EV MARKET SEGMENATION

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Performing EV Sales Analysis for the Indian EV Market based on historical data from IEA Global EV Outlook 2024 dataset.

Problem Statement

To analyze the Indian EV market based on vehicle type and powertrain, we will employ segmentation analysis. Segmentation analysis involves dividing a market into distinct groups based on specific criteria to better understand consumer behavior, preferences, and market trends. In this case, we will focus on three vehicle types (bus, van, car) and three powertrain types (BEV - Battery Electric Vehicle, FCEV - Fuel Cell Electric Vehicle, PHEV - Plug-in Hybrid Electric Vehicle).

Powertrain segments

Battery Electric Vehicles (BEVs)

BEVs are also known as All-Electric Vehicles (AEV). Electric Vehicles using BEV technology run entirely on a battery-powered electric drivetrain. The electricity used to drive the vehicle is stored in a large battery pack which can be charged by plugging into the electricity grid. The charged battery pack then provides power to one or more electric motors to run the electric car.

Main Components of BEV

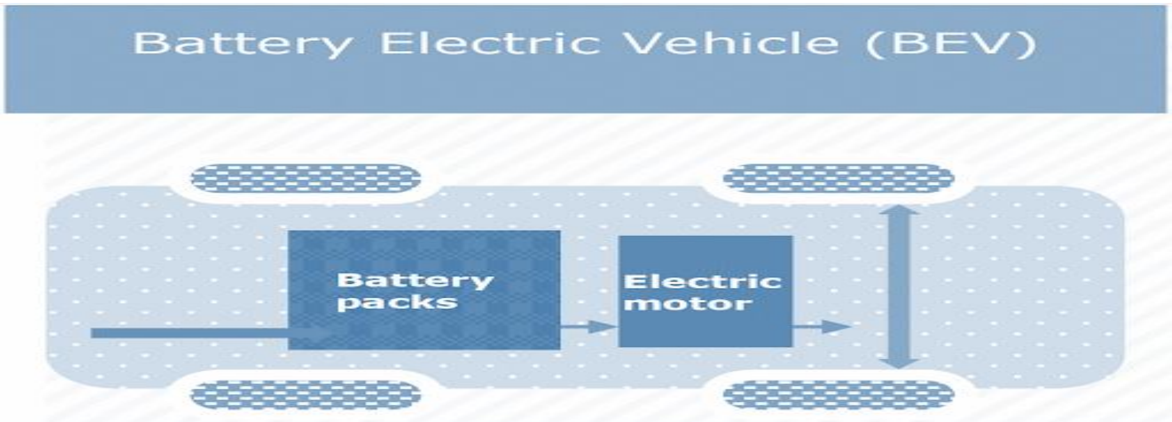
Electric motor, Inverter, Battery, Control Module, Drive train.

Working Principles of BEV

The power for the electric motor is converted from the DC Battery to AC. As the accelerator is pressed, a signal is sent to the controller. The controller adjusts the speed of the vehicle by changing the frequency of the AC power from the inverter to the motor. The motor then connects and leads to the turning of wheels through a cog. If the brakes are pressed, or the electric car is decelerating, the motor becomes an alternator and produces power, which is sent back to the battery

Examples of BEV

MG ZS, TATA Nexon, TATA Tigor, Mahindra E20 plus, Hyundai Kona, Mahindra Verito.



Plug-in Hybrid Electric Vehicle (PHEV)

The PHEVs are also known as series hybrids. They have both engine and a motor. You can choose among the fuels, conventional fuel (such as petrol) or alternative fuel (such as bio-diesel). It can also be powered by a rechargeable battery pack. The battery can be charged externally.

PHEVs can run in at least 2 modes:

- All-electric Mode, in which the motor and battery provide all the car’s energy.
- Hybrid Mode, in which both electricity and petrol/diesel are employed.

Main Components of PHEV

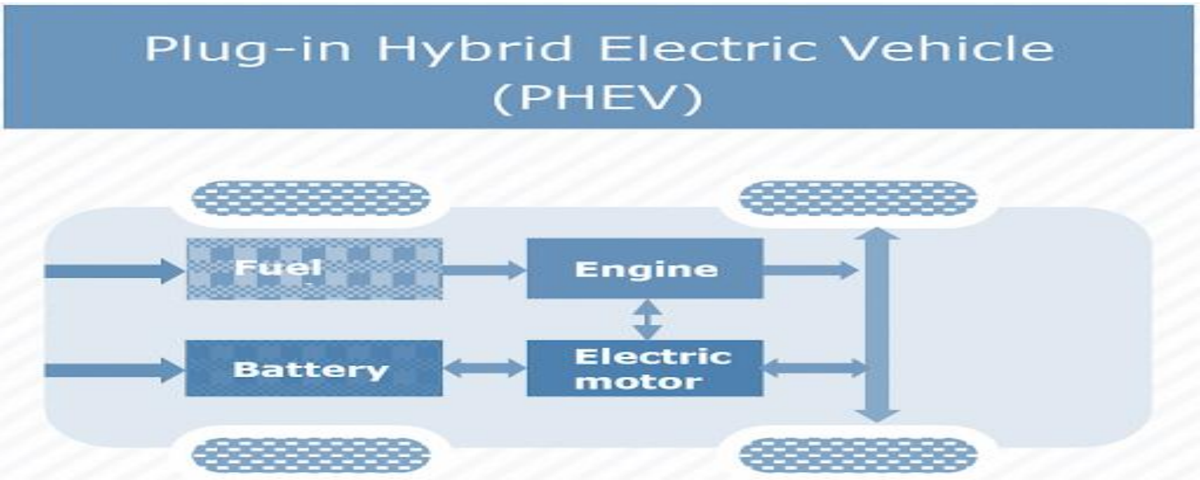
Electric motor, Engine, Inverter, Battery, Fuel tank, Control module, Battery Charger (if onboard model)

Working Principles of PHEV

PHEVs start-up in all-electric mode and make use of electricity until their battery pack is depleted. Once the battery gets drained, the engine takes over, and the vehicle operates as a conventional, non-plug-in hybrid. PHEVs can be charged by plugging into an outside electric power source, engine, or regenerative braking. When brakes are applied, the electric motor acts as a generator, using the energy to charge the battery. The engine’s power is supplemented by the electric motor; as a result, smaller engines can be used, increasing the car’s fuel efficiency without compromising performance.

Examples of PHEV

Porsche Cayenne S E-Hybrid, BMW 330e, Porsche Panamera S E-hybrid, Chevy Volt, Chrysler Pacifica, Ford C-Max Energi, Mercedes C350e, Mercedes S550e, Mercedes GLE550e, Mini Cooper SE Countryman, Ford Fusion Energi, Audi A3 E-Tron, BMW i8, BMW X5 xdrive40e, Fiat 500e, Hyundai Sonata, Kia Optima, Volvo XC90 T8.



Fuel Cell Electric Vehicle (FCEV)

FCEVs are also known as Zero-Emission Vehicles. They employ ‘fuel cell technology’ to generate the electricity required to run the vehicle. The chemical energy of the fuel is converted directly into electric energy.

Main Components of FCEV

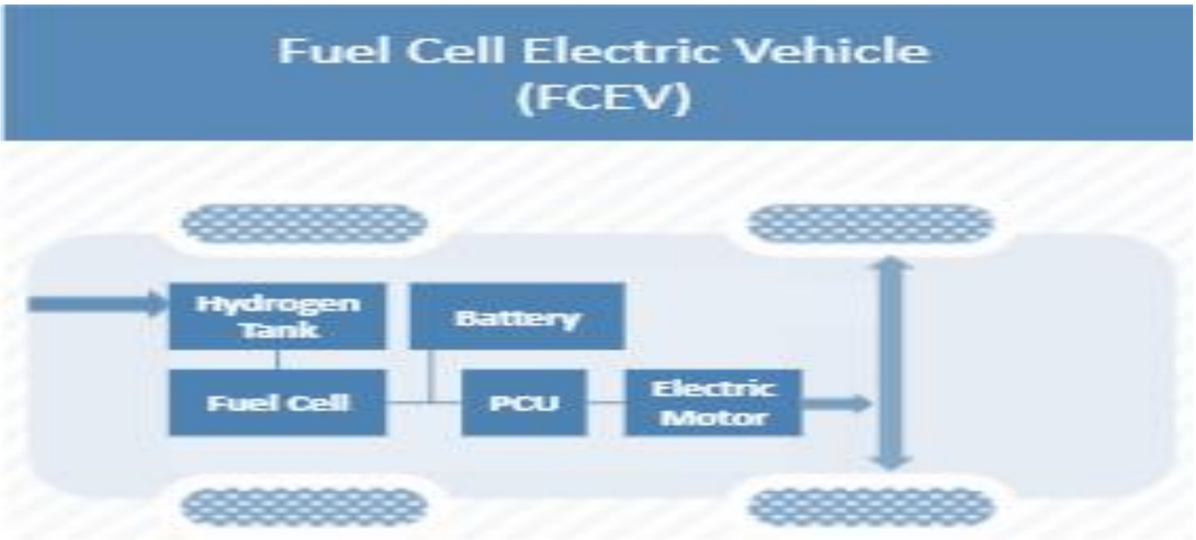
Electric motor, Fuel-cell stack, Hydrogen storage tank, battery with converter and controller.

Working Principles of FCEV

The FCEV generates the electricity required to run this vehicle on the vehicle itself.

Examples of FCEV

Toyota Mirai, Riversimple Rasa, Hyundai Tucson FCEV, Honda Clarity Fuel Cell, Hyundai Nexo.



Market Overview

The Indian electric vehicle market size was valued at USD 220.1 million in 2020 and is expected to grow at a compound annual growth rate (CAGR) of 94.4% from 2021 to 2030. The attractive incentives being offered by the Indian government on the production and purchase of electric vehicles to encourage the adoption of electric vehicles are anticipated to drive the growth of the market over the forecast period. The outbreak of the COVID-19 pandemic triggered a significant decline in the overall sales of passenger and commercial vehicles in 2020. However, the sales of electric vehicles in India remained unaffected. The post-lockdown sale of pure and hybrid electric vehicles is a prominent driving factor for the electric vehicle market in India. The stringent GreenHouse gas (GHG) emission norms drafted by the government, such as the Bharat Stage (BS) VI emission standards introduced by India’s Ministry of Road Transport and Highways (MoRTH), are also expected to play a decisive role in driving the growth of the market.

The increasing prices of conventional fuel are expected to accentuate the development of vehicle electrification. The stringent emission norms being drafted by the government and the growing environmental awareness among Indian consumers are also expected to fuel the demand for electric vehicles. Furthermore, Indian automakers, such as Tata Motors, and Mahindra and Mahindra Ltd., have embarked upon aggressive efforts to add electrified vehicles to their product portfolio, which is expected to encourage Indian consumers to opt for electric vehicles. All these factors bode well for the growth of the electric vehicle market in India over the forecast period.

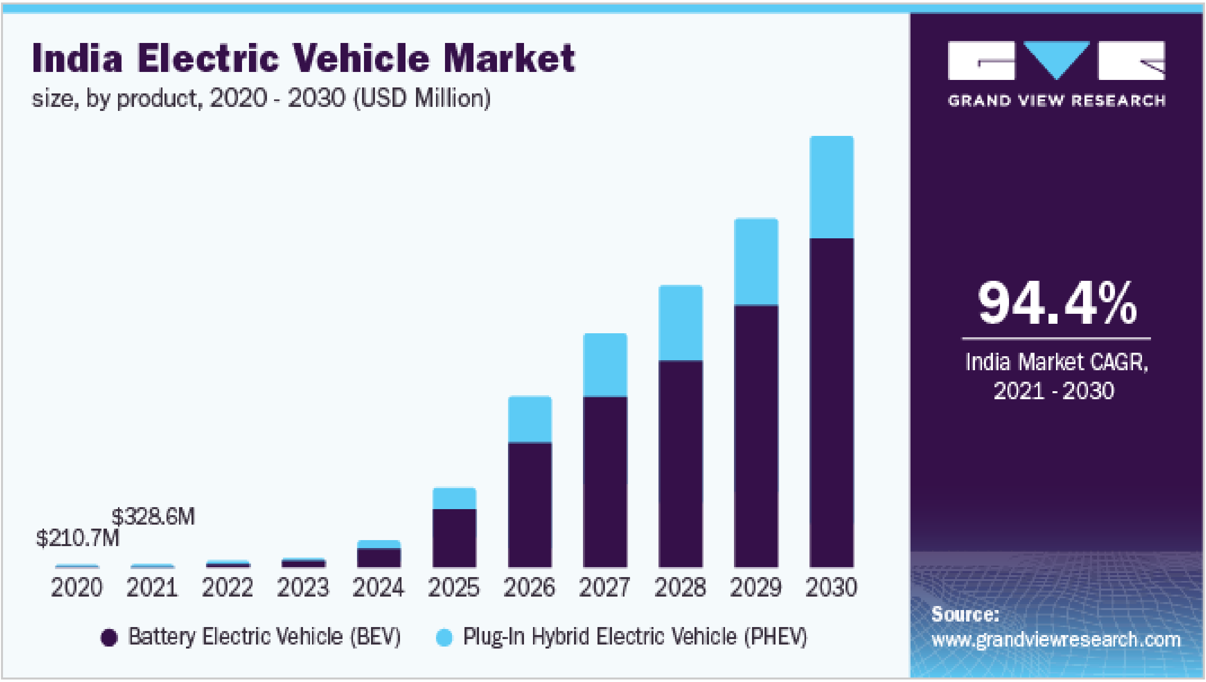
The EV market in India comprised only two electric vehicle models in 2019. As a result, only 0.15% of the new passenger cars registered between April 2019 and March 2020 were BEVs. However, at the beginning of 2021, the India electric vehicle (EV) market consisted of around eight electric vehicle models, thereby offering more options for Indian consumers looking forward to buying electric vehicles. Moreover, the prices of electric vehicles are also expected to decline over the forecast period, thereby allowing EVs to provide a lower Total Cost of Ownership (TCO) as compared to conventional vehicles. This is expected to pave the way for the mass-market penetration of electric vehicles.

India has been recognized as one of the prominent regions in the automotive industry globally. Several companies are aggressively establishing manufacturing facilities in India. For instance, in September 2020, Dana TM4 Inc. announced plans to establish a manufacturing facility in Pune, India. The new 4,600 square-meter facility would produce Dana TM4 low- to high-voltage inverters, electric motors, and vehicle control units. Meanwhile, the Phase-II of the Indian government's Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme envisages further enhancing the adoption of electric mobility and the development of its manufacturing eco-system. Phase-II of the FAME scheme would be implemented through the following verticals, namely incentivizing the demand for EVs; running awareness campaigns, including publicity, and information, education & communication (IEC) activities; and establishing a charging station network.

The outbreak of the COVID-19 pandemic changed the overall business dynamics in 2020 and is anticipated to affect the overall business scenario over the next few years. Lockdowns imposed in different parts of the world as part of the efforts to arrest the spread of coronavirus resulted in supply chains disruptions. Production was also suspended at numerous production facilities as part of the lockdowns. As a result, shipments were delayed and production volumes plummeted, thereby severely affecting automotive production. Manufacturers of electric vehicles continued to confront issues with supplies of raw materials owing to the looming delays in international shipments and hence, reported production delays. Nevertheless, although the pandemic triggered a significant decline in the overall sales of passenger and commercial vehicles, the sales of electric cars in India remained unaffected. According to the Society of Manufacturers of Electric Vehicles (SMEV), the sales of electric cars in India increased over the year by 109% from 2,814 units in 2019 to 5,905 units in 2020. The majority of over 64% of the sales came from the Tata Nexon EV, with a total of 3,805 units sold in 2020.

The BEV segment accounted for the largest revenue share of around 96% of the overall market in 2020. The dominating market share of the segment can be attributable to the increasing preference of consumers towards EVs over ICE vehicles and restrictions on vehicular CO2 emissions. BEVs can help significantly in cutting down vehicular emissions and reducing the total cost of ownership in the long run. Advances in battery technology and the plummeting lithium-ion battery prices are also expected to drive the demand for BEVs over the forecast period.

The PHEV segment is projected to expand at a CAGR of over 105% over the forecast period. Plug-in Hybrid Electric Vehicles (PHEVs) are designed to enhance the use of the internal combustion engine in interaction with a low-range, High Voltage (HV) battery system. PHEVs have a more powerful electric motor and a significantly larger battery that can be recharged not only with the help of an external source of power but also using the ICE and regenerative braking. Hence, PHEVs offer a flexible and convenient mobility option for consumers.



Data Sources

The Global EV Outlook is an annual publication that identifies and discusses recent developments in electric mobility across the globe. It is developed with the support of the members of the Electric Vehicles Initiative (EVI).

Source :

https://www.iea.org/data-and-statistics/data-product/global-ev-outlook-2024#global-ev-data

Data Pre-processing

Code

```
import pandas as pd

import numpy as np

# Load the dataset

data = pd.read_csv('/kaggle/input/evsegm/IEA Global EV Data Clean 2024.csv')

# Check the first few rows and column data types

print(data.head())

print(data.info())

# Drop unnecessary columns
```

```
data = data[['mode', 'powertrain', 'year', 'value']]

# Convert columns to appropriate types

data['year'] = pd.to_numeric(data['year'], errors='coerce')

data['value'] = pd.to_numeric(data['value'], errors='coerce')

# Handle missing values if any

data.dropna(inplace=True)

# Encode categorical variables

data_encoded = pd.get_dummies(data, columns=['mode', 'powertrain'])

print(data_encoded.head())
```

Steps

Data pre processing steps are performed using the pandas and numpy libraries in Python.

The dataset is loaded using the pd.read_csv() function from the pandas library. The dataset is stored in the data variable.

The head() and info() functions are used to display the first few rows of the dataset and provide information about the dataset, such as column names and data types.

The code snippet selects only the columns 'mode', 'powertrain', 'year', and 'value' from the dataset, discarding any unnecessary columns.

The 'year' and 'value' columns are converted to numeric data types using the pd.to_numeric() function. The errors='coerce' parameter handles any conversion errors by replacing them with NaN values.

Any rows with missing values are removed from the dataset using the dropna() function with inplace=True.

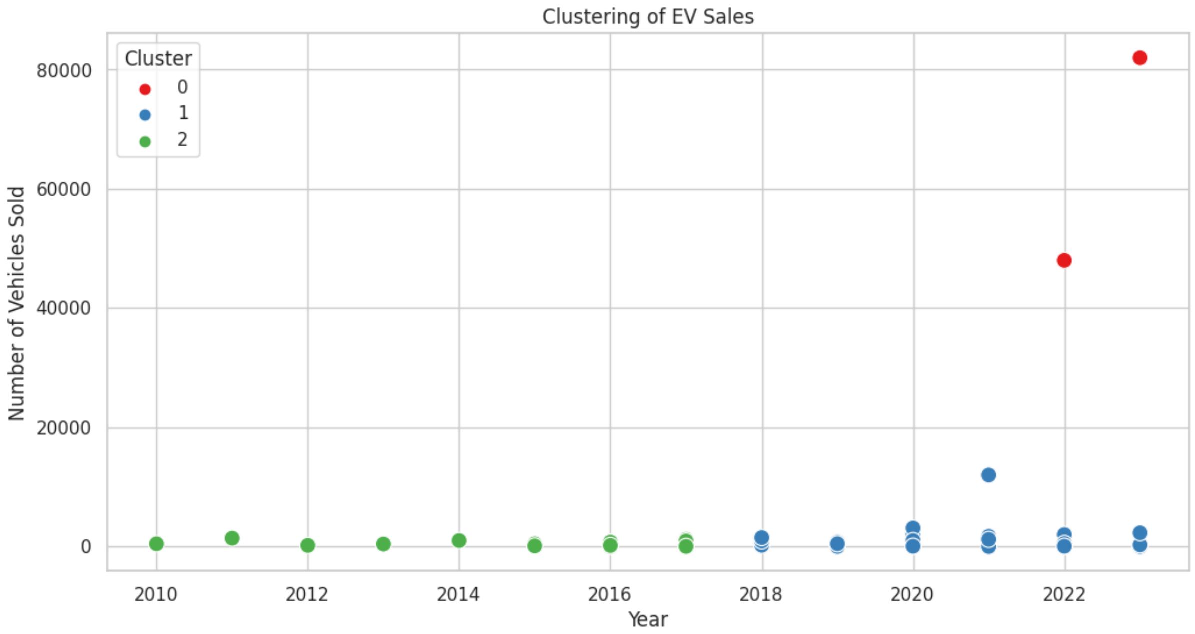
Categorical variables in the 'mode' and 'powertrain' columns are encoded using one-hot encoding with the pd.get_dummies() function. This process creates binary columns for each category, making them suitable for machine learning algorithms.

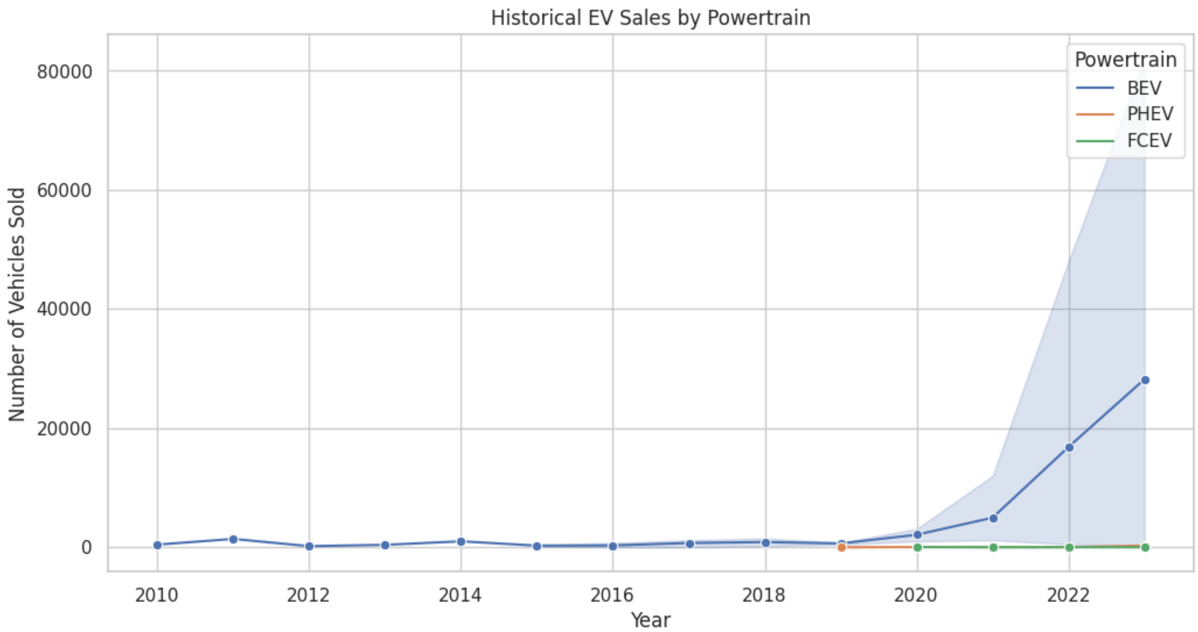
The pandas library is primarily used for data manipulation and pre-processing tasks, while the numpy library may be indirectly utilized by pandas for numerical operations.

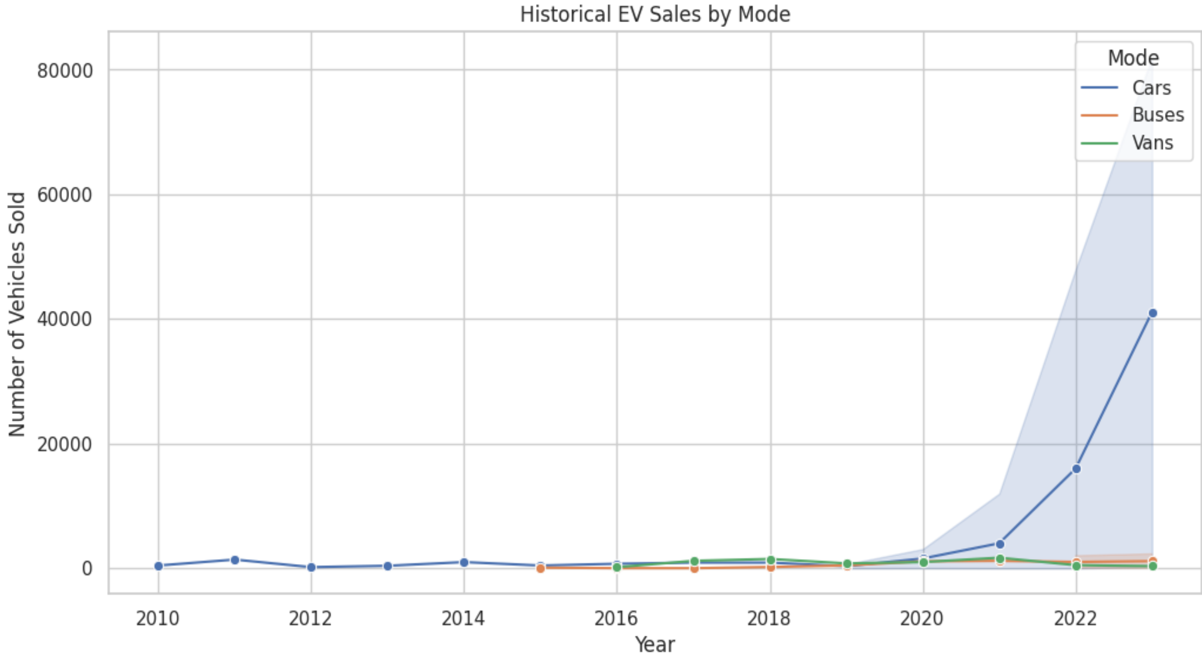
Segment Extraction

The features selected for clustering are 'year' and 'value' from the 'data_encoded' dataset. These features are crucial for identifying patterns and grouping data points based on their values.

The StandardScaler from sklearn.preprocessing is used to standardize the features by removing the mean and scaling to unit variance. This step is essential for ensuring that all features contribute equally to the clustering process, preventing any particular feature from dominating the analysis due to its scale. K-Means is a popular unsupervised machine learning algorithm used for clustering data points into distinct groups based on similarity. The KMeans algorithm is initialized with n_clusters=3, indicating the number of clusters to form. The random_state=42 parameter ensures reproducibility of results. The fit_predict method is used to fit the model to the scaled features and predict the cluster labels for each data point.







Profiling Potential Segments

The following segments were extracted:

Cars – BEV

Cars – PHEV

Cars – FCEV

Buses – BEV

Buses – PHEV

Buses – FCEV

Vans – BEV

Vans – PHEV

Vans – FCEV

Most Optimal Market Segment

Performed hyperparameter tuning for the Random Forest Regressor model using GridSearchCV to find the best combination of parameters for optimal performance. It prints the best parameters found and the best model obtained after tuning. Subsequently, it evaluates the Random Forest model using cross-validation and calculates the Mean Absolute Error (MAE) as a performance metric.

Conducted hyperparameter tuning for the Gradient Boosting Regressor model to identify the best parameters and model. It prints the best parameters and evaluates the model using cross-validation to determine the MAE.

After evaluating both models, we select the best model based on the cross-validated MAE score and then make predictions on the test set using the selected model and calculate the Mean Absolute Error on the test set.

```
Random Forest Cross-Validated MAE: 5556.628466316939
Gradient Boosting Cross-Validated MAE: 5039.490465758342
Using Gradient Boosting Model for Predictions
Mean Absolute Error on Test Set: 6936.071760306829
```

To predict future sales, we prepare future data by creating combinations of years, modes, and powertrains. We encode the future data, apply feature scaling, and predict future sales using the best model selected earlier. Finally, we display the predicted sales for different combinations of future data.

	year	mode	powertrain	predicted_sales
0	2025	Cars	BEV	50532.684804
1	2025	Cars	PHEV	38473.185471
2	2025	Cars	FCEV	37408.243253
3	2025	Buses	BEV	9061.606655
4	2025	Buses	PHEV	6960.298932
5	2025	Buses	FCEV	5646.488273
6	2025	Vans	BEV	4907.569107
7	2025	Vans	PHEV	2526.165048
8	2025	Vans	FCEV	1212.150734

Conclusions

The most optimal four wheeler EV powertrain market segment in India based on the analysis is Cars BEV.

The least optimal four wheeler EV powertrain market segment in India based on the analysis is Vans FCEV.

Github

https://github.com/v1az/Indian-EV-Sales-Analysis.git