37.375000	0.936550
2016-10-01	41.0	1.112859	39.375000	0.935671
2016-11-01	42.0	1.065113	41.375000	0.953050
2016-12-01	44.0	1.011475	43.333333	1.003866

Figure 4. *Results of the ETS model (trend, seasonal, and resid) applied to an FEV sales time series data set*

Multiplicative Model (multiplicative model)
A multiplicative model suggests multiplying the components as follows:

y(t) = Level * Trend * Seasonality * Noise.

A multiplicative model is not linear like quadratic or exponential. Changes increase or decrease over time. A nonlinear trend is a curved line. A nonlinear seasonality has a frequency and/or amplitude that increases or decreases over time.

This study separated Time Series Data into Trend and Seasonality with the multiplicative model for fully electric vehicles between 2016-2023 and transferred to the SARIMA model. The ADF time series result is given in Figure 5 to help understand the ETS model. In Figure 5, sales increases and peak values can be seen especially. The most significant increase of the FEV sales, except for Tesla, is obtained in 2020 summer time.

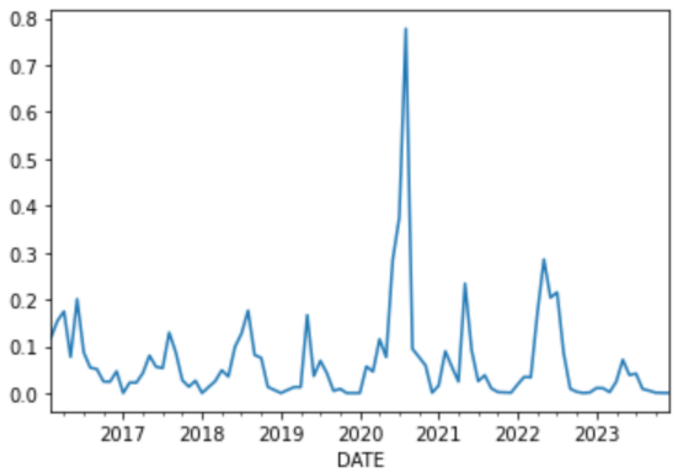


Figure 5. *ADF time series*

The trend and seasonality information obtained from the series looks reasonable. Interestingly, the residuals also represent a period of high variability in the time data series in the summer of 2020 (due to the high increase in sales). When the ADF and PADF results of the series were examined, it was seen that the expected results before ETS were obtained by distributing the residues. Autocorrelation and partial autocorrelation results are also given in Figure 6.

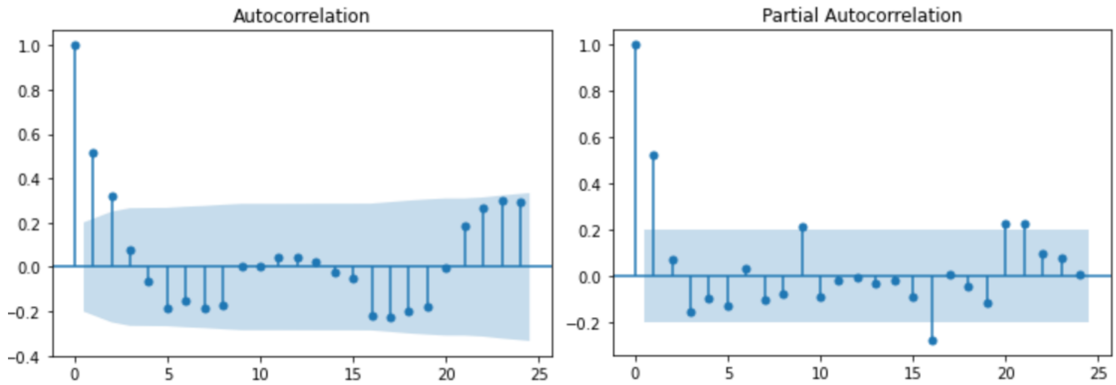


Figure 6. *ADF and PADF results of the FEV time series*

As seen in the figure, the BIC value of the model is 17.875. BIC is used to evaluate the quality of the model and generally produces results similar to AIC. A low BIC value indicates that the model fits and explains the data well enough without overfitting. Quinn Information Criterion is used in model selection and is calculated as 21.002. This indicates that the model captures the dataset well and has an appropriate model complexity. Covariance Type: The covariance type of the model is ‘up’; This indicates that the ‘outer product of gradients’ method calculates the model’s covariance parameter estimates.

The 96-month time series of FEV showed an exponential trend in sales intent (Figure 7). MAPE value of the ETS model; MAPE_Train: 0.040432974677989626 and MAPE_Test: 0.024232019088546015. Following the ETS model, the SARIMA model was prepared.

5.3. Forecasting and Comparison

FEV sales data were analyzed, and Türkiye’s FEV sales value was estimated in the next five-year period using the ARIMA (4,1,4) model. According to the research results, the FEV sales rate in Türkiye is expected to increase by an average value of 58.2% in the next five-year period, and the annual sales amount, excluding Tesla, will be 17459 (Table 3).

Table 3. *Full EV sales in Türkiye between 2016 and 2023 and forecasting between 2024-2028*

Years	FEV
2016	44
2017	77
2018	155
2019	222
2020	1579
2021	2846
2022	8210
2023	10166
2024	11520
2025	12956
2026	14598
2027	15989
2028	17459

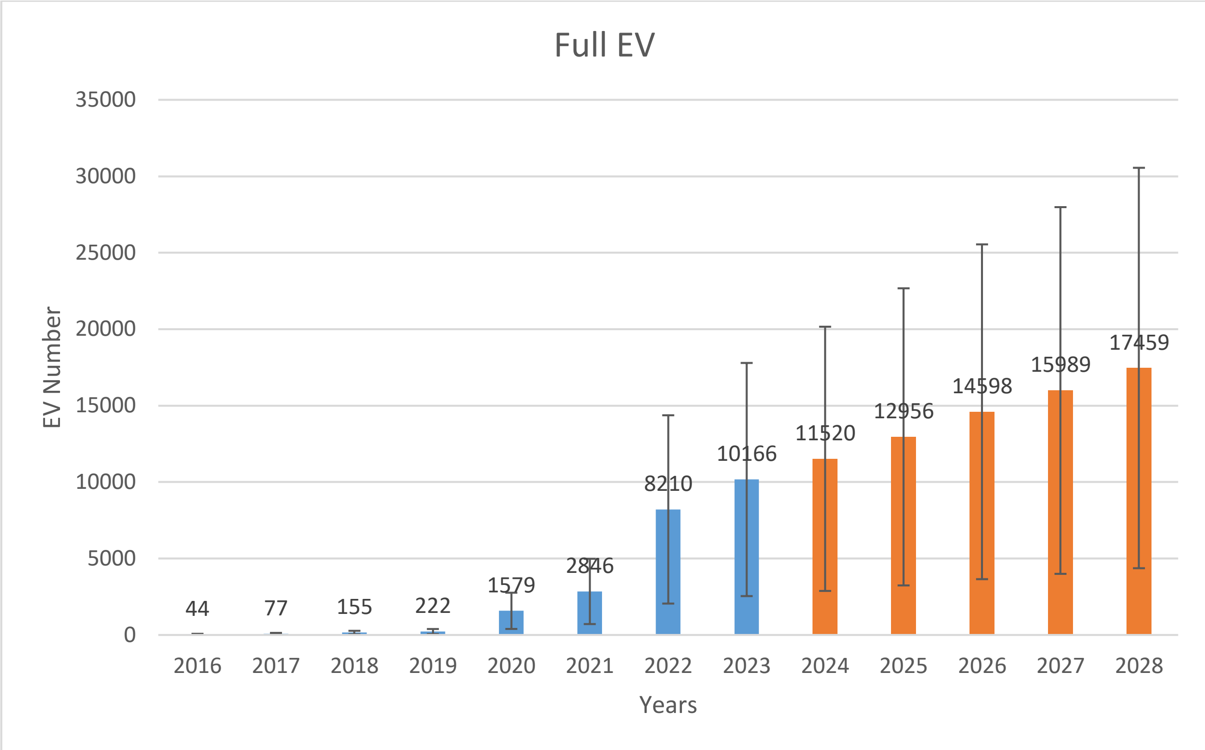


Figure 7. *5-year FEV sales number forecast based on data between 2016 and 2023*

When the margin of error in the analysis is calculated as the deviation/margin of error compared to the change in previous values and included in the forecast value, the new 5-year forecast data can be seen in Figure 7 by including the margin of error according to past data. The forecast models were developed using the periodic ARIMA (SARIMA) technique. It was determined that the SARIMA (1,0,1) (0,1,1) 96 model, which incorporated weekly delays, achieved the lowest forecast error values for the given time series. These findings indicated that the changes in FEV sales were comparable to those observed in the previous month. Hence, it is evident that incorporating seasonality is crucial in short-term forecasting models for FEV sales. Based on the investigation, it was concluded that the same SARIMA model is appropriate for time series analysis. Upon comparing the models constructed using monthly lag and yearly lag values (96 and 12), it was observed that models with monthly lag yielded superior outcomes within the same model category. Specifically, the value of FEV sales from one year ago held greater significance than the preceding value. Based on the test data performances of the models, it is evident that they are suitable for predicting short-term changes in FEV sales numbers. Future research can involve the development of novel models utilizing other modelling techniques and conducting comparisons with the SARIMA models established in this study. Hence, instead of employing identical models for time series analysis, more efficient models can be devised by utilizing distinct models for each series.

The values are accompanied by error bars, represented by closed black lines at both ends, indicating the uncertainty range based on past data. The error value, determined by artificial intelligence, is precisely 74.97%. Based on future marketing methods, it signifies the upper and lower bounds of the FEV sales rate during the next five years. Based on marketing methods, the figure indicates that the FEV sales rate in the next five years can surpass an annual threshold of 30 thousand units or decline to a lower threshold of 5 thousand units if incorrect techniques are implemented.

6. DISCUSSION

The results obtained from ARIMA and SARIMA models provide valuable insights into the patterns and trends within Türkiye's EV sales data from 2016 to 2023. The time series analysis, utilizing ARIMA, helps uncover significant aspects of the EV market, setting the stage for a comprehensive discussion on the implications and strategic considerations for stakeholders in the electric mobility landscape and applying ARIMA and SARIMA methodologies allowed for a deep dive into the dynamics of EV sales in Türkiye.

The analysis reveals consistent monthly fully electric vehicle sales growth, as illustrated in Figure 1. The models, selected based on Theil equality coefficient and MAPE values, highlight the efficacy of ARIMA (4,1,4). The spectral analysis graph in Figure 2 further aids in identifying periodic or seasonal components in the data. The study goes beyond the quantitative aspects by emphasizing the importance of choosing a model with a Theil equality coefficient below one and minimal MAPE values. Additionally, the results showcase the significance of factors like economic indicators and environmental considerations, as supported by the literature [123]. Introducing a multiplicative model for the Time Series Data sheds light on the trend and seasonality components, providing a more nuanced understanding of the EV market dynamics.

The ETS model brings an additional layer of analysis, incorporating the "Error, Trend, Seasonality" components. Figure 3 displays the seasonal moving average, while Figure 4 delves into the trend, seasonal, and residual components, contributing to a comprehensive evaluation of the model's performance. The non-linear nature of the multiplicative model allows for a more flexible representation of trends and seasonality. The ADF time series result in Figure 5 aligns with the observed increase in FEV sales, particularly in the summer of 2020. The residuals analysis, as depicted in Figure 6, underlines the model's ability to capture variations, reinforcing its effectiveness. The discussion around the AIC, BIC, and Quinn Information Criterion adds rigor to the evaluation, establishing the suitability of the ETS model for time series forecasting.

The forecasting section utilizes ARIMA (4,1,4) to predict FEV sales in Türkiye between 2024 and 2028. The analysis suggests a robust growth rate, averaging 58.2% annually, positioning the FEV market as a key player in the future. The incorporation of error bars in Figure 7 emphasizes the uncertainty range based on past data, offering a realistic perspective on the potential variations in sales. The discussion extends beyond quantitative predictions, emphasizing the strategic implications for stakeholders. It underscores the importance of considering seasonality, especially in short-term forecasting models, aligning with findings from previous research [128]. Moreover, the error bars highlight the need for adaptive marketing strategies, acknowledging the uncertainty inherent in future projections.

In synthesizing the results, the discussion connects back to integrating marketing strategies with analytical insights, emphasizing the role of accurate information and education in shaping consumer behavior. The findings underscore the significance of aligning marketing efforts with the identified trends and patterns, providing a roadmap for stakeholders in the electric mobility landscape.

The results and subsequent discussion not only contribute to a nuanced understanding of EV sales dynamics in Türkiye but also provide actionable insights for industry players, policymakers, and researchers. Future research avenues could explore alternative modeling techniques and conduct comparative analyses further to enhance the predictive capabilities in the dynamic EV market. The discussion sets the stage for an integrated approach, where analytical insights guide strategic decisions, fostering sustainable growth in the electric vehicle sector.

7. CONCLUSION

This comprehensive investigation into electric vehicle adoption in Türkiye unfolded the intricacies of integrating marketing strategies with analytical insights and educational endeavors to drive EV adoption. The alignment of marketing strategies with analytical models, including ARIMA, SARIMA, and ETS, provided a nuanced understanding of patterns and trends in Türkiye's EV sales. Educational marketing emerged as a transformative force, reshaping consumer attitudes by emphasizing economic benefits, reduced emissions, and technological advancements. The study addressed the pressing need for a holistic understanding of consumer behavior, market dynamics, and external influences for effective EV marketing. The findings underscore the pivotal role of education in shaping consumer behavior and the potential for collaborative strategies in overcoming industry challenges. The study resonates with the global push toward sustainable transportation and is relevant to policymakers, industry stakeholders, and researchers. Acknowledging the transparency and contextual interpretation, certain limitations of the study are recognized. These include the reliance on historical data, potential contextual variations, and the dynamic nature of consumer preferences. These constraints provide avenues for future research to refine and expand our understanding. Future research could delve into the long-term effects of educational campaigns, the evolving role of digital platforms in marketing, and the dynamic nature of consumer preferences in the ever-changing electric mobility landscape that will contribute to a more nuanced understanding of EV adoption factors. Emphasizing educational initiatives, strategic marketing partnerships, and responsive communication strategies emerges as a strategic approach for navigating the evolving electric mobility landscape. These strategies can directly influence consumer attitudes and drive widespread EV adoption. This study emphasizes integrating marketing strategies, analytical insights, and educational endeavors. This synthesis is pivotal for successfully addressing consumer hesitations, fostering positive attitudes, and navigating the evolving landscape of electric mobility. By integrating diverse elements, this study contributes to the transformative journey toward sustainable transportation and paves the way for a sustainable and environmentally responsible future. Consideration of the educational impact, collaborative strategies, and the dynamic nature of consumer behavior should guide future initiatives for promoting electric mobility that contribute to a greener, more sustainable future.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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