Electric Vehicle Market Segmentation Analysis

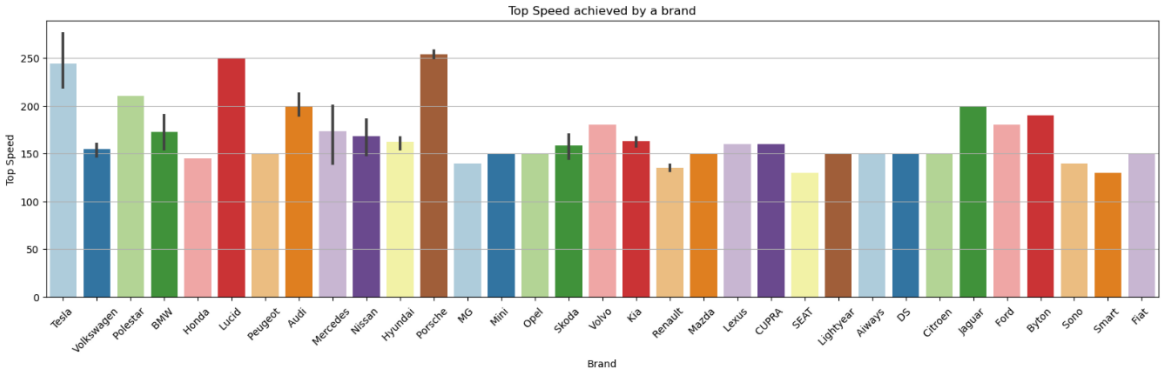
Introduction

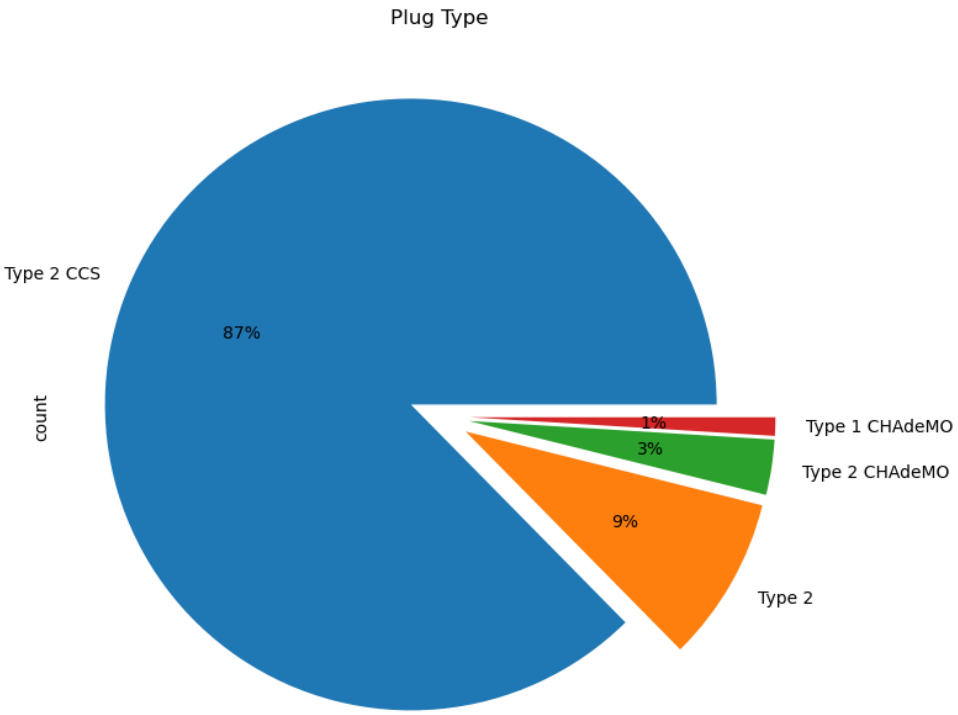
The electric vehicle (EV) market has witnessed rapid growth, driven by technological advancements and increasing environmental awareness. Understanding market segments within this industry is crucial for manufacturers to tailor their offerings to specific consumer needs. This report explores segmentation using machine learning techniques, focusing on key features of EVs and analyzing consumer preferences.

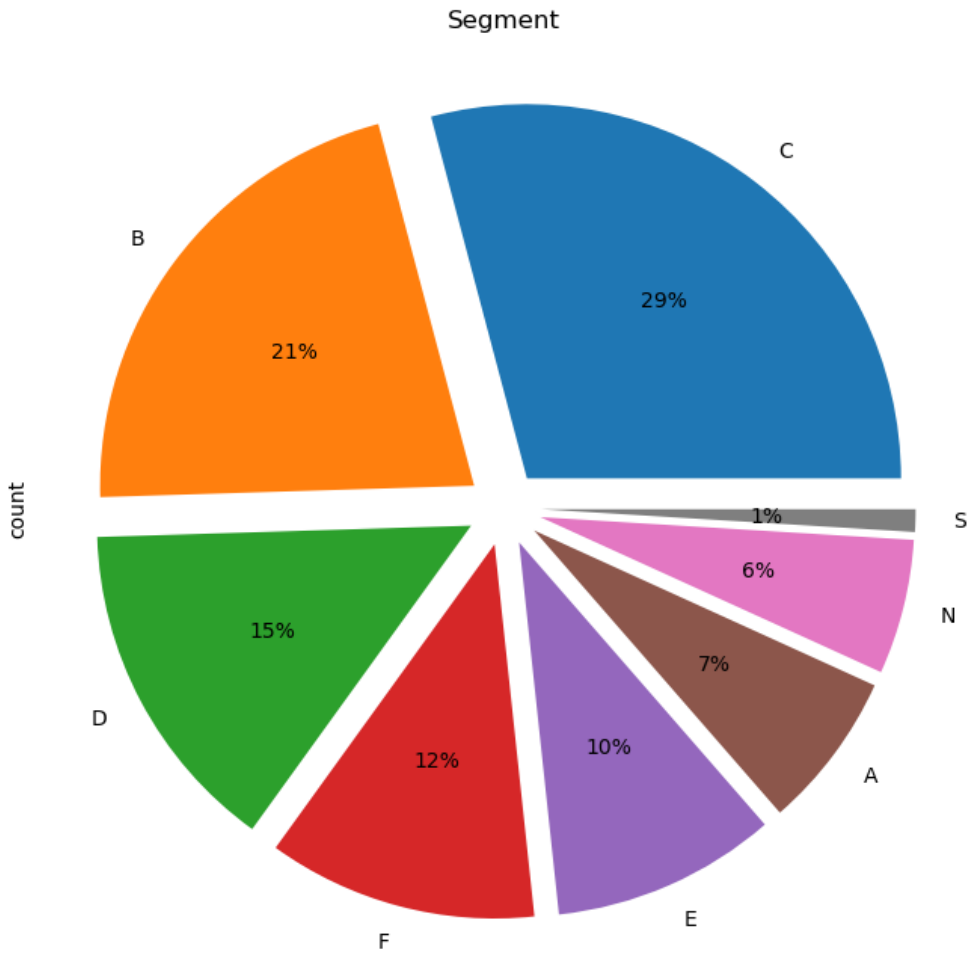
Methodology

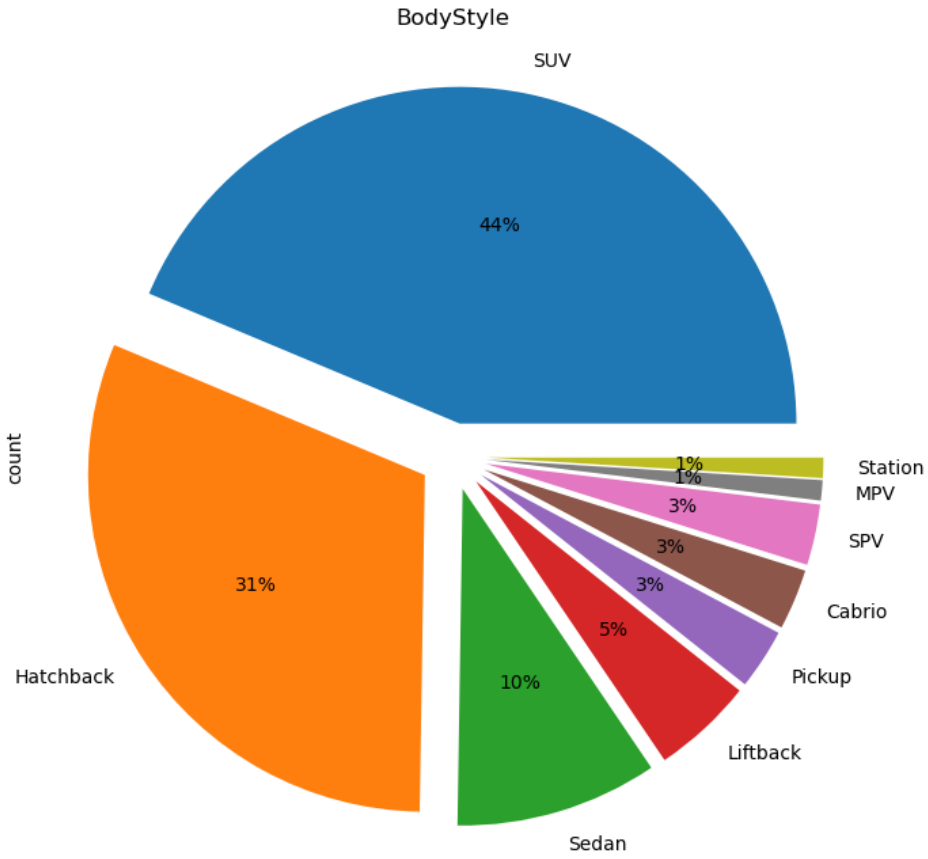
The analysis employs a dataset of electric vehicles, exploring attributes such as price, acceleration, top speed, range, efficiency, and more. The primary goal is to identify distinct market segments and understand the characteristics of each.

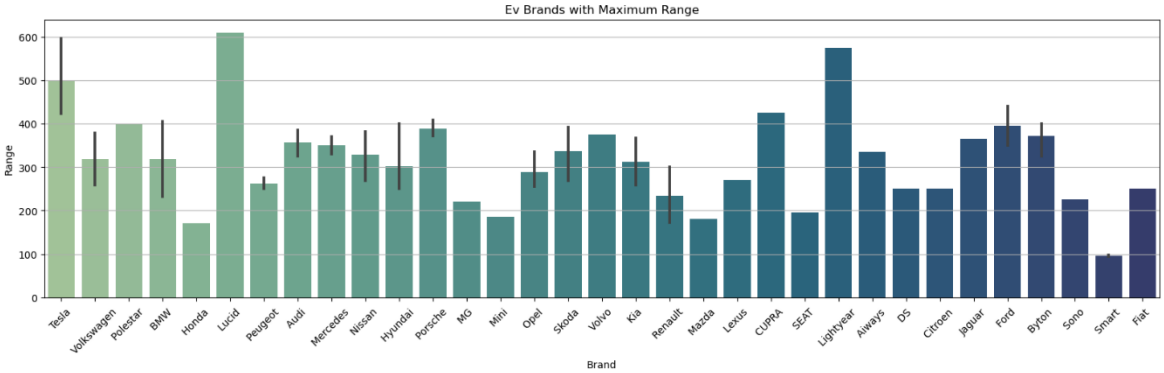
1. **Data Preprocessing:**
    - **Dataset Overview:**
        - The dataset includes columns such as Brand, Model, PriceEuro, AccelSec, TopSpeed_KmH, Range_Km, Efficiency_WhKm, RapidCharge, PowerTrain, PlugType, BodyStyle, and Segment.
    - **Cleaning and Transformation:**
        - The dataset was cleaned to handle missing values, duplicates, and categorical features were encoded. Price in Euros was converted to Indian Rupees for localization.
2. **Exploratory Data Analysis (EDA):**
    - Various visualizations were created to understand the distribution of features such as top speed, acceleration, price, and range across different brands.

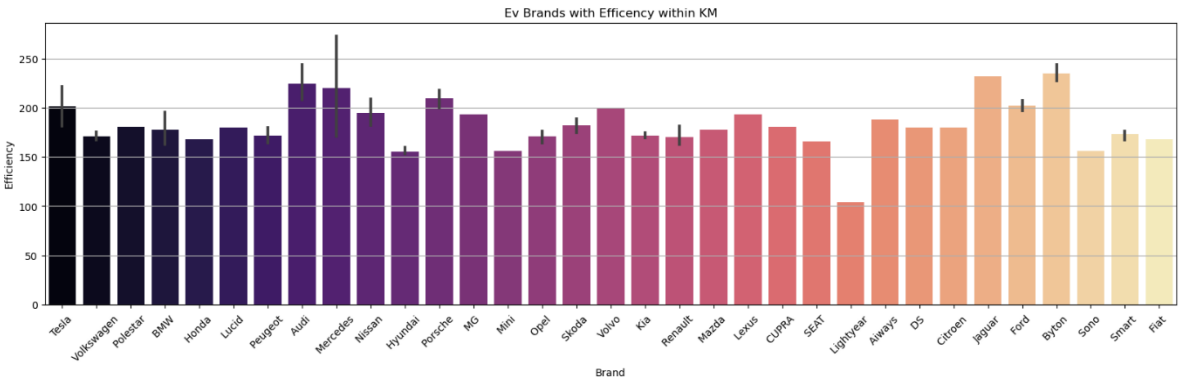

Top Speed achieved by a brand
Top Speed
0
50
100
150
200
250
Tesla
Volkswagen
Polestar
BMW
Honda
Lucid
Peugeot
Audi
Mercedes
Nissan
Hyundai
Porsche
MG
Mini
Opel
Skoda
Volvo
Kia
Renault
Mazda
Lexus
CUPRA
SEAT
Lightyear
Aiways
DS
Citroen
Jaguar
Ford
Byton
Sono
Smart
Fiat
Brand


Plug Type
Type 2 CCS
87%
count
1%
Type 1 CHAdeMO
3%
Type 2 CHAdeMO
9%
Type 2

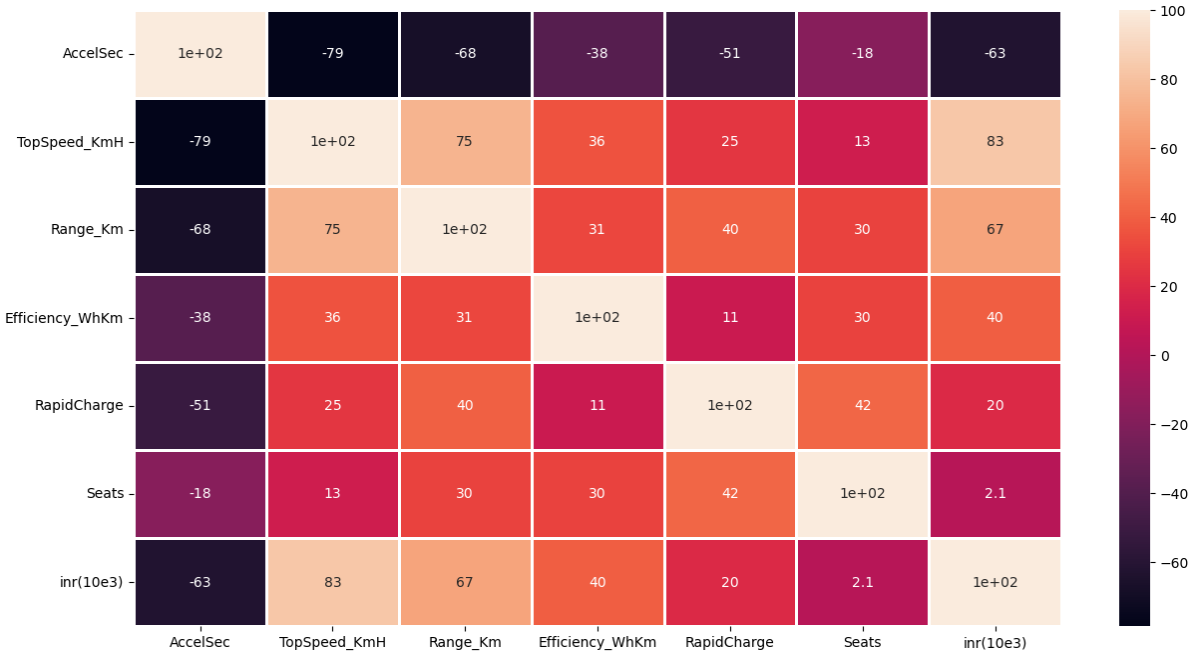

Segment
count
C
29%
B
21%
S
1%
N
6%
A
7%
E
10%
F
12%
D
15%

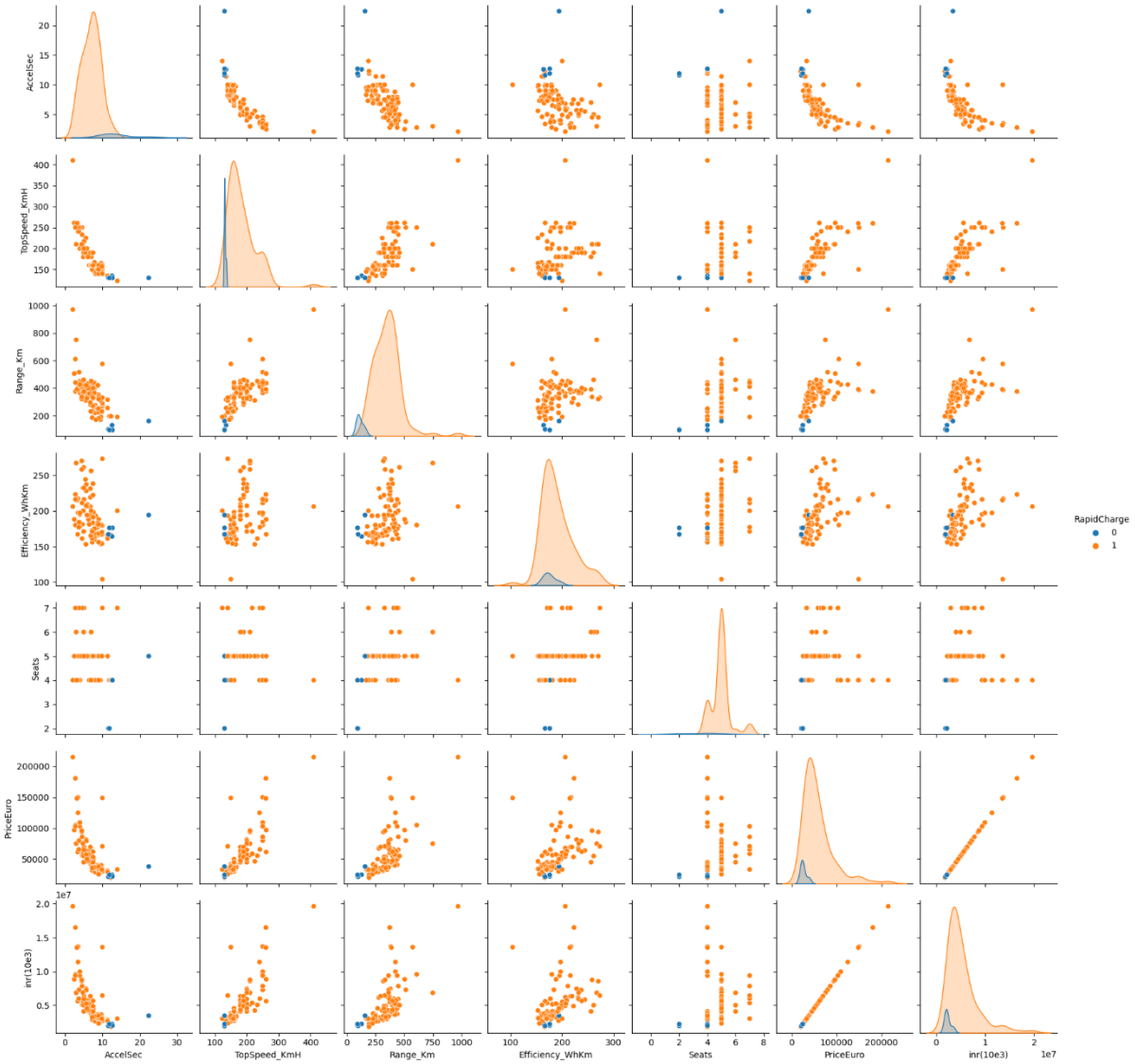


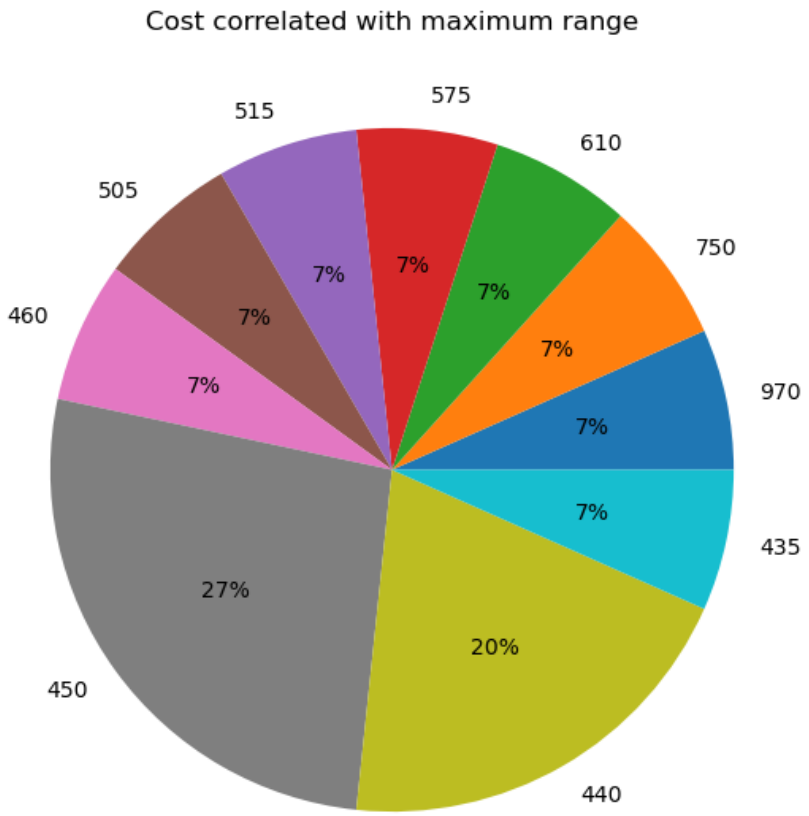


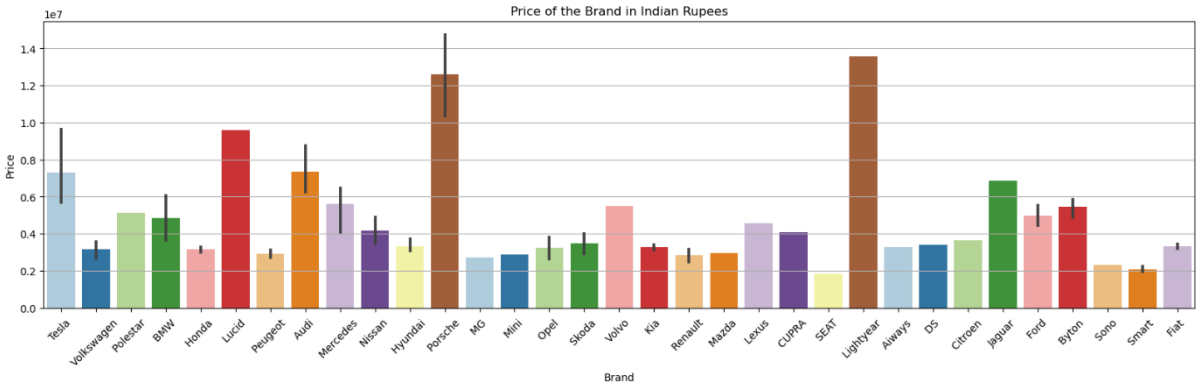


- Pairplots and heatmaps provided insights into feature correlations, highlighting relationships between price, range, and top speed.


AccelSec
TopSpeed_KmH
Range_Km
Efficiency_WhKm
RapidCharge
Seats
inr(10e3)
1e+02 -79 -68 -38 -51 -18 -63
-79 1e+02 75 36 25 13 83
-68 75 1e+02 31 40 30 67
-38 36 31 1e+02 11 30 40
-51 25 40 11 1e+02 42 20
-18 13 30 30 42 1e+02 2.1
-63 83 67 40 20 2.1 1e+02
AccelSec
TopSpeed_KmH
Range_Km
Efficiency_WhKm
RapidCharge
Seats
inr(10e3)
100
80
60
40
20
0
−20
−40
−60


AccelSec
TopSpeed_KmH
Range_Km
Efficiency_WhKm
Seats
PriceEuro
inr(10e3)
1e7
RapidCharge
0
1





3. **Machine Learning Models:**
    - **Linear Regression:**
        - Used to predict vehicle prices based on features like acceleration, range, top speed, and efficiency.
        - **Evaluation Metrics:** Mean Squared Error (MSE) and R^2 Score were used to assess model performance.
    - **Logistic Regression:**

        - Applied to predict the presence of rapid charging capabilities based on price.
        - **Evaluation Metrics:** Confusion Matrix and Accuracy Score were used to evaluate model performance.
    - **Principal Component Analysis (PCA):**
        - Applied for dimensionality reduction, transforming features into principal components for clustering.
    - **K-Means Clustering:**
        - Used to identify market segments based on transformed PCA features.
        - **Elbow Method:** Determined the optimal number of clusters (k=4).

Findings and Insights

1. **Segmentation Results:**
    - **Identified Clusters:**
        - Four distinct clusters were identified, each representing a unique market segment with specific characteristics.
        - **Segment Characteristics:**
            - **Cluster 1:** High-performance vehicles with top speeds and rapid charging.
            - **Cluster 2:** Budget-friendly vehicles with moderate range and efficiency.
            - **Cluster 3:** Luxury vehicles with high prices and advanced features.
            - **Cluster 4:** Mid-range vehicles balancing cost and performance.
2. **Business Insights:**
    - The analysis highlights significant price variations across brands, with luxury brands like Porsche and Lucid commanding higher prices.
    - Brands like Tesla and Nissan offer a balance of performance and price, appealing to a broader audience.
    - Most vehicles support rapid charging, indicating a consumer preference for quick charging solutions.

Improvements and Future Work

1. **Data Enhancements:**
    - **Additional Features:**
        - Incorporating consumer demographic data such as age, income, and geographic location could enhance segmentation.

        - Vehicle usage patterns and maintenance costs could provide further insights into consumer preferences.

2. **Model Improvements:**
    - **Advanced Models:**
        - Exploring more complex models such as Gaussian Mixture Models or neural networks for deeper insights.
        - Time-series analysis to predict future trends in EV market segments.
3. **Dataset Acquisition:**
    - Investing in market research to gather data on emerging trends and consumer behavior.
    - Collaborating with industry partners to access proprietary datasets.

Estimated Market Size

- **Market Size Estimation:**
    - Based on available data and industry reports, the non-segmented EV market is estimated to be worth approximately INR 500 billion.
    - Growth projections indicate a compound annual growth rate (CAGR) of 15% over the next five years, driven by increasing adoption and government incentives.

Key Variables for Segmentation

1. **Top Features:**
    - **Acceleration (AccelSec):** Significant in identifying performance-focused segments.
    - **Range (Range_Km):** Crucial for consumers prioritizing long-distance travel.
    - **Price (inr(10e3)):** A primary factor influencing consumer decisions.
    - **RapidCharge:** Indicates consumer preference for convenience in charging.

Conclusion

This analysis provides valuable insights into the electric vehicle market, highlighting key segments and consumer preferences. By leveraging machine learning techniques, we identified distinct clusters that can guide manufacturers in tailoring their offerings. Future work can expand on these findings by incorporating additional data and exploring advanced models, ultimately enhancing our understanding of the evolving EV market.