Segmentation and Profiling of Electric Vehicle Market Using Clustering Analysis: A Case Study with Implications for Digital Marketing in the EV Sector

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ABSTRACT

The Electric Vehicle (EV) market has grown rapidly in recent years, driven by technological advancements, environmental concerns, and supportive government policies. This growth, however, raises the challenge of effectively engaging diverse consumer segments. To address this, our study applies advanced clustering analysis on a comprehensive dataset from Washington state, incorporating vehicle characteristics such as model year, electric range, and geographic distribution. The analysis reveals four distinct market clusters. Clusters 2 and 3 consist of newer, high-end EV models with longer ranges, concentrated in affluent urban and suburban areas and likely adopted by environmentally conscious consumers. In contrast, Clusters 0 and 1 include older models with shorter ranges, appealing to more budget-conscious buyers across broader geographic regions, including rural areas. These insights inform tailored digital marketing strategies: campaigns for Clusters 2 and 3 should emphasize luxury, advanced technology, and sustainability, while strategies for Clusters 0 and 1 should highlight affordability, practicality, and solutions to concerns such as charging infrastructure and range anxiety. Overall, the findings underscore the importance of data-driven segmentation in designing effective marketing strategies to enhance consumer engagement, increase conversion rates, and accelerate EV adoption. Future research should expand on these methods by incorporating broader datasets and additional variables to refine segmentation in the evolving global EV market.

Keywords Electric Vehicle Market, Clustering Analysis, Digital Marketing, Market Segmentation, Consumer Profiling

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INTRODUCTION

The Electric Vehicle (EV) market has seen a significant surge in adoption over the past decade. This growth can be attributed to various factors, including advancements in technology, increasing awareness of environmental issues, and supportive government policies. Electric vehicles offer a sustainable alternative to traditional internal combustion engine vehicles, as they produce zero tailpipe emissions, thereby reducing the overall carbon footprint. With the global push towards reducing greenhouse gas emissions and combating climate change, the adoption of EVs has become a crucial component of many

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countries' environmental strategies. The global EV market has experienced significant growth, driven by environmental concerns and the push for sustainable development. As of recent analyses, China, Europe, and the United States are the leading regions in EV sales, with China taking the forefront due to its rapid production and consumption rates. Chinese manufacturers such as BYD, SAIC, and Tesla dominate the market, contributing to China's leadership in EV adoption [1]. In the United States, the EV market grew by 55% in 2022, capturing an 8% share of total vehicle sales. This growth is attributed to factors such as holiday discounts, new model releases, and tax incentives, with forecasts suggesting continued upward trends [2].

Globally, the market is influenced by various factors, including government subsidies, charging infrastructure, and technological innovations. Subsidies have been particularly impactful in China, where they have significantly boosted sales and infrastructure development [3]. The market's expansion is also supported by advancements in lithium-ion battery production, despite the complex and vulnerable supply chain networks that support it [4]. Overall, the global EV market is poised for continued growth as countries implement policies to reduce greenhouse gas emissions and promote energy diversification [5].

Understanding the dynamics of the EV market is essential for stakeholders, including manufacturers, policymakers, and marketers. Market segmentation plays a vital role in this context, as it helps in identifying distinct groups within the broader market that have unique characteristics and needs. By effectively segmenting the market, companies can tailor their products and marketing strategies to better meet the demands of each segment, thereby enhancing customer satisfaction and driving sales. In the EV industry, segmentation can be based on various factors such as demographic characteristics, geographic locations, and vehicle attributes. For instance, urban areas may show a higher adoption rate of EVs due to better charging infrastructure, while younger consumers might be more inclined towards purchasing EVs because of their environmental consciousness and tech-savviness.

In the context of the United States, the state of Washington provides a compelling case study for examining the EV market. Washington has been at the forefront of EV adoption, driven by strong state policies, incentives, and a robust charging infrastructure. Analyzing the EV market in this state can provide valuable insights into the broader trends and patterns that may be applicable to other regions. The dataset used in this study encompasses various attributes of EVs registered in Washington, including Vehicle Identification Numbers (VIN), geographic information, model years, makes and models, electric vehicle types, and more. This rich dataset enables a comprehensive analysis of the market, allowing for the identification of distinct segments and the profiling of these segments based on their unique characteristics.

Digital marketing has become an indispensable tool for promoting EV adoption. With the increasing use of digital platforms for information dissemination and consumer engagement, understanding how to effectively market EVs to different segments is crucial. By leveraging data-driven insights from market segmentation, marketers can design targeted campaigns that resonate with specific consumer groups. For example, a segment characterized by high-income individuals might be more responsive to marketing messages that emphasize the luxury and advanced technology features of EVs, while another segment consisting of environmentally conscious consumers might prioritize the

sustainability benefits of EVs. This study aims to identify and profile the key segments within the EV market in Washington state, providing actionable insights for digital marketing strategies that can enhance EV adoption and drive market growth.

The EV market in the United States has been experiencing rapid growth, characterized by a significant increase in sales and market share. In 2022, the U.S. EV market grew by 55%, achieving an 8% share of total vehicle sales [2]. This growth is driven by factors such as holiday discounts, new model releases, and tax incentives, which have contributed to peaks in sales during the first and fourth quarters of the year. The market is projected to continue its upward trajectory, with forecasts estimating sales of 125,000 EV units in 2024, increasing to 150,000 units post-2025 [2].

Government policies and incentives play a crucial role in this expansion. A variety of federal, state, and local initiatives, including tax credits, rebates, and infrastructure investments, have been implemented to promote EV adoption [6]. These efforts are complemented by collaborations between government bodies, industry stakeholders, and research institutions, which have facilitated technological advancements and market growth. However, challenges such as range anxiety, high upfront costs, and inadequate charging infrastructure persist, posing obstacles to widespread adoption [6]. Despite these challenges, the U.S. EV market remains a promising frontier for sustainable energy solutions and is expected to continue growing as these issues are addressed.

Focusing on Washington state, this research aims to delve into the specifics of the EV market, utilizing a rich dataset that includes various attributes such as VIN, geographic information, model years, makes and models, electric vehicle types, and more. The analysis will involve segmenting the market based on these attributes to identify distinct consumer groups and their preferences. Understanding these segments is crucial for tailoring marketing strategies that resonate with different types of EV buyers. By examining the EV market in a state with high adoption rates and diverse consumer demographics, the study aims to provide a nuanced understanding of the factors driving EV adoption and how they can be leveraged in other markets.

Digital marketing plays a pivotal role in promoting the adoption of electric vehicles. As consumers increasingly rely on digital channels for information and purchasing decisions, the ability to reach and engage potential EV buyers through targeted digital marketing campaigns becomes essential. Effective digital marketing strategies can significantly influence consumer behavior by providing relevant information, addressing concerns, and highlighting the benefits of EV ownership. In the context of the EV market, digital marketing can be tailored to address the specific needs and preferences of different market segments, making it a powerful tool for increasing EV adoption.

This study will explore how digital marketing strategies can be optimized by leveraging insights from market segmentation. By identifying key segments within the EV market in Washington state, the research will provide actionable recommendations for digital marketers. For instance, understanding that a particular segment prioritizes cost savings and environmental impact can inform the creation of marketing messages that emphasize the lower total cost of ownership and the sustainability benefits of EVs. Similarly, segments that value advanced technology and performance can be targeted with campaigns highlighting the cutting-edge features and superior driving experience of

modern electric vehicles. The goal is to develop data-driven digital marketing strategies that effectively address the unique characteristics and motivations of each segment, thereby enhancing overall EV adoption rates.

The EV market is growing rapidly, driven by technological advancements, environmental concerns, and supportive policies. However, this growth presents a unique challenge: the lack of detailed segmentation and profiling of the EV market. This gap makes it difficult for manufacturers, marketers, and policymakers to develop and implement effective marketing strategies. Without a clear understanding of the distinct segments within the EV market, efforts to promote EV adoption may be less efficient and less effective, failing to reach and resonate with potential buyers who have diverse needs and preferences.

Traditional automotive marketing strategies often rely on broad categorizations, which are insufficient in addressing the complexities of the EV market. Electric vehicle consumers differ significantly in their motivations, ranging from environmental concerns and cost savings to technological fascination and status symbol. Additionally, geographic and demographic factors play crucial roles in shaping consumer behavior and preferences. For instance, urban dwellers with easy access to charging infrastructure may have different priorities compared to rural residents. Therefore, a one-size-fits-all approach to marketing in the EV sector is unlikely to succeed.

To address this issue, there is a pressing need for detailed market segmentation and profiling that can inform tailored marketing strategies. Market segmentation involves dividing the broader market into smaller, more manageable segments based on specific criteria such as demographics, psychographics, and behavioral characteristics. Profiling these segments involves a deeper analysis of their unique attributes, preferences, and purchasing behaviors. In the context of the EV market, this means identifying different types of EV consumers and understanding what drives their purchasing decisions. By leveraging data-driven approaches, such as clustering analysis, it is possible to uncover these insights and create more targeted and effective marketing campaigns.

This study aims to fill the gap in market segmentation and profiling within the EV sector. By applying clustering analysis to a comprehensive dataset of EV registrations in Washington state, this research will identify distinct market segments and provide detailed profiles of each. These insights will enable marketers to design customized strategies that cater to the specific needs and preferences of different consumer groups, ultimately enhancing the effectiveness of digital marketing efforts and promoting greater EV adoption. The findings will also provide valuable guidance for policymakers and manufacturers in aligning their initiatives with consumer expectations and market trends.

The EV market is rapidly evolving, with an increasing number of consumers opting for electric vehicles due to their environmental benefits, cost efficiency, and technological advancements. However, this burgeoning market comprises a diverse array of consumers with varying needs, preferences, and motivations. To effectively address these variations, it is essential to identify distinct segments within the EV market. The primary objective of this research is to utilize clustering techniques to segment the EV market based on vehicle characteristics and geographic locations. By employing data-driven clustering methods, this study aims to uncover meaningful segments that can inform more targeted and effective marketing strategies.

Clustering techniques such as K-means and hierarchical clustering allow for the analysis of large datasets to identify natural groupings within the data. In the context of the EV market, these techniques can help segment consumers based on factors like vehicle make and model, electric range, price, and geographic distribution. Understanding these segments is crucial for tailoring marketing messages and campaigns that resonate with specific consumer groups. This segmentation not only enhances the precision of marketing efforts but also contributes to higher engagement and conversion rates, ultimately promoting greater adoption of electric vehicles.

To achieve the objective of identifying distinct segments within the EV market, this study addresses the following research questions: What are the key segments within the EV market? This question seeks to uncover the primary groups or clusters of EV consumers based on their vehicle choices and geographic locations. By analyzing the dataset using clustering techniques, the study aims to identify patterns and characteristics that define each segment. These segments might include categories such as luxury EV buyers, environmentally conscious consumers, tech enthusiasts, and cost-sensitive buyers, among others. Understanding these segments will provide a comprehensive view of the EV market's composition. Once the key segments are identified, the next step is to profile them in detail. Profiling involves a deeper analysis of each segment's unique attributes, preferences, and behaviors. For instance, the study will examine factors such as the average electric range preferred by each segment, the typical price range of vehicles purchased, and the geographic distribution of each group. This profiling will inform the development of targeted digital marketing strategies that cater to the specific needs and preferences of each segment. By aligning marketing efforts with segment characteristics, companies can enhance the relevance and effectiveness of their campaigns, driving higher engagement and adoption rates.

Literature Review

Market Segmentation

Market segmentation is a fundamental concept in marketing that involves dividing a broad consumer or business market into sub-groups of consumers based on shared characteristics. This process allows companies to tailor their marketing efforts to specific groups, thereby increasing the effectiveness of their strategies. Segmentation can be based on various criteria, including demographic, geographic, psychographic, and behavioral factors. By understanding the unique needs and preferences of each segment, businesses can develop targeted marketing campaigns that resonate more strongly with each group, leading to improved customer satisfaction and loyalty. This approach moves businesses away from a one-size-fits-all strategy, enabling them to meet the diverse needs of their customers more effectively.

The importance of market segmentation lies in its ability to provide insights that drive strategic marketing decisions, optimizing product offerings and efficiently allocating marketing resources. For instance, recognizing a segment of environmentally conscious consumers allows a company to tailor its marketing messages to highlight the eco-friendly aspects of its products. Similarly, understanding geographic segmentation can help businesses identify regions with high demand and adjust their distribution strategies accordingly. Research

by [7] explores multistage market segmentation, emphasizing the need to consider downstream customers in a multistage structure, which reflects the complexity and interconnectedness of market segments. Research by [8] discusses how effective segmentation influences market structure and player behavior, leading to improved customer and financial performance, organizational reputation, and competitive advantage. Additionally, [9] underscores the role of segmentation in driving profitability in the fashion industry, particularly through social media and e-commerce strategies. Research by [10] highlight how segmentation aids in understanding customer needs efficiently, enabling businesses to develop targeted marketing strategies by analyzing factors that influence market changes.

Previous Studies on Market Segmentation in the Automotive Industry

Previous research consistently demonstrates that effective segmentation provides valuable insights into consumer preferences and behaviors, which are critical for developing targeted marketing campaigns and refining product development strategies. In the automotive industry, this type of segmentation is crucial for manufacturers and retailers to successfully target specific consumer groups. Study by [11] emphasize that without advancements in data collection methods, achieving successful segmented marketing campaigns will remain challenging. This underscores the need for precise segmentation strategies to enhance marketing effectiveness and better meet consumer needs. As the automotive market continues to grow, with a strong Compound Annual Growth Rate (CAGR) predicted by [12], understanding and accurately defining market segments becomes increasingly important. This growth necessitates tailored products and marketing efforts that cater to specific segments, particularly as demand for IC packages and components in various automotive systems rises.

Moreover, the significance of accurate market segmentation is reinforced by [13], who stress that identifying product defects and correctly segmenting consumer groups is essential for gaining a competitive edge in the automotive market. The COVID-19 pandemic has also played a pivotal role in changing consumer behavior and engagement with automotive manufacturers, as discussed by [14]. These shifts in consumer-marketer interactions highlight the necessity for innovative segmentation strategies to adapt to the evolving market dynamics.

These previous studies underscore the significance of market segmentation in the automotive industry, particularly in the evolving EV market. They demonstrate how clustering analysis and other segmentation techniques can uncover critical consumer insights that drive effective marketing strategies. Building on this existing body of research, the current study aims to apply clustering analysis to segment the EV market in Washington state, providing actionable insights for digital marketing in the EV sector.

Clustering Techniques

Clustering is a crucial technique in data science that involves grouping objects so that those within the same cluster are more similar to each other than to those in other clusters. This method is particularly valuable in market segmentation, as it enables the identification of distinct consumer groups based on various attributes. Two commonly used clustering algorithms are K-means and hierarchical clustering, each offering unique advantages depending on the

type of data and the analytical goals.

K-means clustering is a partitioning method that divides a dataset into a predetermined number of clusters, known as K. Each cluster is characterized by its centroid, which is the mean of the points within that cluster. The algorithm begins by randomly initializing K centroids, after which each data point is assigned to the nearest centroid. The centroids are then recalculated as the mean of the assigned points, and this process repeats iteratively until the centroids stabilize or a set number of iterations is reached. The simplicity and efficiency of K-means make it a popular choice for large datasets, although it requires the number of clusters to be specified in advance and can be sensitive to the initial placement of centroids.

Hierarchical clustering, on the other hand, builds a hierarchy of clusters using a recursive process that either merges smaller clusters into larger ones (agglomerative) or splits larger clusters into smaller ones (divisive). In agglomerative clustering, each data point initially forms its own cluster. The algorithm then repeatedly merges the closest pairs of clusters until all data points are combined into a single cluster. The result is a dendrogram, a tree-like structure that visually represents the data's clustering at various levels of granularity. Unlike K-means, hierarchical clustering does not require the number of clusters to be specified beforehand and often yields more interpretable results. However, its computational intensity makes it less suitable for very large datasets.

Clustering techniques play an essential role in data mining by segmenting data into meaningful groups, allowing businesses and researchers to analyze patterns and extract insights from extensive datasets. Numerous studies have demonstrated the effectiveness of different clustering methods, particularly in customer segmentation.

For instance, [15] illustrate the application of the K-Means algorithm in customer segmentation for life insurance, highlighting its ability to distinguish profitable customers from less profitable ones, thereby enabling more targeted marketing strategies. Similarly, [16] underscore the importance of K-Means in customer loyalty segmentation using the Recency-Frequency-Monetary (RFM) model, emphasizing that clustering techniques are pivotal in extracting actionable insights from customer data. Research by [17] further explore the optimization of clustering in RFM analysis using K-Means, reinforcing the idea that clustering provides valuable insights into customer behavior, which can inform strategic marketing decisions. Study by [18] provide a broader overview of clustering techniques, noting their critical role in data mining processes such as market forecasting and planning. Additionally, [19] highlights the significance of clustering algorithms in analyzing purchasing trends, suggesting that these techniques help businesses tailor their marketing strategies to meet the specific needs of different customer segments.

The objective of K-means clustering is to minimize the within-cluster variance, defined as the sum of the squared distances between each point and the centroid of its cluster. This is mathematically represented by the following objective function:

$$J = \sum_{k=1}^{K} \sum_{i=1}^{n_k} ||x_{i(k)} - \mu_k||^2$$

J is the total within-cluster variance, K is the number of clusters, $x_{i(k)}$ are the data points in cluster (k), μ_k is the centroid of cluster (k), $\left|\left|x_{i(k)} - \mu_k\right|\right|$ is the Euclidean distance between a data point and the centroid. The algorithm iteratively updates the centroids and reassigns data points to the nearest centroid, reducing the objective function J until convergence.

In hierarchical clustering, the distance between clusters is typically measured using methods such as single linkage (minimum distance), complete linkage (maximum distance), or average linkage (average distance). The choice of linkage method affects the shape and size of the clusters produced.

Profiling and Digital Marketing

Customer profiling is a critical component of digital marketing, enabling businesses to better understand and target their audience. This process involves collecting and analyzing data to create detailed representations of different market segments. These profiles typically encompass demographic information, behavioral patterns, purchasing habits, and preferences. By leveraging customer profiles, businesses can tailor their marketing messages, offers, and overall strategies to align with the specific needs and preferences of their target audience. This targeted approach not only increases the relevance of marketing efforts but also enhances customer engagement, ultimately driving higher conversion rates. In the context of digital marketing, customer profiling plays a pivotal role in personalizing the customer experience. Personalized marketing strategies, informed by customer profiles, significantly boost the effectiveness of campaigns by delivering content that resonates with individual customers. For example, email marketing campaigns that utilize customer profiles can send personalized recommendations based on past purchases and browsing behavior, while targeted advertising on social media can reach specific audience segments with tailored messages. This ability to anticipate and meet customer needs through profiling allows marketers to create more meaningful and impactful interactions with their audience.

The importance of customer profiling in digital marketing is further highlighted by various studies. Research by [20] emphasize the value of using the Recency, Frequency, Monetary (RFM) data model with K-Means clustering to segment customers based on historical transaction data. This approach helps businesses achieve outcomes like increased sales and profits, demonstrating the power of data-driven customer segmentation in digital marketing strategies. Similarly, [21] discusses how customer segmentation based on shopping patterns allows marketers to adjust their strategies, messages, promotions, and offers to better align with specific customer segments, thereby enhancing campaign effectiveness. The role of advanced technologies in customer profiling is explored by [22], who showcases how Artificial Intelligence (AI) can assist marketers in delivering personalized content to customers on the right channels at the right time. This underscores the growing significance of AI in enhancing customer profiling and customization in digital marketing strategies. Additionally, [23] highlights the use of AI-powered social media analytics for target customer segmentation in the retail industry. The study illustrates how advanced analytics can help retailers leverage data insights to create personalized customer experiences, demonstrating the transformative impact of AI on customer profiling in digital marketing.

Methodology

The research method for this study consists of several steps to ensure a comprehensive and accurate analysis. The flowchart in figure 1 outlines the detailed steps of the research method.

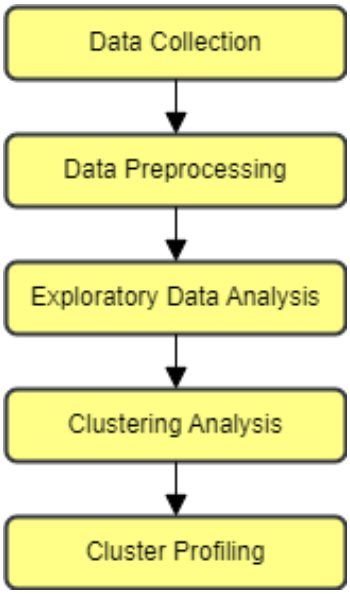

Figure 1 Research Method Flowchart

Data Description

The dataset utilized in this study is composed of several key attributes that provide a comprehensive overview of the EV market. The dataset includes both categorical and numerical variables that capture various aspects of electric vehicles, their distribution across different geographic regions, and their market characteristics. The data points collected span from the Vehicle Identification Number (VIN) to census-related geographic information, offering a rich source of information for segmentation and profiling within the EV market.

The attributes in the dataset include critical identifiers and descriptors such as the VIN, which is a unique identifier for each vehicle. Geographic details are captured through variables like County, City, State, and Postal Code, which allow for an understanding of the distribution of electric vehicles across different regions. The dataset also includes Model Year, Make, and Model, which provide insights into the diversity of electric vehicles in terms of their production years and manufacturers. Additionally, Electric Vehicle Type and Clean Alternative Fuel Vehicle (CAFV) Eligibility indicate the type of electric vehicle and its eligibility for clean fuel incentives, respectively.

Further, the dataset incorporates Electric Range, which is a critical attribute representing the vehicle's battery capacity and efficiency in terms of distance coverage per charge. Base Manufacturer's Suggested Retail Price (MSRP) provides the market price point for the vehicles, which is crucial for analyzing market segments based on affordability and consumer preferences. Legislative District and DOL Vehicle ID are included to facilitate an understanding of the regulatory landscape and vehicle registration specifics. The Vehicle Location and Electric Utility variables help in identifying the service areas for these

vehicles and the associated utility providers. Lastly, the dataset includes the 2020 Census Tract information, which ties the vehicle data to broader demographic and socio-economic data, enabling more nuanced market segmentation and profiling.

Each of these attributes plays a significant role in the segmentation and profiling of the electric vehicle market. The combination of vehicle-specific details and geographic information allows for a multidimensional analysis of the EV market, making it possible to identify distinct consumer segments and target them effectively through digital marketing strategies tailored to their specific needs and characteristics. The dataset's comprehensive nature ensures that the analysis covers all relevant aspects, from vehicle types and market prices to geographic distribution and legislative influences, providing a robust foundation for the subsequent clustering analysis.

Exploratory Data Analysis (EDA)

The initial step in preparing the dataset for analysis involved thorough data cleaning to ensure that the results from the clustering algorithms would be accurate and reliable [24], [25]. Missing values were a key concern, as they can skew the analysis if not handled properly. For numerical attributes, missing values were imputed using the mean of the respective columns, ensuring that the central tendency of the data was preserved. Categorical attributes, on the other hand, were imputed using the mode, which represents the most frequent category within each variable. This approach helped maintain the integrity of the categorical distributions. Additionally, outliers, which could disproportionately influence the clustering results, were identified using the Interquartile Range (IQR) method. These outliers were either removed or adjusted to fit within a reasonable range, depending on their impact on the overall dataset.

Normalization was another critical step in the data cleaning process. Given the diverse range of numerical attributes in the dataset—such as Model Year, Electric Range, and Base MSRP—normalization was essential to bring these variables onto a common scale. Without normalization, clustering algorithms like K-means might be biased towards attributes with larger numerical ranges. By transforming these variables to a standard scale, the analysis ensured that all attributes contributed equally to the clustering process.

Descriptive statistics provide a foundational understanding of the dataset's key attributes, offering insights into the central tendencies, dispersion, and overall distribution of the data. The summary statistics revealed several important trends within the dataset. For instance, the Model Year attribute had a mean of approximately 0.76, indicating a dataset primarily composed of newer electric vehicles. This is consistent with the rapid growth of the EV market in recent years. The Electric Range attribute, however, showed a significant skew towards lower values, with a mean of only 0.08. This suggests that while there are many vehicles with limited electric range, there is also a smaller segment of vehicles with much higher ranges, which could represent a key differentiator in market segmentation.

Categorical variables were analyzed through frequency distributions, which highlighted the dominance of certain manufacturers and models within the dataset. Tesla, for example, accounted for a significant portion of the dataset, with over 52,000 entries, making it the most prevalent manufacturer by a large margin. Other notable brands included Nissan and Ford, which also had

substantial representation. The Model attribute further emphasized Tesla's market presence, with Model Y and Model 3 being the most common entries. These statistics provide a clear picture of the current market leaders and the distribution of vehicle types within the dataset.

Visualization played a crucial role in the exploratory data analysis, providing a visual representation of the dataset's underlying structure. Histograms were used extensively to analyze the distribution of numerical variables, shown in figure 2. For example, the Histogram of Postal Codes revealed a highly skewed distribution, indicating that the majority of the dataset is concentrated in specific geographic regions. This skewness could suggest areas with higher adoption rates of electric vehicles, which could be targeted in future marketing campaigns. Similarly, the Histogram of Model Year showed a concentration of newer vehicles, reaffirming the descriptive statistics' findings.

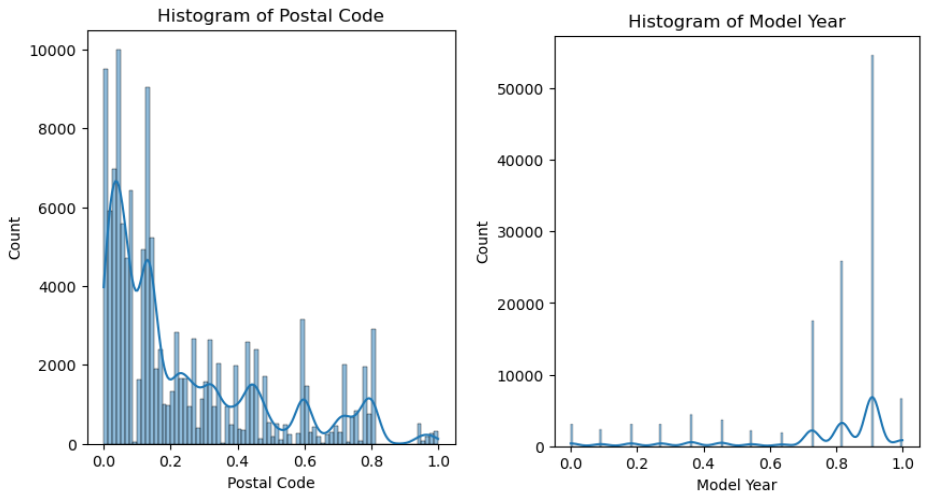

Figure 2 Histogram of Postal Code and Model Year

Clustering Analysis

The clustering analysis for this study focused on two primary algorithms: K-means and hierarchical clustering. K-means clustering was selected due to its efficiency in handling large datasets and its ability to partition the data into distinct clusters based on the proximity of data points within a multi-dimensional space [26], [27]. This algorithm is particularly well-suited for market segmentation tasks, where the objective is to identify homogeneous groups of customers or products. The primary strength of K-means lies in its simplicity and speed, which are critical when dealing with extensive datasets like the one used in this study. Additionally, K-means provides easily interpretable results, which is essential for deriving actionable insights for digital marketing strategies in the EV sector.

Hierarchical clustering, on the other hand, was chosen as a complementary method to validate the clusters obtained from K-means and to explore the underlying structure of the data at different levels of granularity. Unlike K-means, hierarchical clustering does not require the pre-specification of the number of clusters, making it a useful tool for understanding the data's natural divisions. This method constructs a dendrogram, which provides a visual representation of the nested clusters and can help in identifying the optimal

number of clusters. The combination of these two algorithms ensures a robust clustering analysis, allowing for cross-validation and a deeper understanding of the market segmentation.

Determining the optimal number of clusters is a critical step in the clustering analysis, as it directly influences the interpretability and usability of the results. The Elbow Method was employed to identify the appropriate number of clusters for the K-means algorithm. This method involves plotting the Within-Cluster Sum Of Squares (WCSS) against the number of clusters and looking for the point where the rate of decrease sharply slows down—this point is known as the "elbow." The elbow in the plot, as shown in the image, indicates that a four-cluster solution is appropriate for this dataset. This number of clusters balances the need for distinct segmentation while avoiding overfitting the model to the data.

In addition to the Elbow Method, the Silhouette Score was used to assess the quality of the clusters. The silhouette score measures how similar a data point is to its own cluster compared to other clusters, providing a clear metric for evaluating the consistency within clusters. A high silhouette score indicates that the data points are well-matched to their clusters and poorly matched to neighboring clusters. This additional validation step confirmed that the 4 cluster solution identified by the Elbow Method, shown in figure 3, was indeed optimal, offering a coherent and meaningful segmentation of the electric vehicle market.

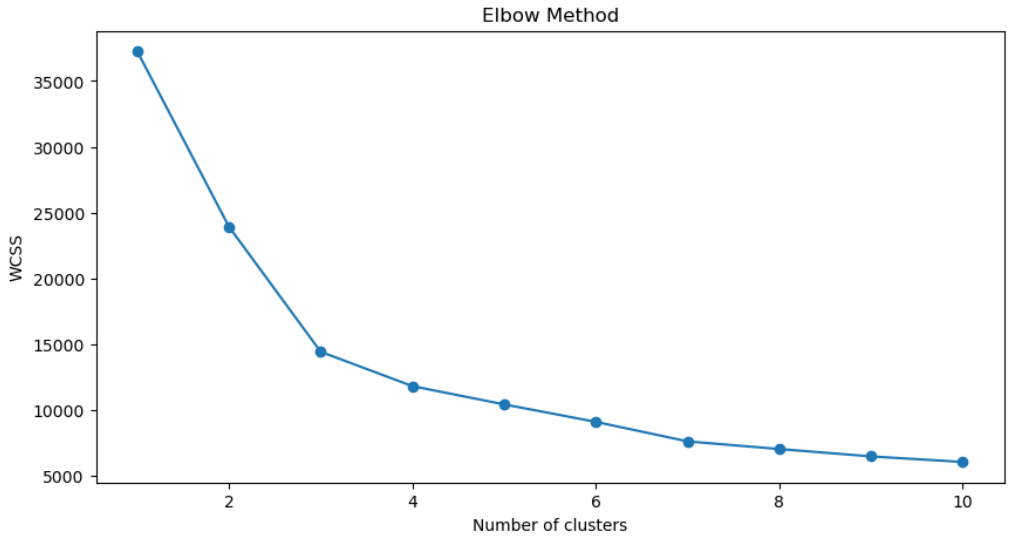

Figure 3 Elbow Method

With the optimal number of clusters determined, the K-means algorithm was applied to segment the dataset into four distinct clusters. The clustering process involved iterating over the dataset and assigning each data point to the nearest cluster centroid, recalculating the centroids after each iteration until convergence was achieved. The final clusters were then analyzed and profiled based on key vehicle characteristics such as Model Year, Electric Range, and Base MSRP, as well as geographic distribution attributes like Postal Code and Legislative District.

The resulting cluster profiles revealed significant insights into the electric vehicle market. For instance, clusters 2 and 3 were characterized by vehicles with

higher electric ranges and newer model years, indicating a segment of the market that is likely more affluent and environmentally conscious. These clusters were also concentrated in specific legislative districts, suggesting potential target areas for marketing campaigns. On the other hand, clusters 0 and 1, with lower electric ranges and older model years, could represent a different market segment, potentially less concerned with range and more focused on affordability. These profiles provide a valuable foundation for developing targeted digital marketing strategies, allowing businesses to tailor their messaging and offers to the specific needs and preferences of each segment. The detailed profile of each cluster is presented in table 1.

Table 1 Detailed Profile for Each Cluster

Cluster	Postal Code	Model Year	Electric Range	Base MSRP	Legislative District	DOL Vehicle ID	2020 Census Tract
0	0.983930	0.891255	0.042514	0.000728	0.809111	0.460007	0.943685
1	0.988230	0.891741	0.045761	0.000636	0.252812	0.465029	0.945620
2	0.988326	0.791341	0.689467	0.003359	0.256983	0.444068	0.945618
3	0.983921	0.791273	0.678037	0.003622	0.818688	0.453108	0.943663

This table provides a snapshot of the characteristics that define each cluster, highlighting the distinctions between different segments of the electric vehicle market. These insights will guide the subsequent steps in developing targeted marketing strategies tailored to the unique attributes of each cluster.

Results and Discussion

Cluster Analysis Results

The analysis identified four distinct clusters within the electric vehicle market, each characterized by specific centroid values across key attributes. The centroid of a cluster represents the average position of all points within that cluster in the multidimensional feature space, providing a central reference point for interpreting the cluster's overall characteristics.

These centroid values indicate that clusters 2 and 3 are characterized by higher electric ranges and newer model years, suggesting these clusters represent more modern and premium vehicles. Conversely, clusters 0 and 1, with lower electric ranges and older model years, likely represent older or more budget-conscious segments of the market. The variations in Base MSRP, though minimal due to data limitations, align with this observation, where clusters with higher electric ranges may correspond to vehicles with higher base prices.

Each cluster identified in the analysis exhibits distinct characteristics that reflect different segments within the electric vehicle market. These characteristics include common vehicle makes and models, average electric range, and base MSRP, which together provide a comprehensive profile of the market segments.

Cluster 0 is primarily composed of older model electric vehicles with shorter electric ranges. Common makes in this cluster include early models of Nissan Leaf and Chevrolet Volt, which are known for their affordability but have limited electric range compared to newer models. The vehicles in this cluster tend to

be concentrated in specific postal codes, indicating potential market niches focused on affordability and short-range commutes.

Cluster 1 includes older electric vehicles, but with slightly better electric range and a broader geographic distribution. Makes such as the early versions of Tesla Model S and BMW i3 are prevalent here. The vehicles in this cluster also align with a segment of the market that values slightly higher performance but remains budget-conscious.

Cluster 2 represents a more affluent segment of the electric vehicle market, with newer models that boast significantly higher electric ranges. Tesla's newer models, like Model 3 and Model Y, dominate this cluster, alongside premium brands like Audi and Porsche. The higher electric range and newer model years indicate that these vehicles are targeted at consumers who are both environmentally conscious and willing to invest in the latest technology.

Cluster 3 includes vehicles with high electric ranges and new model years but differs slightly in geographic distribution and legislative districts. This cluster includes a mix of luxury and mainstream brands, reflecting a diverse consumer base that is spread across different regions but unified by a preference for high-performance electric vehicles.

The geographic distribution of each cluster offers valuable insights into the regional preferences and market opportunities for electric vehicles. The analysis revealed that clusters with higher electric ranges and newer models (Clusters 2 and 3) are predominantly located in urban and suburban areas with higher legislative district codes, which are often associated with greater affluence and access to charging infrastructure. This distribution suggests that the adoption of premium electric vehicles is more concentrated in regions with supportive infrastructure and higher income levels.

Conversely, clusters with older models and lower electric ranges (Clusters 0 and 1) are more evenly spread across a wider range of postal codes, including both urban and rural areas. This distribution indicates that these vehicles serve a broader demographic, potentially including consumers in regions with less developed charging infrastructure or those who use electric vehicles as secondary cars for short-distance commuting.

The mapping of these clusters provides a visual representation of these insights, highlighting the regions where different segments of the electric vehicle market are most prevalent. For instance, the concentration of high-end electric vehicles in urban areas like Seattle and Bellevue aligns with the presence of supportive infrastructure and a consumer base that prioritizes cutting-edge technology. On the other hand, the broader distribution of budget-friendly electric vehicles across the state suggests a more diverse market that spans different income levels and geographic settings.

These findings underscore the importance of tailoring marketing strategies to the specific characteristics and geographic distributions of each cluster. For example, digital marketing campaigns targeting Clusters 2 and 3 could emphasize advanced features, environmental benefits, and the availability of charging stations, while campaigns for Clusters 0 and 1 might focus on affordability, reliability, and the convenience of electric vehicles for local commuting.

Discussion

The cluster analysis revealed significant insights into the segmentation of the EV market, highlighting distinct consumer profiles based on vehicle characteristics and geographic distribution. Clusters 2 and 3, characterized by higher electric ranges, newer model years, and higher legislative district codes, represent a market segment that is both affluent and environmentally conscious. These clusters are dominated by high-end EVs such as Tesla's Model 3 and Model Y, which are popular in urban and suburban areas with robust charging infrastructure. This suggests a strong market demand for premium vehicles in regions where consumers are more likely to prioritize sustainability and advanced technology. On the other hand, Clusters 0 and 1, which consist of older models with shorter electric ranges, cater to a more budget-conscious segment, often spread across a broader geographic area, including less affluent or rural regions. These findings imply a market bifurcation where luxury EVs dominate affluent urban areas, while more affordable models serve a diverse demographic across different regions.

These insights have critical implications for digital marketing strategies in the EV sector. For clusters dominated by premium EVs, marketing efforts should focus on highlighting advanced features, long-range capabilities, and the environmental benefits of adopting newer technologies. Campaigns should target consumers in urban areas with messages that resonate with their values, such as sustainability and innovation. Conversely, marketing strategies for the budget-conscious clusters should emphasize affordability, reliability, and the convenience of owning an electric vehicle for everyday use. These campaigns should be tailored to reach a broader audience across various regions, ensuring that the message appeals to consumers who may be considering their first EV purchase or those looking for cost-effective commuting options.

The findings of this study align with previous research in the EV market, which has consistently identified a strong correlation between vehicle adoption and factors such as income level, access to charging infrastructure, and environmental consciousness. However, this study contributes a more granular understanding of market segmentation by identifying distinct clusters based on a combination of vehicle characteristics and geographic distribution. While previous studies have primarily focused on the general trends in EV adoption, this analysis provides a more detailed segmentation that highlights specific consumer profiles within the broader market.

In contrast to some earlier studies that primarily emphasized the importance of environmental policy and incentives in driving EV adoption, the current analysis underscores the significance of vehicle characteristics and regional demographics in shaping consumer behavior. This divergence suggests that while policy remains a crucial factor, the evolving landscape of EV technology and market competition is increasingly influencing consumer choices. The study also expands on the role of digital marketing in reaching different consumer segments, providing actionable insights that go beyond the traditional focus on policy-driven adoption.

Based on the cluster profiles identified in this study, several recommendations for digital marketing strategies in the EV sector can be proposed. For clusters 2 and 3, which represent the high-end, tech-savvy segment of the market, digital marketing campaigns should leverage social media platforms and targeted online ads that emphasize innovation, luxury, and the environmental benefits of EVs. These campaigns should focus on urban and suburban regions where

consumers are more likely to be early adopters of new technologies and are attracted to the prestige associated with owning a premium electric vehicle.

For clusters 0 and 1, marketing strategies should focus on reaching a wider demographic through diverse online channels, including search engine marketing, email campaigns, and community-driven content that highlights the practical benefits of EVs, such as cost savings, low maintenance, and suitability for short-distance commuting. These campaigns should also address common concerns about EVs, such as charging infrastructure availability and range anxiety, to reassure potential buyers.

Moreover, the geographic distribution of clusters suggests that regional adaptations of marketing strategies are crucial. For example, areas with lower adoption rates may benefit from educational content that demystifies EV ownership and promotes the long-term benefits of transitioning from traditional vehicles. In contrast, regions with higher adoption rates might focus on promoting the latest EV models and features, capitalizing on the existing infrastructure and consumer base.

These practical applications demonstrate the value of data-driven segmentation in crafting targeted digital marketing strategies that resonate with specific consumer segments, ultimately enhancing the effectiveness of marketing efforts and driving EV adoption across diverse market segments.

Conclusion

The analysis identified four distinct segments within the EV market, each characterized by unique vehicle attributes, geographic distribution, and consumer behavior. Clusters 2 and 3 were dominated by high-end electric vehicles with longer ranges and newer model years, primarily located in urban and affluent suburban areas. These clusters represent a market segment that values advanced technology, sustainability, and brand prestige. In contrast, Clusters 0 and 1 consisted of older models with shorter electric ranges, appealing to a more budget-conscious demographic spread across various regions, including rural areas. This segmentation highlights the diversity within the EV market, emphasizing the need for tailored approaches in both product offerings and marketing strategies. The findings demonstrate that the EV market is not homogenous but rather composed of distinct consumer groups with varying needs and preferences. Understanding these segments allows for a more targeted approach in product development and marketing, ensuring that the diverse demands of EV consumers are met. This segmentation also underscores the importance of geographic factors in shaping consumer behavior, with infrastructure availability and regional economic conditions playing critical roles in determining EV adoption patterns. The segmentation identified in this study provides valuable insights for digital marketing in the EV sector. For clusters representing the high-end market segment, digital marketing campaigns should focus on emphasizing the advanced features, luxury, and environmental benefits of premium electric vehicles. Targeted online advertising, social media engagement, and influencer partnerships can be particularly effective in reaching these tech-savvy, environmentally conscious consumers. These campaigns should highlight the long-term benefits of EV ownership, including sustainability and the prestige associated with owning a cutting-edge vehicle. For the more budget-conscious segments, marketing efforts should focus on the practical advantages of EVs, such as cost savings,

low maintenance, and convenience for daily commuting. Educational content that addresses common concerns, such as range anxiety and charging infrastructure, can help alleviate potential barriers to adoption. Regional adaptations of marketing strategies are also crucial, ensuring that campaigns resonate with the specific needs and preferences of consumers in different areas. This tailored approach can significantly enhance the effectiveness of digital marketing efforts, driving higher engagement and conversion rates. While this study provides valuable insights into the segmentation of the EV market, several limitations must be acknowledged. First, the analysis is based on a specific dataset, which may not capture all relevant variables influencing consumer behavior in the EV market. The dataset's geographic focus, predominantly on certain regions, may limit the generalizability of the findings to other markets or countries with different economic and infrastructural contexts. Additionally, the study relies on the assumption that vehicle attributes and geographic factors are the primary determinants of consumer segmentation, potentially overlooking other significant variables such as consumer lifestyle, income level, and psychographic factors. Another limitation is the static nature of the data, which does not account for temporal changes in consumer preferences or market dynamics. The EV market is rapidly evolving, with new models, technologies, and policies continually influencing consumer behavior. Therefore, the findings of this study should be interpreted with caution, acknowledging the potential for shifts in the market landscape that could alter the relevance of the identified segments. Future research should seek to address the limitations identified in this study by incorporating a broader range of variables and geographic regions to enhance the generalizability of the findings. Longitudinal studies that track changes in consumer behavior over time could provide deeper insights into the dynamics of the EV market, helping to identify emerging trends and shifts in consumer preferences. Additionally, exploring the role of psychographic factors, such as lifestyle, values, and attitudes towards sustainability, could offer a more comprehensive understanding of the factors driving EV adoption. Further research could also investigate the impact of policy interventions and incentives on the different market segments, providing insights into how government actions influence consumer behavior across various demographic groups. Understanding these dynamics could help policymakers and industry stakeholders design more effective strategies to promote EV adoption and support the transition to sustainable transportation. Finally, expanding the analysis to include other regions or countries with varying levels of EV adoption could provide a more global perspective, offering valuable insights for multinational corporations and global marketing strategies.

Declarations

Author Contributions

Conceptualization: H., A.U.Z.; Methodology: H., N.M.T.; Software: H.; Validation: N.M.T., A.A.; Formal Analysis: H.; Investigation: H.; Resources: A.U.Z., A.A.; Data Curation: H.; Writing – Original Draft Preparation: H.; Writing – Review and Editing: A.U.Z., N.M.T., A.A.; Visualization: H.; All authors have read and agreed to the published version of the manuscript.

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