# Electric Vehicle Market in India: An In-depth Analysis

Market Segmentation

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*Electric cars are not going to take the market by storm, but it's going to be a gradual improvement.* **- Carlos Ghosn**

## Abstract

The auto industry within India, as a country, has been undergoing remarkable changes while electric vehicles (EVs) signify the shattering of this development. Not only is this transition a consequence of environmental concerns but also due to governmental incentives, increased prices for fuels and urge from society towards sustainables alternatives.

The use of oil and gas in large portions by the country means that switching over to electric mobility will be a vital move in reducing carbon emissions significantly. The only remaining question therefore becomes; how can a fledgling EV company direct its efforts so as to achieve maximum growth and profitability?

In my research report about India's electric vehicle sector development, I examined sales trends, revenue streams, spatial segregation etc. My intention with this paper was provision for clear course of action which could steer a fresh EV startup into the more lucrative segments within India.

In all through this dissertation I have focused on what they are doing right when it comes to types of cars sold out there as well as modeling their purchase places and determining who is buying them most. Therefore these findings may serve as valuable information for any new entrant who wants make it big in this ever-changing industry.

The interpretation of the increased penetration of electric vehicles in India does not require any emphasis. Over just the last few years, it has been easy to notice an upsurge in both consumer and government interest. Given the high levels of pollution in many big cities and with the government actively encouraging measures to reduce oil consumption, there are all the reasons to believe that there will be a monumental shift to electric mobility.

Despite this positive positioning, this does not mean all segments of the EV market are well poised for growth. While motorcycles have recorded the highest increase in the number of units sold, the amount of revenue generated through their sales is nothing by the sales of cars.

Hence, further examination is required to identify the focus of the growth potential that is especially important for the young organization eager to increase revenue, profit and achieve growth stability. This is the question the report specifically addresses with the help of dependable data and strategic analysis providing specific recommendations concerning the target market of Indian consumers.

## Data Collections

The first key part of this data analysis was collecting the data. I collected data sets from several trusted sources platforms such as Kaggle, data. in and other public data repositories. They together form the foundational datasets feeding into the analysis relating to vehicle types, sales volumes, revenues, EV registrations across states and demographies presented in this Report.

The credibility of data had to be ensured at all costs since it would directly impact the validity of the extracted insights. I then used some Data Preprocessing techniques to clean & prepare the data for any further analysis which would eliminate all kinds of discrepancies within the datasets. Attended to missing values, outliers and anomalies by standardizing wherever applicable.

This involved creating consistency around state names, fixing numerical data (e.g. revenue and sales figures), and demographic variables (e.g. geography) between the datasets. However, in a nation as vast and varied as India, analysing the EV market requires an over-the-top look at the data. Anyway, after the clean-up process I successfully merged and integrated these datasets to build a single analytical framework for analysis.

This yielded a complete portrait of the electric vehicle market, which incorporated sales trends, geo patterns and also customer characteristics. Two-wheeler and 4-wheeler EV data was collected and the collated information allowed for good comparison between the two categories. The dataset also mentioned details of state-wise EV registrations and the charging infrastructure available in various regions. Possessing this data allowed for me to conduct the extensive segmentation and analysis required to shepherd a fresh startup into the Indian EV market.

The data has been collected manually, the sources used are listed chronologically below:

https://www.iea.org/
https://www.statista.com/
https://www.autopunditz.com/
https://www.kaggle.com/
https://vahan.parivahan.gov.in/ (https://cleanmobilityshift.com/)

## Market Segmentation

### Target Market:

The target market of Electric Vehicle Market Segmentation can be categorized into Geographic, SocioDemographic, Behavioral, and Psychographic Segmentation.

**Geographic segmentation**: Searches directly for similarities in geographical reported behavior. Example: prior sales with a similar product, accommodations required for the product building

### Advantages:

- **Increase profits:** As geographic segmentation allows you to target specific audiences and deliver tailored marketing campaigns, you can generate profits faster while saving time and money.
- **Drive growth:** By targeting the right people, you can increase sales and drive business growth. Ensure you revisit your geographic segmentation regularly — especially when entering new markets or advertising new products — to get the best value from your campaigns.
- **Focus efforts:** Geographic segmentation allows you to target location-specific keywords and demands. This is incredibly useful if you're operating with a smaller budget or want to develop awareness in a particular region.
- **Improve communication:** Every region has different needs, shopping habits and ways of doing business. Geographic segmentation takes into consideration the way people communicate within regions and communities. With this kind of insight, you can move forward with confidence and ensure a high engagement rate from the start.

### Disadvantages:

- **Limited reach:** Geographic segmentation may not reach all audiences.
- **Increased marketing costs:** Geographic segmentation may increase marketing costs.
- **Reduced brand consistency:** Geographic segmentation may reduce brand consistency.
- **Overlooks cultural preferences:** Geographic segmentation may overlook cultural preferences and the complexity of consumer behavior.

## Segmenting for the Electric Vehicle Market

The market segmentation approach aims at defining actionable, manageable, homogenous subgroups of individual customers to whom the marketers can target with a similar set of marketing strategies.

### EV Type:

We need to know which EV category and type startup should focus as a Startup does'nt have much funds for big segment. So generally a startup should focus on a paricluar Vehicle type and its category.

### Geographic Location:

This variable can impact geographic segmentation by covering a small area, like a neighbourhood, or a large area like a continent, with towns, cities, states and countries in between.

## Implementation

### Packages/Tools used:

1. 1. Numpy: To calculate various calculations related to arrays.
2. 2. Pandas: To read or load the datasets.
3. 3. SKLearn: We have used LabelEncoder() to encode our values.

## Data-Preprocessing

### Data Cleaning:

The data collected is compact and is partly used for visualization purposes and partly for clustering. Python libraries such as NumPy, Pandas, and Scikit-Learn are used for the workflow, and the results obtained are ensured to be reproducible.

```
[88] import pandas as pd
     import numpy as np
     import matplotlib.pyplot as plt
     import seaborn as sns
     import plotly.express as px
```

```
[115] parivahar_dashboard_data = pd.read_csv("EV-Dashboard-Data-as-on-20240202.csv")
      parivahar_dashboard_data.head()
```

| | Year | Month_name | Day | Date | State | Vehicle Class | Vehicle Category | Vehicle Type | CNG ONLY | DIESEL | ... | METHANOL | NOT APPLICABLE | PETROL | PETROL/CNG | PETROL/ETHANOL | PETROL/HYBRID | PETROL/LPG | PETROL/METHANOL | SOLAR | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 2022 | feb | 1 | 2022-02-01 | Andaman & Nicobar Island | GOODS CARRIER | Others | Others | 0 | 15 | ... | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| 1 | 2022 | feb | 1 | 2022-02-01 | Andaman & Nicobar Island | MAXI CAB | Others | Others | 0 | 1 | ... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 2 | 2022 | feb | 1 | 2022-02-01 | Andaman & Nicobar Island | M-CYCLE/SCOOTER | 2-Wheelers | 2W_Personal | 0 | 0 | ... | 0 | 0 | 326 | 0 | 0 | 0 | 0 | 0 | 0 | 326 |
| 3 | 2022 | feb | 1 | 2022-02-01 | Andaman & Nicobar Island | MOPED | 2-Wheelers | 2W_Personal | 0 | 0 | ... | 0 | 0 | 61 | 0 | 0 | 0 | 0 | 0 | 0 | 61 |
| 4 | 2022 | feb | 1 | 2022-02-01 | Andaman & Nicobar Island | MOTOR CAB | 4-Wheelers | 4W_Shared | 0 | 0 | ... | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

5 rows × 30 columns

```
[116] parivahar_dashboard_data.columns
```

```
Index(['Year', 'Month_name', 'Day', 'Date', 'State', 'Vehicle Class',
       'Vehicle Category', 'Vehicle Type', 'CNG ONLY', 'DIESEL',
       'DIESEL/HYBRID', 'DI-METHYL ETHER', 'DUAL DIESEL/BIO CNG',
       'DUAL DIESEL/CNG', 'DUAL DIESEL/LNG', 'ELECTRIC(BOV)', 'ETHANOL',
       'FUEL CELL HYDROGEN', 'LNG', 'LPG ONLY', 'METHANOL', 'NOT APPLICABLE',
       'PETROL', 'PETROL/CNG', 'PETROL/ETHANOL', 'PETROL/HYBRID', 'PETROL/LPG',
       'PETROL/METHANOL', 'SOLAR', 'Total'],
      dtype='object')
```

```
ev_type_sales = pd.read_csv("IEA-EV-dataEV_salesHistoricalCars.csv")
ev_type_sales.sample(5)
```

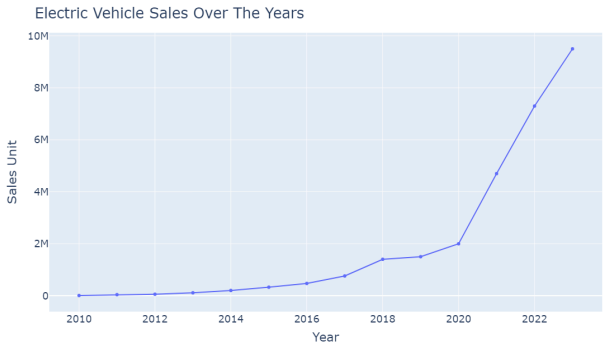
| | region | category | parameter | mode | powertrain | year | unit | value |
|---|---|---|---|---|---|---|---|---|
| 973 | EU27 | Historical | EV sales share | Cars | EV | 2017 | percent | 1.30 |
| 407 | Canada | Historical | EV sales | Cars | BEV | 2015 | Vehicles | 4400.00 |
| 819 | Denmark | Historical | EV stock | Cars | PHEV | 2015 | Vehicles | 570.00 |
| 1851 | Israel | Historical | EV sales | Cars | PHEV | 2020 | Vehicles | 5400.00 |
| 2846 | Rest of the world | Historical | EV sales share | Cars | EV | 2021 | percent | 0.28 |

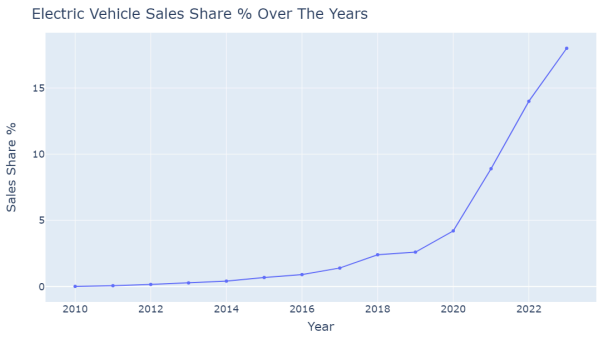
## EDA

We start the Exploratory Data Analysis with some data Analysis drawn from the data without Principal Component Analysis and with some Principal Component Analysis in the dataset obtained from the combination of all the data we have.

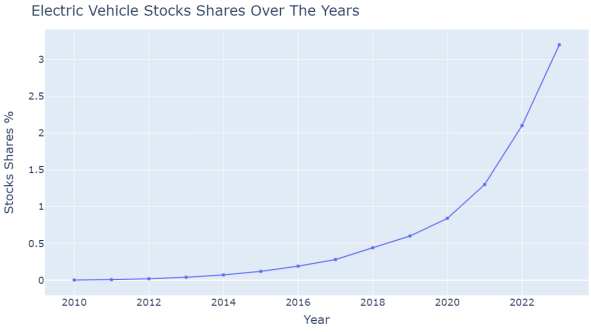
PCA is a statistical process that converts the observations of correlated features into a set of linearly uncorrelated features with the help of orthogonal transformation. These new transformed features are called the Principal Components. The process helps in reducing dimensions of the data to make the process of classification/regression or any form of machine learning, cost-effective.

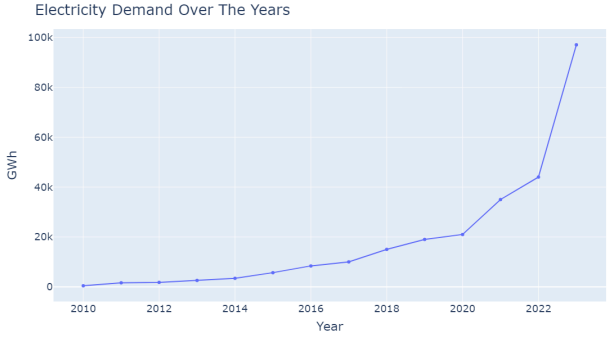
## EV Market Trends Across World:

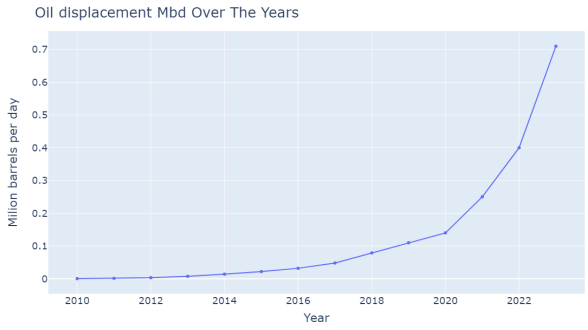






## EV sales share

- The global EV sales share has been increasing exponentially in recent years. In 2022, EVs accounted for 14% of global car sales, up from 4% in 2020.
- This growth is being driven by a number of factors, including government incentives, declining battery prices, and increasing consumer awareness of the environmental benefits of EVs.
- The IEA projects that the global EV sales share will reach 30% by 2030.

## EV stock

- The global EV stock (the number of EVs in operation) has also been increasing exponentially in recent years.
- In 2022, there were over 100 million EVs in operation worldwide, up from just 1 million in 2010. This growth is being driven by the same factors that are driving EV sales growth.
- The IEA projects that the global EV stock will reach 250 million by 2030.

## EV sales

- The global EV sales have been increasing exponentially in recent years. In 2022, there were over 10 million EVs sold worldwide, up from just 2 million in 2020.
- This growth is being driven by the same factors that are driving EV sales share and EV stock growth.
- The IEA projects that the global EV sales will reach 20 million by 2030.

## Oil displacement Mbd

- Oil displacement Mbd (million barrels per day) is the amount of oil that is displaced by EVs.
- In 2022, EVs displaced 1.5 million barrels of oil per day. This is equivalent to about 3% of global oil demand.
- The IEA projects that EV oil displacement will reach 5 million barrels per day by 2030.

## Oil displacement, million lge

- Oil displacement, million lge (million liters of gasoline equivalent) is the amount of gasoline that is displaced by EVs.
- In 2022, EVs displaced 20 million liters of gasoline per day.
- This is equivalent to about 5% of global gasoline demand.
- The IEA projects that EV oil displacement will reach 100 million liters of gasoline per day by 2030.

## EV stock share

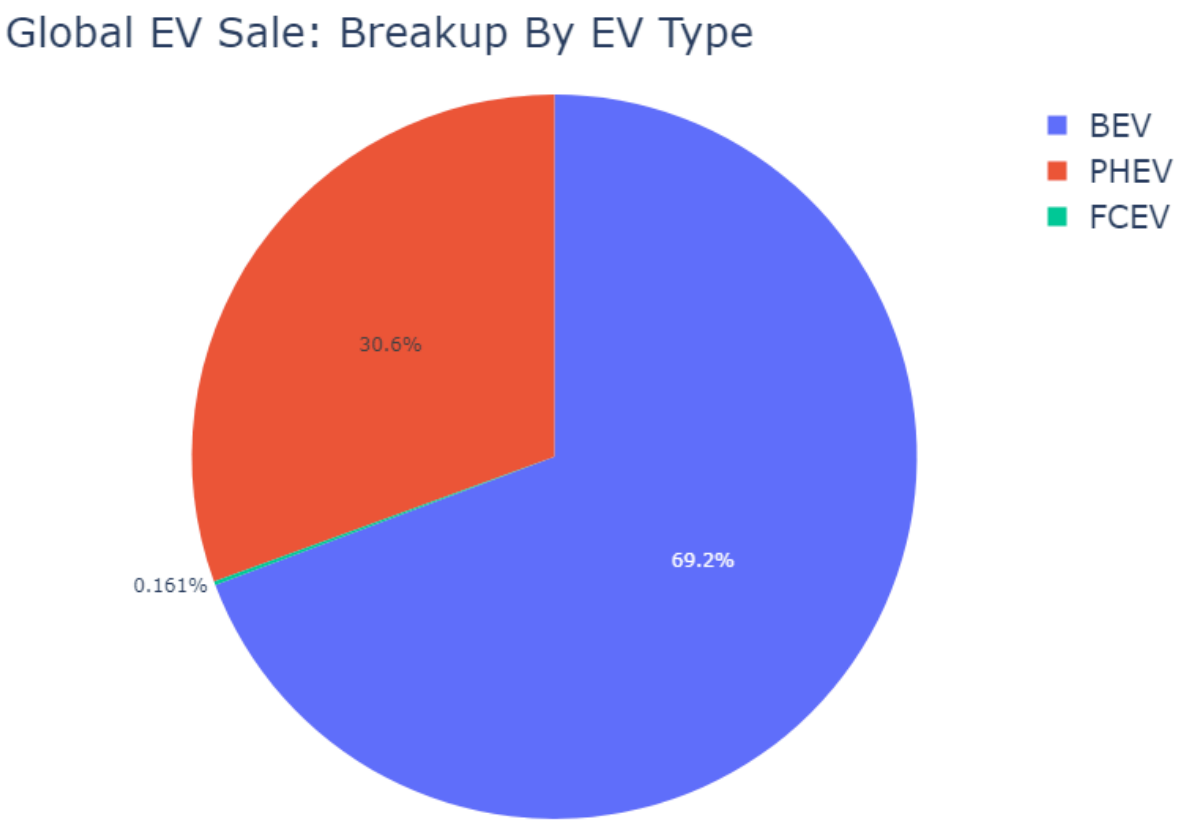
- The EV stock share is the percentage of the total vehicle stock that is made up of EVs.
- In 2022, the EV stock share was about 3%.
- This is expected to icrease to 10% by 2030.

## Electricity demand

- The increase in EV sales and stock is putting a strain on the electricity grid.
- In order to meet the growing demand for electricity from EVs, the grid will need to be upgraded and expanded.
- This is a challenge, but it is one that can be overcome.

**Overall, the data shows that the adoption of EVs is growing rapidly. This is good news for the environment, as EVs help to reduce air pollution and our dependence on oil.**

**How much does EV Type vary across the World:**




**PHEV**: Plug-in hybrid

**BEV**: Battery Electric Vehicle

The above graph shows the sales of plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) from 2015 to 2022. As you can see, the sales of BEVs have been increasing exponentially over the past few years, while the sales of PHEVs have been decreasing.

There are a few reasons for this trend. First, BEVs are becoming more affordable. The cost of batteries has been declining, and governments are offering incentives to purchase BEVs. Second, BEVs are becoming more capable. They have longer ranges and faster charging times. Third, consumers are becoming more aware of the environmental benefits of BEVs.

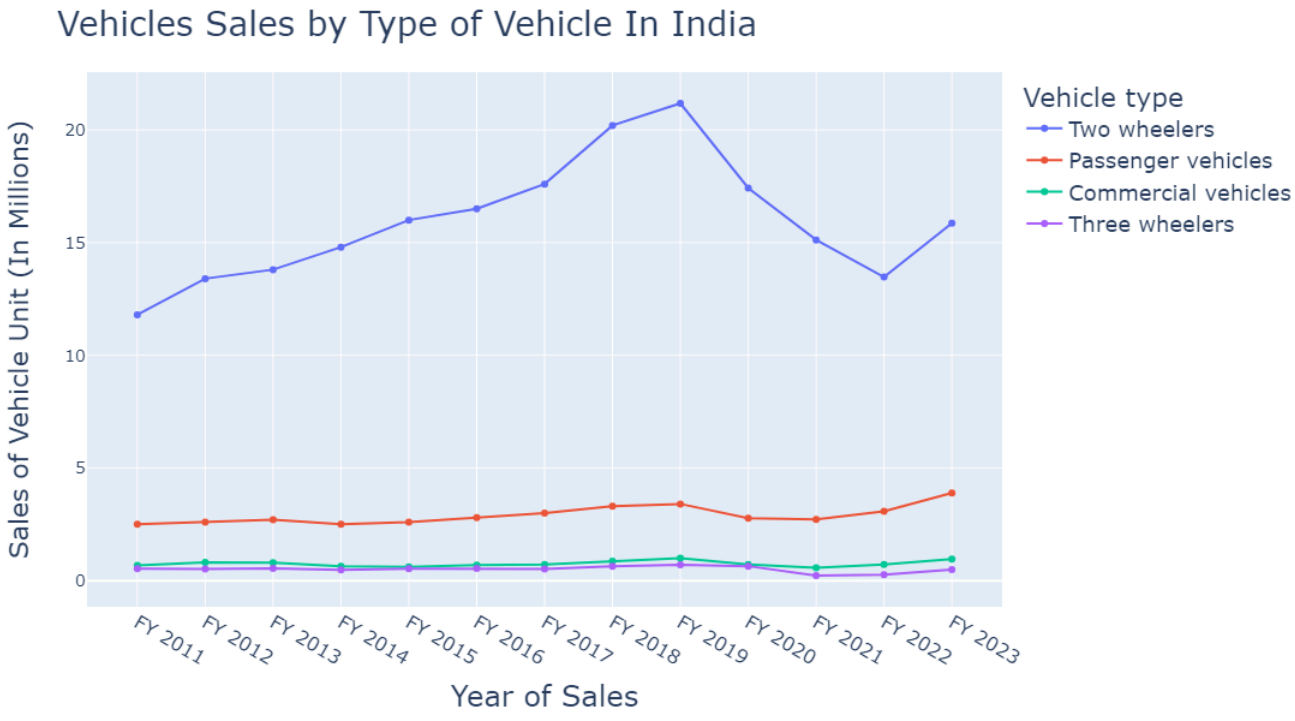
As a result of these factors, By 2030, it is estimated that BEVs will account for more than 80% of global electric vehicle sales.

**Why BEVs are becoming more popular:**

- Lower operating costs. BEVs have lower fuel costs than gasoline or diesel vehicles.
- This is because electricity is cheaper than gasoline or diesel, and BEVs are more efficient.  Lower emissions.
- BEVs produce zero emissions, which helps to improve air quality.  Government incentives. Many governments offer incentives to purchase BEVs, such as tax breaks and rebates.
- Improved technology. Battery technology has improved significantly in recent years, which has led to longer ranges and faster charging times for BEVs.
- Growing consumer awareness. More and more consumers are becoming aware of the benefits of BEVs.

## All Vehicle Type and Sales Analysis

This graph, which is broken down by vehicle type, provides a thorough summary of  India's car sales trends from FY 2011 to FY 2023.



This above graph displays vehicle sales in India over the years, categorized into Four types of vehicles: Two-wheelers, Passenger vehicles, Commercial vehicles, and Three-wheelers.

1. **Two-Wheelers (Blue Line):**
    - This category shows a steady increase from FY 2011 to FY 2019, peaking at around 21 million units.
    - After FY 2019, there is a sharp decline, particularly noticeable during FY 2020-2022, probably due to market disruptions or external factors, possibly the pandemic.
    - By FY 2023, the sales slightly rebound but remain below their peak.

2. **Passenger Vehicles (Red Line):**
    - Sales of passenger vehicles are relatively steady, starting around 2.5 million units in FY 2011.
    - There is a slight upward trend, especially between FY 2015 and FY 2023, where sales grow to around 3.5 million units.
    - Despite some minor fluctuations, the trend is generally positive.

3. **Commercial Vehicles (Green Line):**
    - This category has the lowest sales, starting under 1 million units in FY 2011.
    - The trend remains mostly flat, with slight growth around FY 2018 but dips in FY 2020, indicating a volatile market.
    - A minor recovery is seen in FY 2023, but overall sales stay below 1 million units.

4. **Three-Wheelers (Purple Line):**
    - Three-wheelers also show a relatively flat trend, beginning with low sales around 0.5 million units.
    - There is a slight increase and subsequent dip, particularly around FY 2020-2021.
    - In FY 2023, the trend seems to stabilize but remains small compared to other categories.

Two-wheelers dominate the market overall, though there have been notable changes throughout time. The second-largest market is for passenger cars, which, and the other segments exhibit steady and moderate trends. **It's crucial to remember that even while two-wheelers are sold in large quantities, their revenue is significantly lower than that of four-wheelers.**

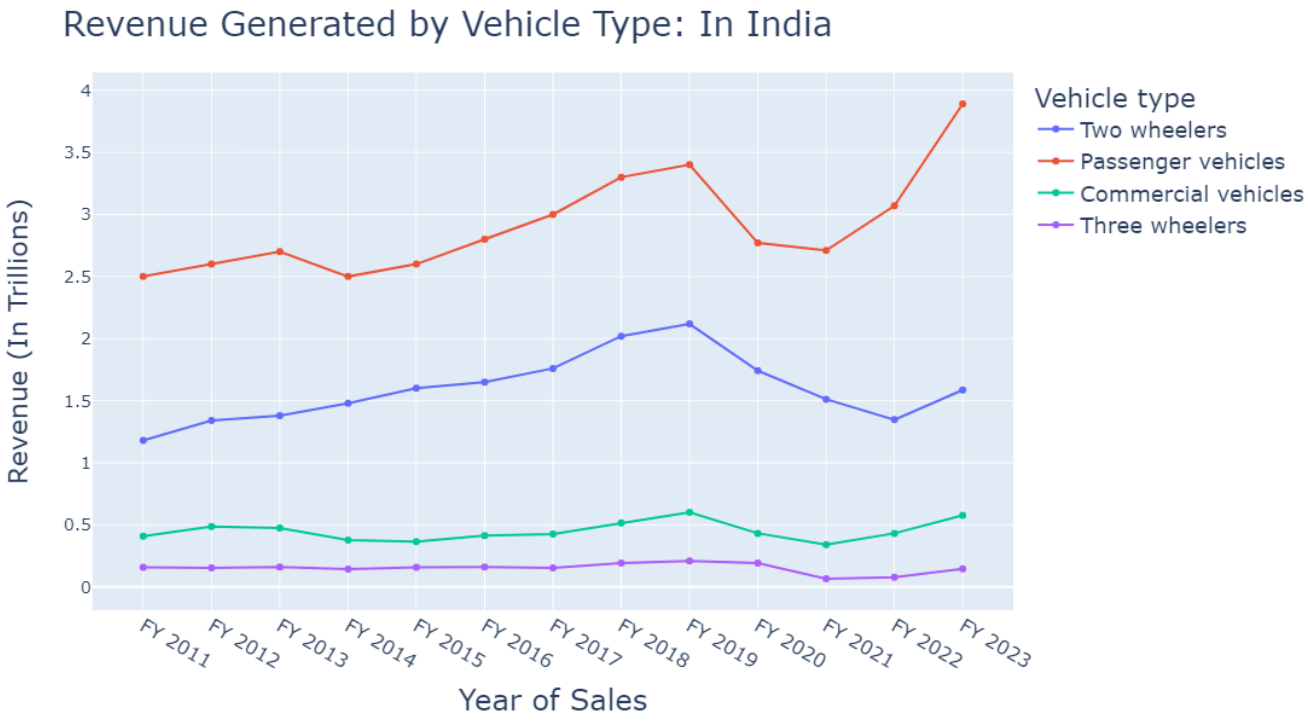
- Despite their popularity, two-wheelers usually have lower prices, which means that producers have to make smaller profits.
- Due to traffic jams and the necessity for reasonably priced transportation, these vehicles are especially well-liked in metropolitan and semi-urban areas.
- However, if we stand back and consider the bigger picture, it's evident that, even though they dominate the sales volume market, **two-wheelers are not the most lucrative market for a new electric vehicle company.**

**This takes us to 4-wheelers, which are where the big money is made even though they sell fewer units.**

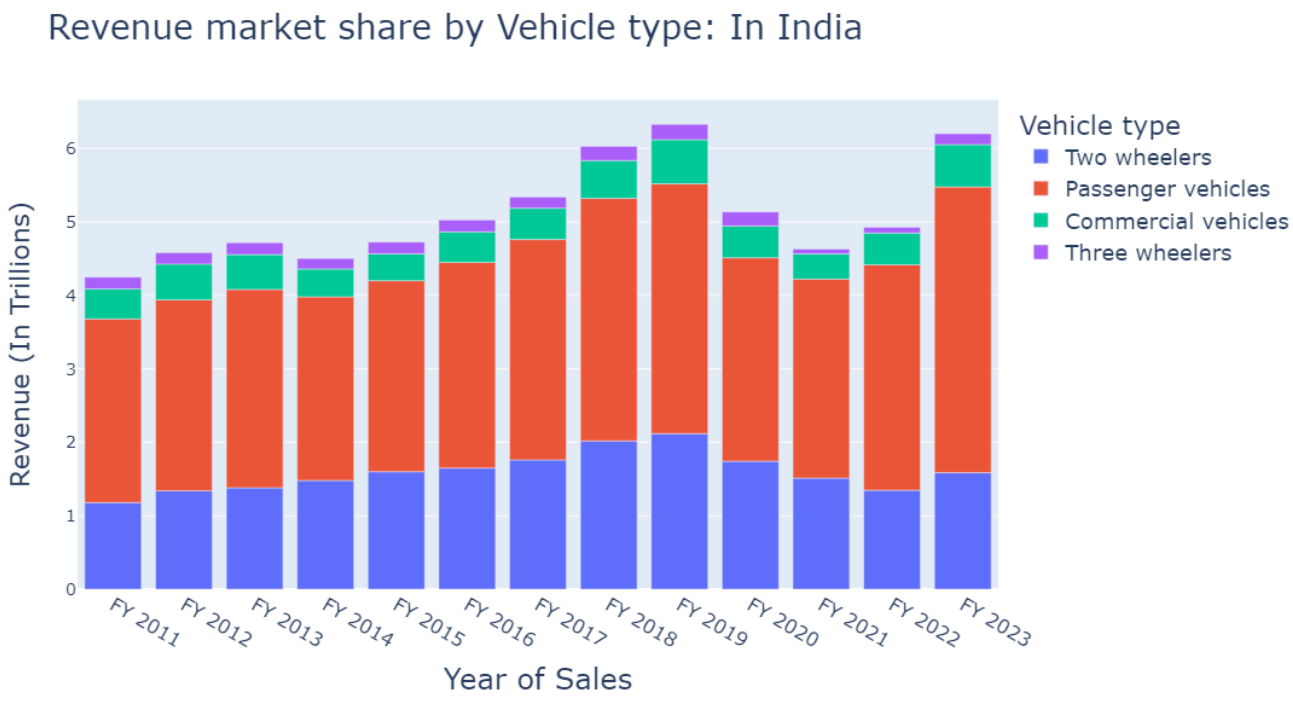
## Revenue Analysis by Vehicle Type

The narrative takes an intriguing turn when we move our attention from sales volume to **income creation**. Even though they sell the most units by far, two-wheelers make up a much smaller portion of total revenue than four-wheelers. The explanation is straightforward: 4-wheelers are more expensive than 2-wheelers. These cars are more costly than two-wheelers, but they also appeal to a certain group of people who can afford to buy more expensive versions.

If we multiply each vehicle unit with its average vehicle category price, we get to see the revenue generated by each type.



In contrast to two-wheelers, which are mostly used by the general public, four-wheelers serve a wealthier demographic. Customers are prepared to spend more for these cars because of their perceived position as status symbols and because of their comfort, power, and elegance.



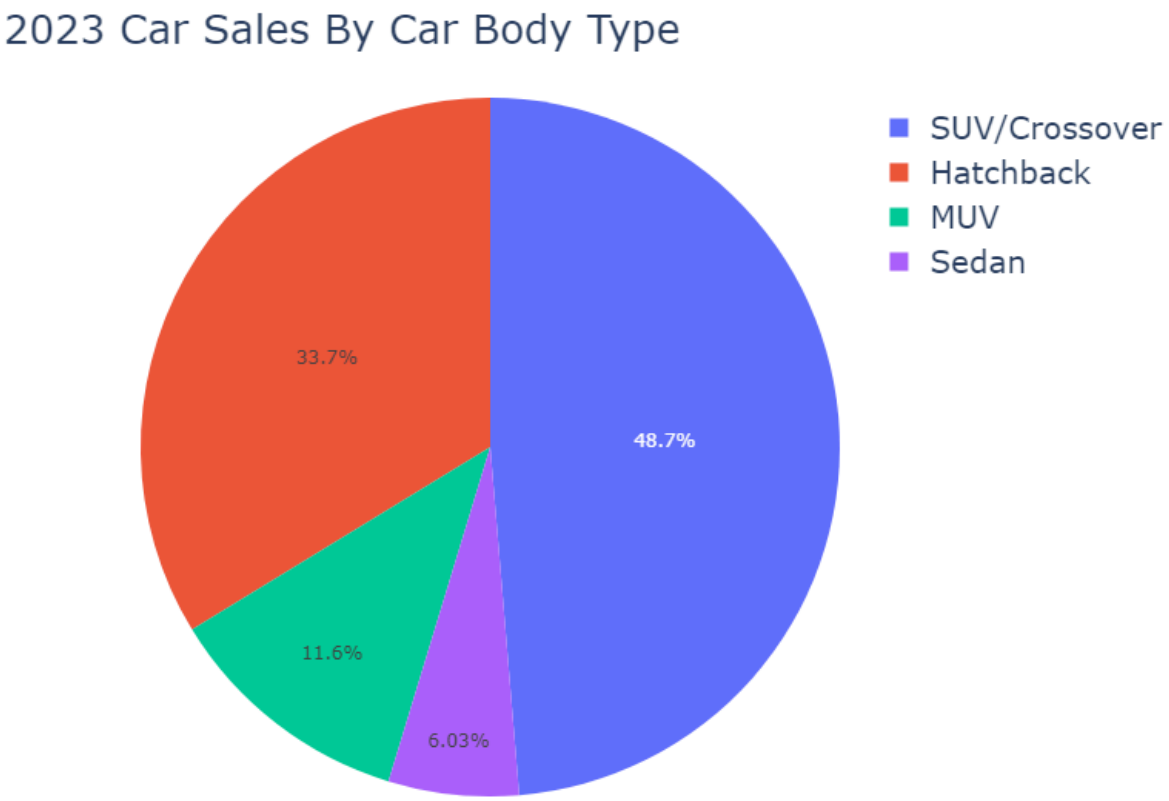

**So for target vehicle type, we will choose 4 Wheelers as our EV Vehicle type for the startup.**

## 4 Wheelers Type Sales Analysis

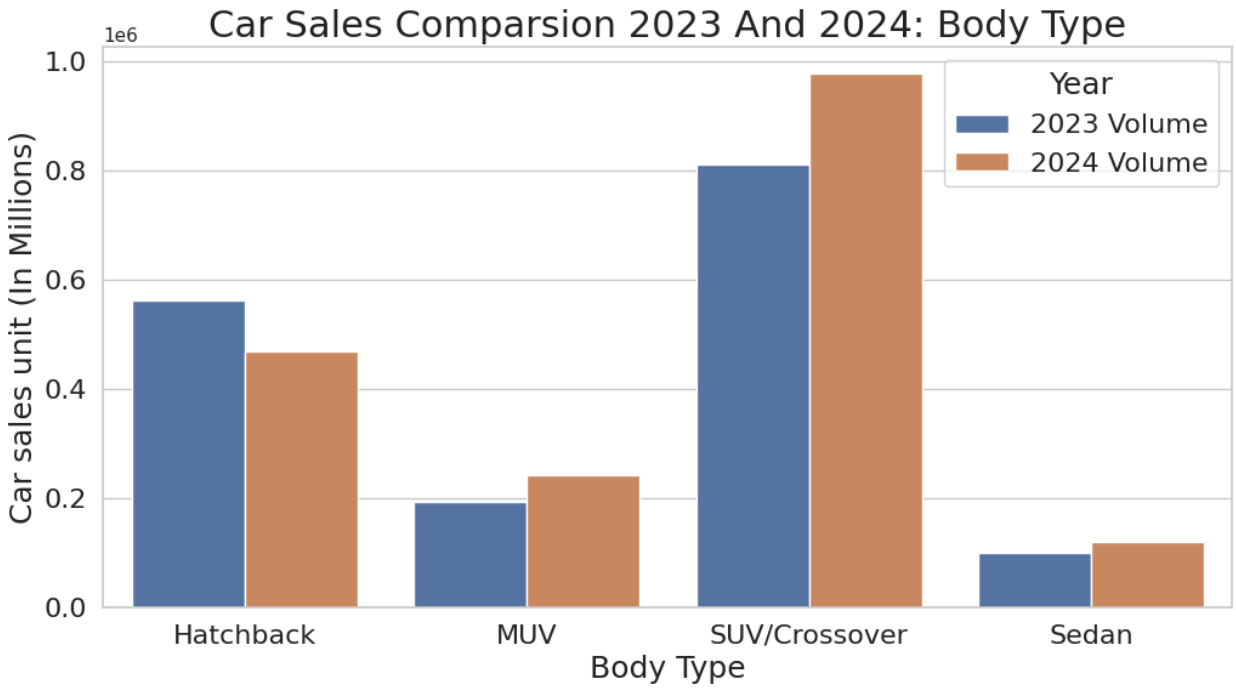
Data from **Autopunditz**, a popular vehicle analysis website, describes the most sold cars in India in 2023 and their body type.

It's interesting to note that among 4-wheelers, the **SUV/crossover** market has grown at the fastest rate in terms of conventional internal combustion engine (ICE) vehicles. This is consistent with a global trend in which SUVs are becoming more and more popular because of their adaptability and attraction to consumers in both urban and rural areas. In order to optimize profitability for an electric vehicle startup, the four-wheeler SUV/crossover market offers.

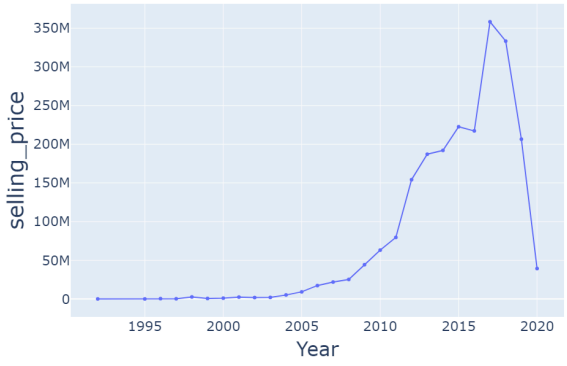
As shown in the charts below, the 4-wheeler segment, particularly **SUVs and crossovers**, far outpaces other body type in terms of sales. This trend underscores the importance of targeting high-value customers who are willing to invest in premium vehicles. For an EV startup, this insight is invaluable, as it provides a clear roadmap for capturing a share of the lucrative 4-wheeler market.

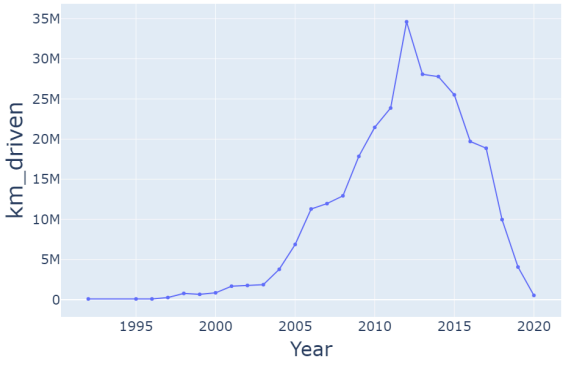



In addition to controlling the market for automobiles today, **SUVs and crossovers** have had exceptional growth between 2023 and 2024. The SUV/crossover sector stands out as the sole category to enjoy considerable and continuous sales growth throughout this period.



## Petrol/Diesel Vehicle Selling Price Decreasing




The graph above illustrates that the **selling price of petrol and diesel vehicles has steadily declined** from 2017 to 2020. Several factors may have contributed to this trend.

- Firstly, the growing appeal of electric vehicles is placing downward pressure on the prices of petrol and diesel cars. EVs are not only cheaper to maintain but also more efficient to operate, making them a more attractive option for many buyers. Additionally, their lower emissions add to their allure, particularly for environmentally conscious consumers.
- Secondly, the rising cost of petrol and diesel fuel has made conventional vehicles less affordable for the average consumer, resulting in decreased demand. As fuel prices rise, the overall operating costs for petrol and diesel vehicles increase, making them less desirable compared to their electric counterparts.
- New technological advancements have also played a significant role. The introduction of lightweight materials and more efficient engines has made it cheaper to produce petrol and diesel vehicles, contributing to the reduction in selling prices.
- Government policies are another major factor. In many regions, governments are offering financial incentives such as tax breaks and rebates for the purchase of electric vehicles, making them more affordable and accessible to a larger portion of the population.
- Lastly, the impact of the COVID-19 pandemic cannot be ignored. With fewer people commuting to work or traveling, the demand for petrol and diesel vehicles significantly dropped, further driving down their prices.

In conclusion, the combination of these various factors—ranging from rising fuel costs to government incentives and the impact of new technology—has contributed to the decline in the selling price of petrol and diesel vehicles. While it's difficult to predict if this trend will continue, the current trajectory suggests that the market for traditional fuel vehicles faces ongoing pressure.

**Decline in Kilometers Driven by Petrol/Diesel Vehicles (2013-2020):**

- There has also been a noticeable decline in the number of kilometers driven by petrol and diesel vehicles from 2013 to 2020. This can be attributed to several societal and technological shifts.

- The rise of ride-hailing services like Uber and car-sharing platforms has provided consumers with more convenient and affordable transportation alternatives, reducing the need for personal vehicle ownership. Consequently, people are driving less.

- Electric vehicles, being more efficient than traditional petrol/diesel vehicles, can travel further on a single charge. This makes them a cost-effective option for consumers looking to reduce their fuel expenses, contributing to the reduced mileage driven by conventional vehicles.

- The pandemic has also had a significant impact here, as lockdowns and work-from-home policies led to fewer commutes and overall travel. Many individuals are driving less as a result.

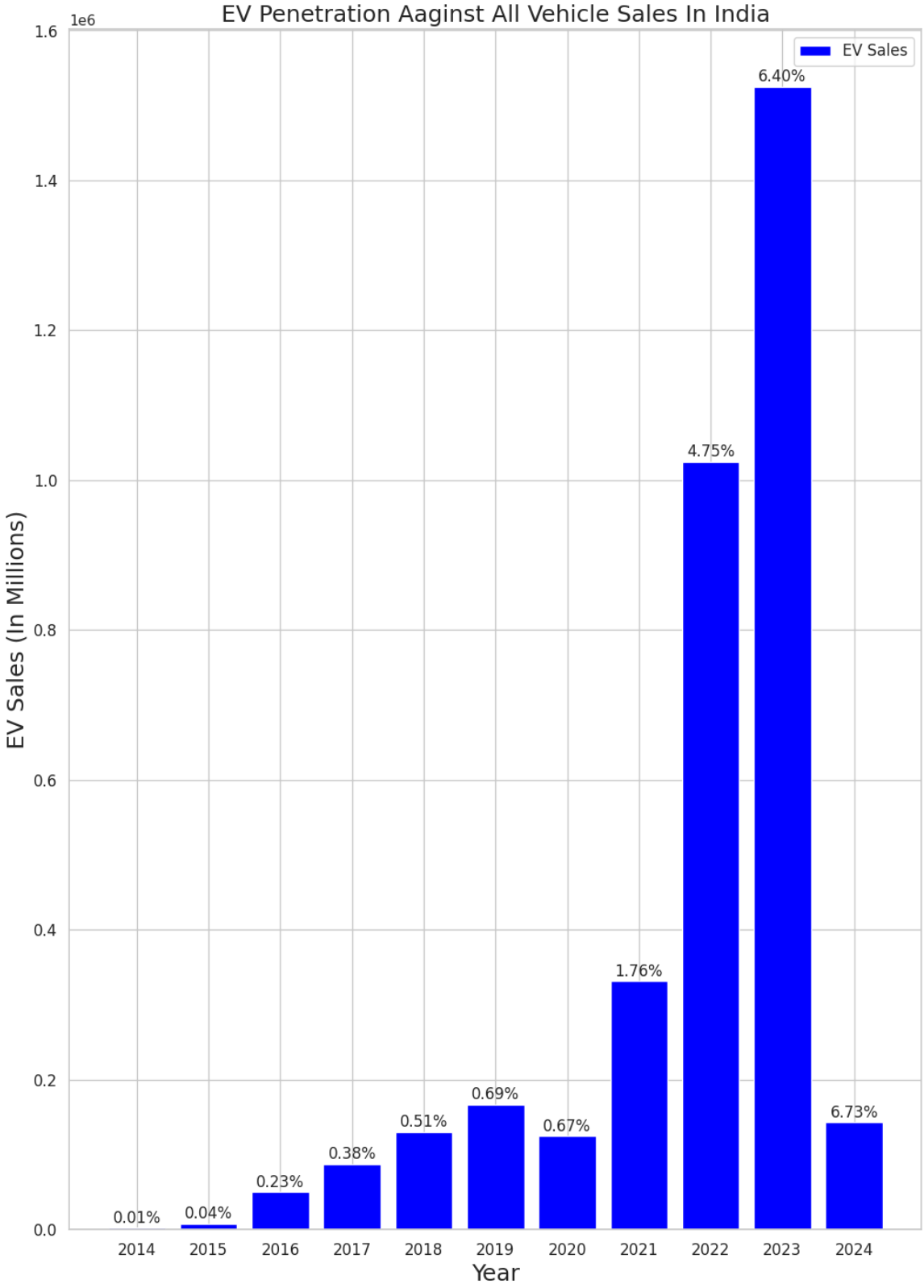
The rising fuel prices have made driving petrol and diesel vehicles more expensive, further reducing the number of kilometers driven. With operating costs rising, people are becoming more conscious of how much they drive to minimize expenses.

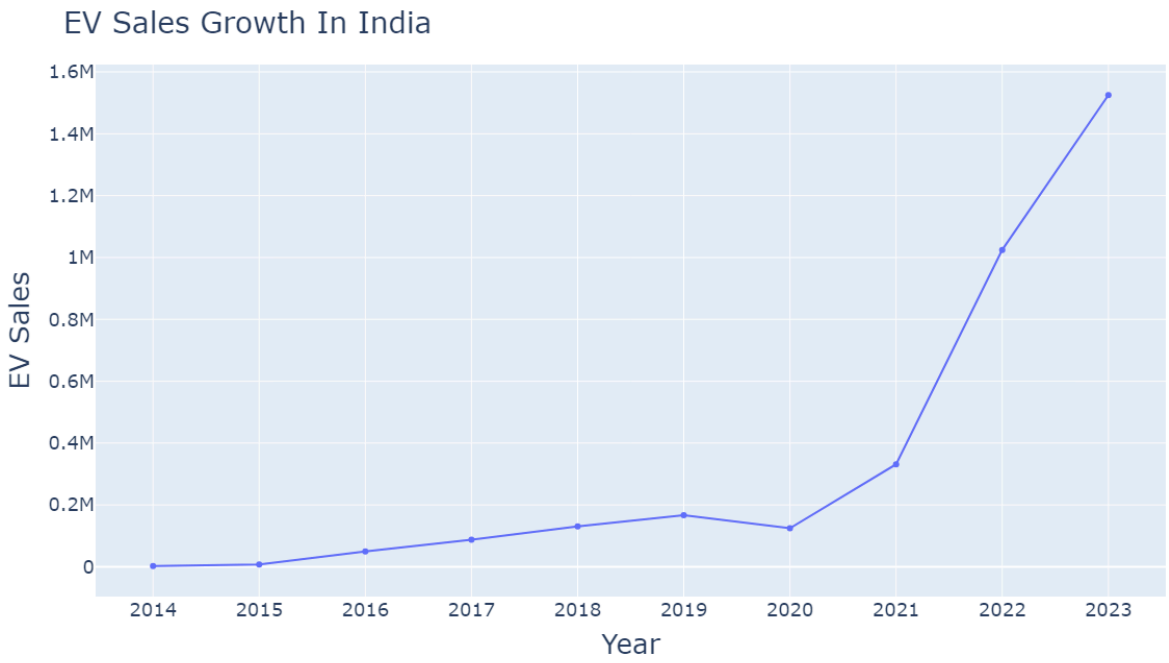
Public transportation improvements in many urban areas have also contributed to the decrease in personal vehicle usage. As public transit becomes more efficient and reliable, people are increasingly opting for these alternatives to reduce their carbon footprint.

Moreover, growing awareness of environmental concerns related to petrol and diesel vehicles has led many to limit their driving or switch to more sustainable modes of transport.

In sum, it is likely that a combination of these factors has contributed to the significant decline in kilometers driven by petrol and diesel vehicles. Going forward, the trend may continue as government policies increasingly incentivize electric vehicle adoption, and consumers become more environmentally conscious.

## Overview of EV Sales in India






**Electric vehicles (EVs) tend to be benefit in some factors, which is why they are gaining attention:**

**Weight:** EVs are typically lighter than gasoline-powered cars because they don't have an engine or fuel tank. This means that they require less energy to move, which results in better fuel efficiency.

**Maintenance:** Electric vehicles (EVs) generally require less maintenance than gasoline-powered cars because they have fewer moving parts.

**Instant Torque:** One of the key benefits of EVs is their ability to deliver instant torque. Unlike traditional gasoline engines that need to build up power, electric motors provide immediate acceleration, making the driving experience smoother and more responsive.

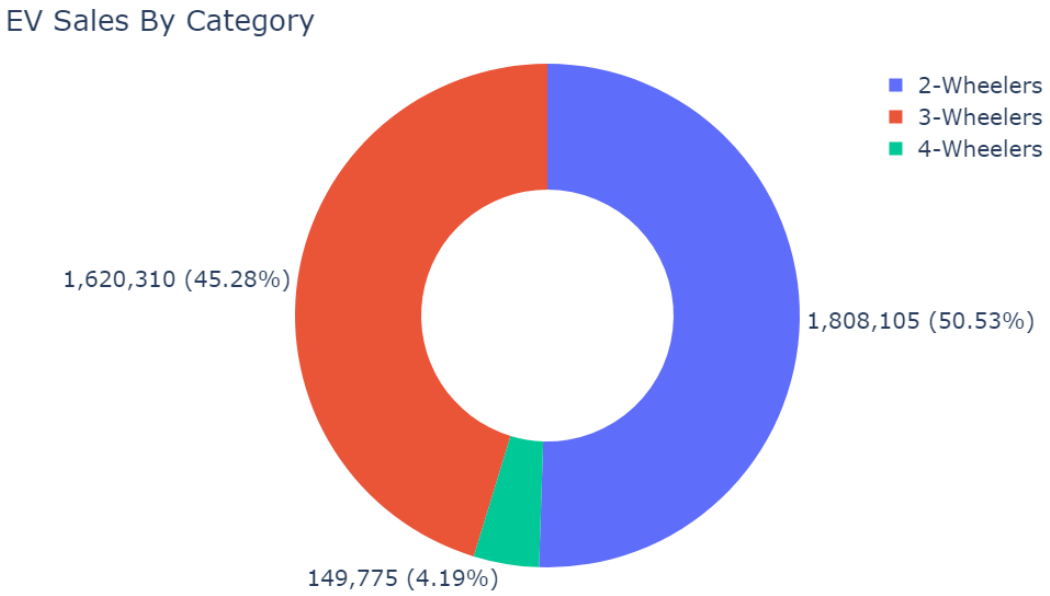
**Energy Efficiency:** Electric vehicles are far more energy-efficient compared to internal combustion engine vehicles. EVs convert over 77% of the electrical energy from the grid into power for the wheels, whereas gasoline vehicles only convert about 12%–30% of the energy stored in gasoline.

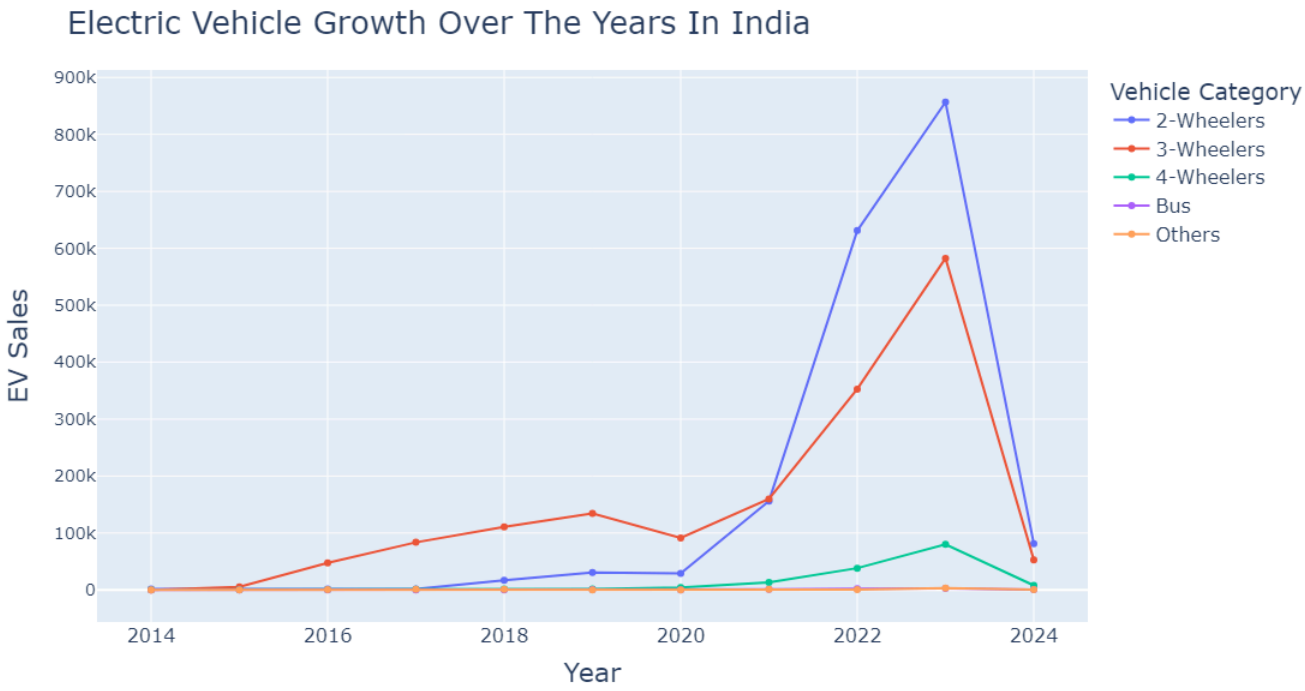
**Regenerative Braking:** EVs come equipped with regenerative braking systems, which capture and store energy that would otherwise be lost during braking. This feature not only improves the overall efficiency of the vehicle but also extends the lifespan of the brakes by reducing wear.

**Environmental Impact:** Electric vehicles produce zero tailpipe emissions, significantly reducing the environmental impact compared to gasoline or diesel vehicles. This reduction in emissions helps combat air pollution and global warming, especially in urban areas with dense traffic.

**Lower Operating Costs:** The cost of electricity is generally lower than gasoline or diesel fuel. Additionally, many countries and regions offer financial incentives, rebates, or tax credits for EV owners, which further lowers the overall cost of ownership. Moreover, EVs can be charged at home, eliminating the need for frequent visits to gas stations.

**EV vehicle market also follows the same trend of Petrol/Diesel vehicle.** In terms of units sold, two-wheelers have dominated the Indian EV market, making them the most sold electric vehicles in the country. However, it's important to note that while the number of 2-wheeler EVs sold is high, they generate far less revenue compared to their 4-wheeler counterparts.






Two-wheelers, though popular, are typically priced lower and thus offer smaller margins to manufacturers.

These vehicles are particularly popular in urban and semi-urban areas, where traffic congestion and the need for affordable transportation make them an attractive option. But, if we take a step back and look at the broader picture, it becomes clear that 2-wheelers, despite their dominance in terms of sales volume, are not the most profitable segment for a new EV startup.

This brings us to **4-wheelers**, which, although selling fewer units, are where the real money is made.

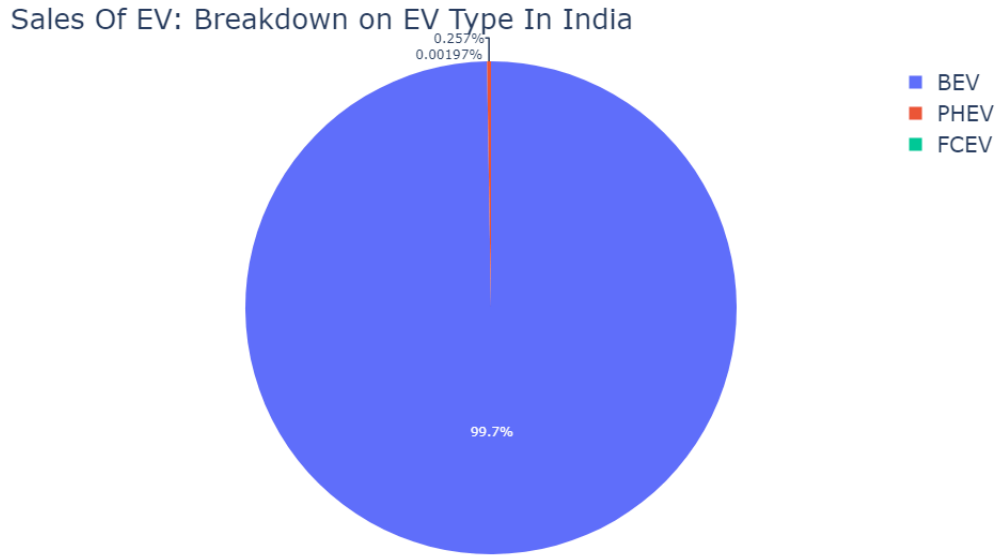
Unlike two-wheelers, which cater mostly to the masses, **4-wheelers**, particularly **SUVs** and **crossovers**, cater to a more affluent segment of the population

These vehicles are seen as status symbols, and consumers are willing to pay a premium for the comfort, power, and luxury they provide. Interestingly, the SUV/Crossover segment has shown the most robust growth within the 4-wheeler category, both in terms of traditional internal combustion engine (ICE) vehicles and electric vehicles.

This mirrors a global trend, where SUVs have become increasingly popular due to their versatility and appeal to both urban and rural buyers. For an EV startup looking to maximize profitability, the 4-wheeler SUV/Crossover segment presents a golden opportunity.

**Lets look in depth for EV cars already present in India to better understand EV Car market:**

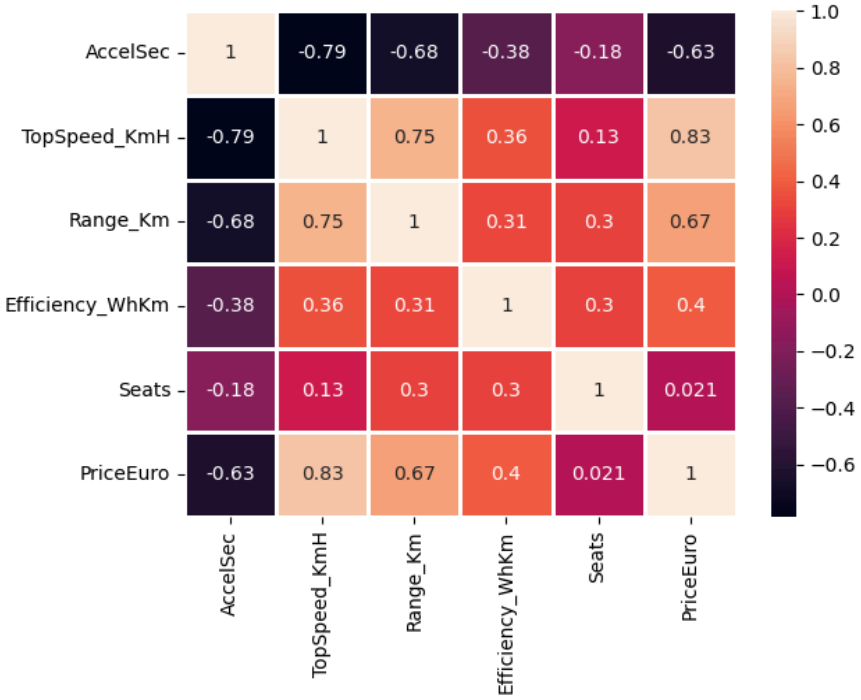
**EV Battery Type:**




When looking at the Indian market for electric vehicles (EVs), battery electric vehicles (BEVs) are by far the most popular option. This tendency is consistent with global shifts toward greener and more sustainable modes of transportation.

**EV Correlation Heatmap:**

This correlation heatmap illustrates the relationships between various vehicle Attributes such as acceleration, top speed, range, efficiency, seats, and price. Darker colors indicate stronger negative or positive correlations, with Price strongly correlated with top speed and range, while acceleration has a negative relationship with these factors.

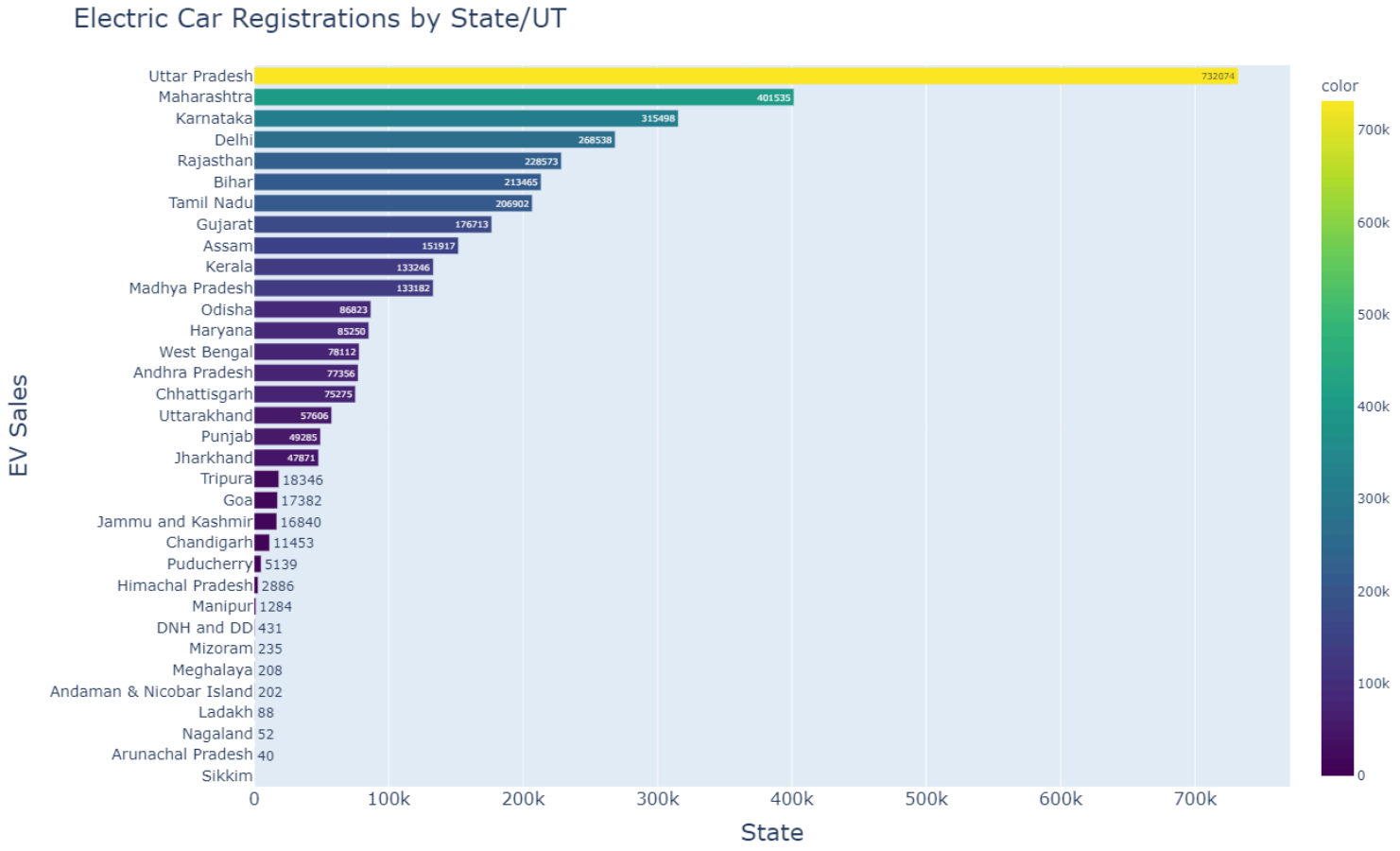


## Geographical Market Segmentation

### EV Registrations by State

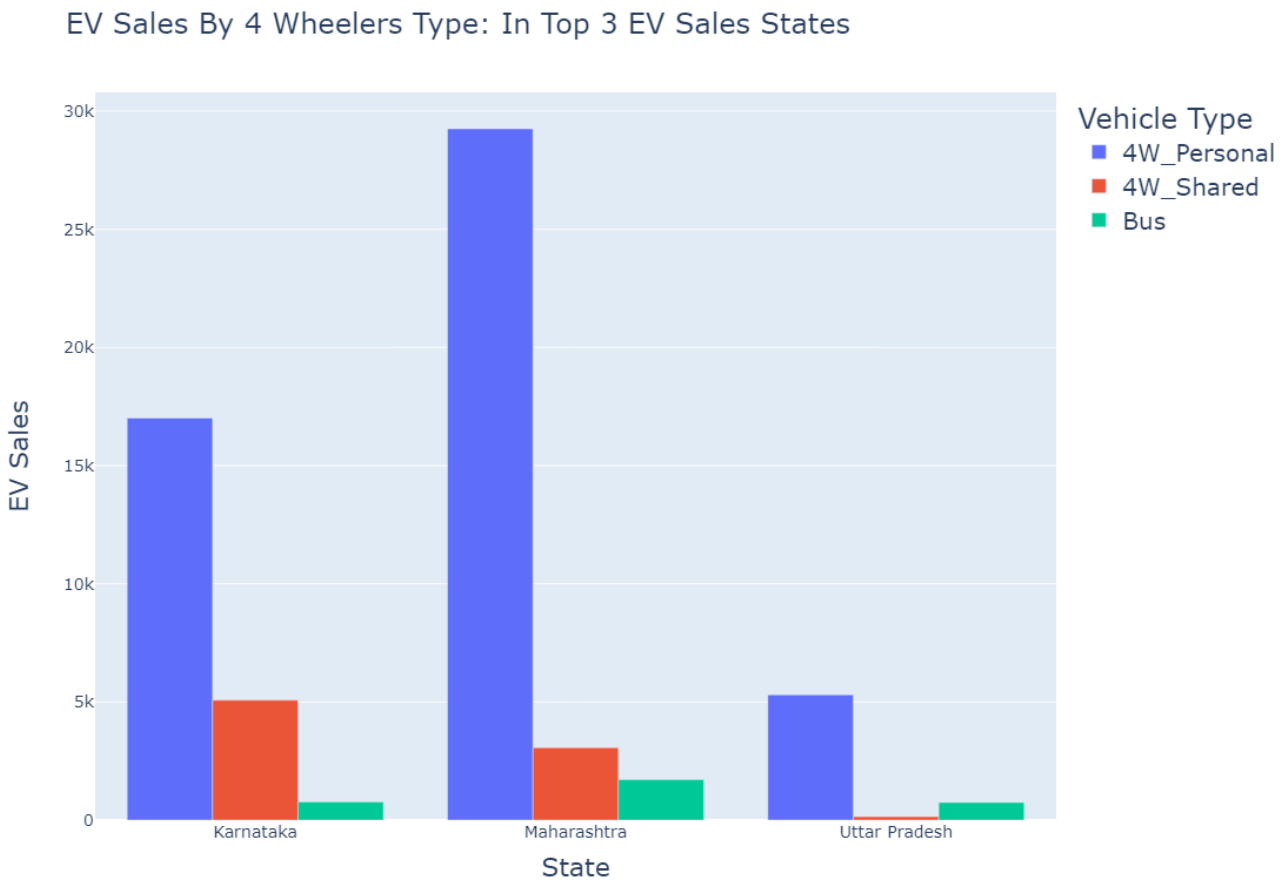
There are regional variations in India's electric vehicle market. Due to a mix of infrastructure development, consumer knowledge, and government incentives, some states have welcomed EVs with greater fervor than others. Looking at state-by-state EV registration data to see where the best chances are for an EV entrepreneurial venture.

In terms of EV registrations, the top three states are **Uttar Pradesh**, **Maharashtra**, and **Karnataka**, with Uttar Pradesh at the top of the list.




The electric vehicle registrations in India's UTs and several states are displayed in this bar chart. With almost **732,000** registrations, Uttar Pradesh is in the lead, followed by Maharashtra (**401,535**) and Karnataka **(315,498**). The color gradient, which goes from purple to yellow, represents the number of electric vehicle registrations; the largest numbers are indicated by states like Uttar Pradesh, which stand out in yellow. The graph unequivocally demonstrates how a small number of states dominate the adoption of EVs, with smaller regions having comparatively lower registration rates.

1. **Uttar Pradesh**, **Maharashtra**, and **Karnataka** have emerged as the leading states in terms of overall EV registrations.
2. **However**, since our focus is specifically on the electric **4-wheeler** segment, we need to dive deeper into the registration data for **EV cars** in these states.
3. Analyzing this specific category will provide more detailed insights. By narrowing our focus, we can better understand the trends in electric car adoption within these top-performing regions.




When we narrow our focus to **4-wheeler EVs**, it becomes clear that **Maharashtra** and **Karnataka** are the real hotspots. Both of these states have well-established automotive industries, making them natural hubs for EV adoption and manufacturing.

A well-developed infrastructure is crucial for the growth and success of any product. In the case of electric vehicles, the availability of **charging stations** plays a significant role in driving adoption.

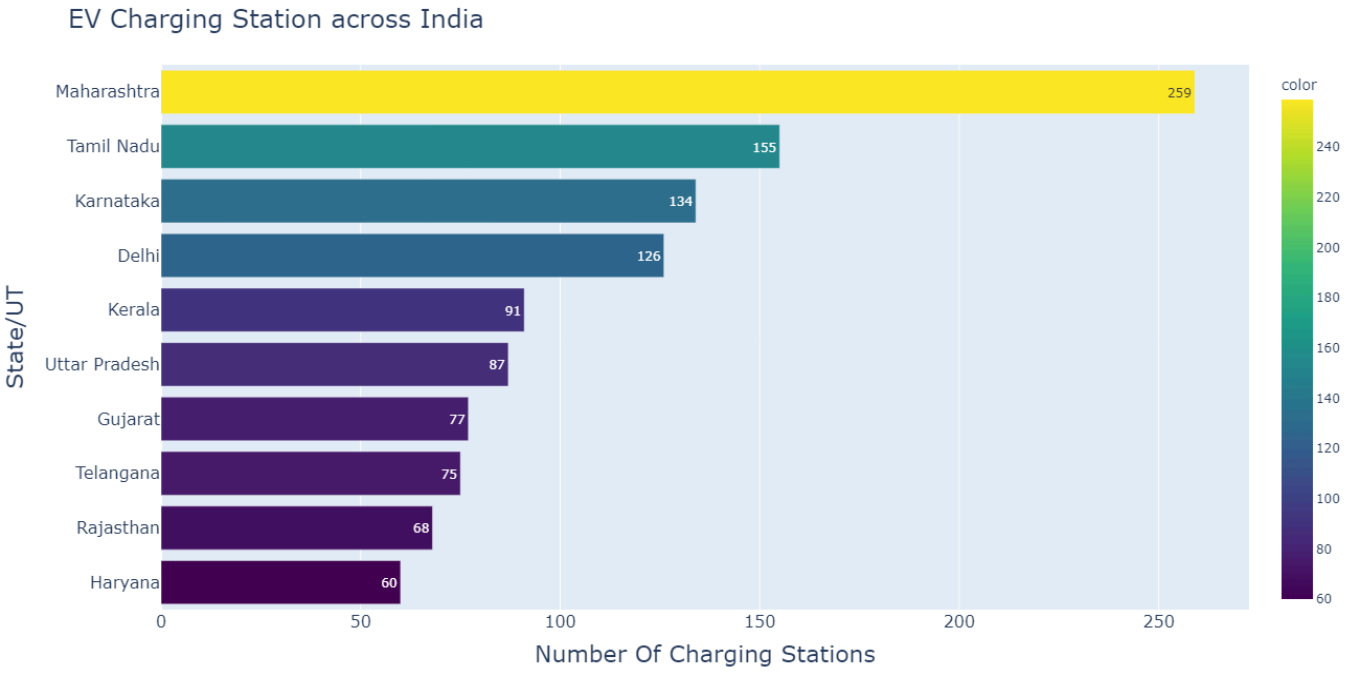
## Charging Infrastructure

A critical factor that influences EV adoption is the availability of charging infrastructure. Without a robust network of **charging stations**, potential EV buyers may be hesitant to make the switch from traditional internal combustion engine vehicles. This is why the development of charging infrastructure is seen as a key enabler of EV growth.

```
charging_stations_india = pd.read_csv("ev-charging-stations-india.csv")
charging_stations_india.head()
```

| | name | state | city | address | lattitude | longitude | type |
|---|---|---|---|---|---|---|---|
| 0 | Neelkanth Star DC Charging Station | Haryana | Gurugram | Neelkanth Star Karnal, NH 44, Gharunda, Kutail... | 29.6019 | 76.9803 | 12.0 |
| 1 | Galleria DC Charging Station | Haryana | Gurugram | DLF Phase IV, Sector 28, Gurugram, Haryana 122022 | 28.4673 | 77.0818 | 12.0 |
| 2 | Highway Xpress (Jaipur-Delhi) DC charging station | Rajasthan | Behror | Jaipur to Delhi Road, Behror Midway, Behror, R... | 27.8751 | 76.2760 | 12.0 |
| 3 | Food Carnival DC Charging Station | Uttar Pradesh | Khatauli | Fun and Food Carnival, NH 58, Khatauli Bypass,... | 29.3105 | 77.7218 | 12.0 |
| 4 | Food Carnival AC Charging Station | Uttar Pradesh | Khatauli | NH 58, Khatauli Bypass, Bhainsi, Uttar Pradesh... | 29.3105 | 77.7218 | 12.0 |

Let's look at how many **charging stations** are accessible in each Indian state. This will give us important information about infrastructure readiness and assist us in choosing the best target state from **Maharashtra** and **Karnataka** for our market niche. For electric vehicles to be successfully adopted, a robust charging network is necessary, and this analysis will direct our strategic focus.



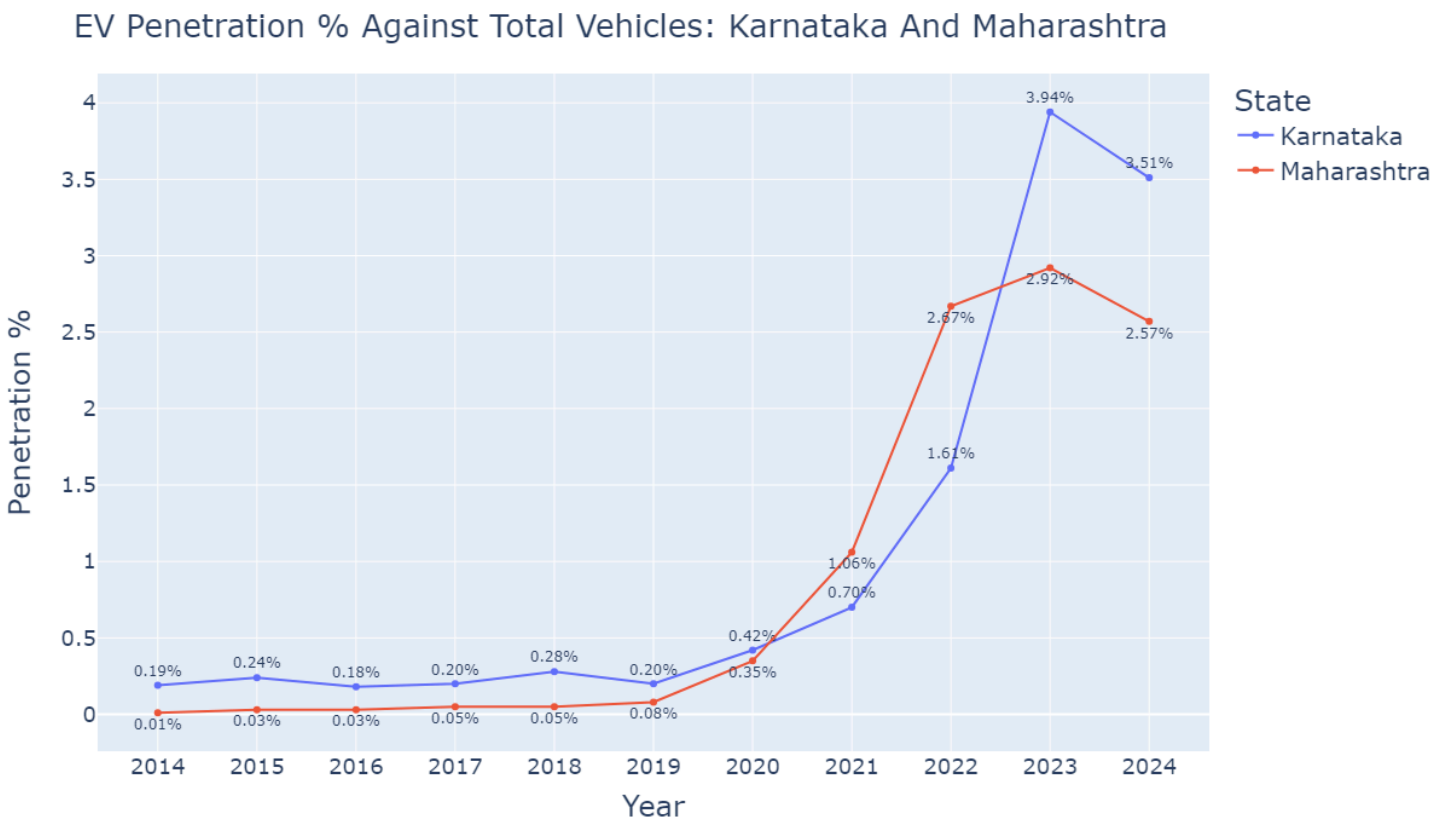
States like **Maharashtra**, **Karnataka**, and **Tamil Nadu** have taken the lead in setting up charging stations, making them ideal regions for launching a new EV startup.

For instance, the government of Maharashtra has launched a number of programmes to encourage the installation of EV charging stations in public areas, apartment buildings, and business spaces. Conversely, Karnataka has concentrated on incorporating charging infrastructure into its current power system, guaranteeing EV owners have access to dependable and quick-charging choices.

**Maharashtra** and **Karnataka** not only have the highest number of EV registrations but are also investing heavily in the infrastructure needed to support long-term EV adoption. This presents a **significant opportunity for a new EV startup**, as entering a market with well-established infrastructure reduces the barriers to entry and increases the chances of success.

- At first glance, **Maharashtra** seems like a strong candidate for the **geographical segment** to target, especially given its robust infrastructure. The state has a well-established network of charging stations, which is a critical factor in supporting electric vehicle adoption.
- However, there's a more important aspect to consider beyond the availability of charging stations: **the rate of EV penetration in each state**. While infrastructure is essential, the true growth potential of an EV startup lies in how well the public is adopting electric vehicles.
- Understanding the **behaviour for level of EV adoption** in both states is crucial. This will help us measure the extent to which the population is shifting towards electric vehicles and how open they are to embracing new, sustainable technologies.
- The rate of consumer acceptance is a key indicator of future market growth. High penetration rates suggest that the population is not only aware of EVs but also ready to integrate them into their daily lives, creating a fertile environment for a startup.
- In addition to EV penetration, we must also consider the **demographic composition** of these states. States with younger, tech-savvy populations may show faster adoption of electric vehicles, further supporting the growth of the market segment.
- Finally, it's important to analyze the government policies in place. States that offer strong incentives, subsidies, or favorable policies for EV buyers and manufacturers will likely see faster market growth, making them ideal for launching an EV startup.

**Lets look at how much EV car sales is penetrating towards total vehicle sales in both states:**




The graph illustrates the penetration of electric vehicles (EVs) as a percentage of total vehicle sales in Karnataka and Maharashtra from 2014 to 2024. **Karnataka** shows a consistent upward trend, particularly from 2021 onwards, reaching its peak at nearly 4% in 202. In contrast, **Maharashtra** also exhibits growth, but its rise is more gradual and slightly behind Karnataka, peaking around 3%.

This behavior indicates that Karnataka has been more aggressive in adopting EV technology compared to Maharashtra. For a startup in the EV sector, this trend is critical for several reasons:

1. **Market Readiness:** Karnataka's higher penetration rate suggests a larger market share of early adopters, which can be essential for driving initial sales and growing brand loyalty.

2. **Consumer Mindset:** Understanding that Karnataka consumers are quicker to adopt sustainable technology could allow startups to tailor marketing strategies and product features to meet this region’s specific needs, ensuring better market penetration and growth.

## Analysis Techniques

### Principal Component Analysis (PCA)

Principal components analysis (PCA) is a statistical method that reduces a large set of correlated variables to a more manageable set of uncorrelated variables. As a result, the dataset can be made simpler while maintaining the majority of its variation, which facilitates data visualization and analysis.

### How PCA Works:

The first principal component captures the most variance, followed by the second, and so on. These components are ranked according to how much variance they explain. Prior to using K-Means clustering in this investigation, the dataset's dimensionality was reduced using PCA.

The following shows how PCA simplified the data:

```
[105] from sklearn.preprocessing import StandardScaler

      ss = StandardScaler()
      s_features = ss.fit_transform(features_encoded)
      s_features
```

```
array([[-0.3864146 , 17.64904782, -0.18940636, ..., -0.45467338,
        -0.15210973, -0.29446202],
       [-0.39400395, 17.64904782, -0.18940636, ...,  2.19938102,
        -0.15210973, -0.29446202],
       [-0.39865655, 17.64904782, -0.18940636, ..., -0.45467338,
        -0.15210973, -0.29446202],
       ...,
       [-0.36922306, -0.05666028, -0.18940636, ..., -0.45467338,
        -0.15210973, -0.29446202],
       [-0.23690435, -0.05666028, -0.18940636, ..., -0.45467338,
        -0.15210973, -0.29446202],
       [-0.39878854, -0.05666028, -0.18940636, ..., -0.45467338,
        -0.15210973, -0.29446202]])
```

```
[106] from sklearn.decomposition import PCA
      from sklearn.metrics import mean_squared_error, silhouette_score

      pca = PCA(n_components=2)
      pca_features = pca.fit_transform(s_features)
      print(pca_features)
```

```
[[ 2.2385272   0.38030956]
 [ 0.12165915  4.37260918]
 [ 1.64268157  0.76536666]
 ...
 [-1.52410157 -0.6690403 ]
 [-1.51608926 -0.73497259]
 [-1.44323601 -0.57734068]]
```

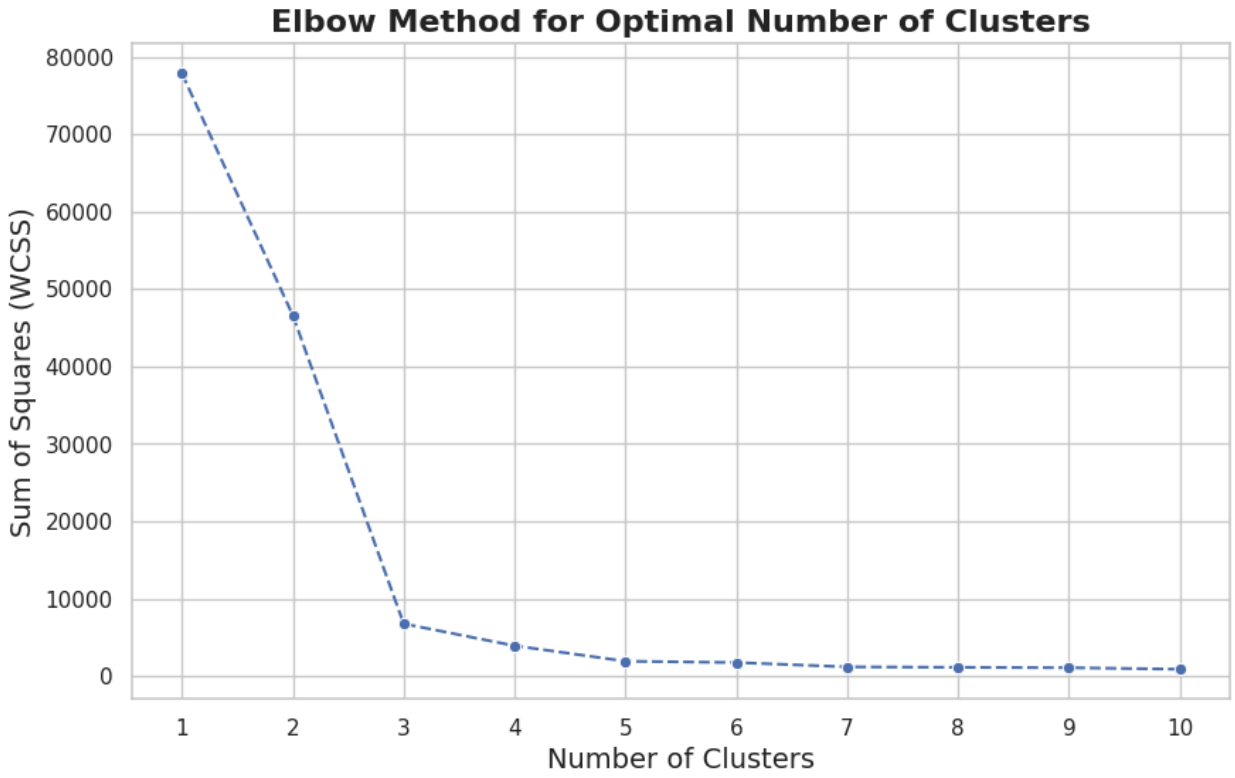
## K-Means Clustering for Customer Segmentation

To accurately segment the EV market and identify the most promising customer groups, I employed K-Means clustering, a machine learning algorithm that is widely used for grouping data into distinct clusters based on similarities. K-Means is particularly effective for this kind of analysis because it helps uncover patterns in large datasets, allowing us to group potential customers based on their behaviors, preferences, and demographic characteristics.

### How K-Means Works

A dataset is divided into K clusters using the K-Means algorithm, and each cluster is identified by its centroid, or central point. K locations are first chosen at random by the algorithm to serve as the initial centroids. After that, each data point is assigned to the closest centroid, thereby assembling related data points into groups. The centroids are updated based on the average of the data points in each cluster following each assignment. Until the centroids stop moving, indicating that the clusters are stable, this process is repeated.

I calculated the ideal number of clusters using the **Elbow approach**. Plotting the variation explained by various values of K and determining the value at which the rate of improvement begins to decrease are the steps involved in the Elbow technique. As a result, the graph displays a "elbow" that represents the optimal number of clusters.



The relationship between the number of clusters utilized in the KMeans clustering algorithm and the Within-Cluster Sum of Squares (WCSS) is seen in the scree plot above.

This analysis's main goal is to find the "elbow" point, which denotes the point at which the benefits of WCSS reduction reduce with the number of clusters added.

**Key Observations:**

1. **Decrease in WCSS (1 to 3 clusters)**:
    - Between 1 and 3 clusters, we observe a steep reduction in WCSS. This indicates that increasing the number of clusters significantly improves the clustering performance by reducing the variation within clusters.
2. **Elbow Point (At 3 clusters)**:
    - The "elbow" of the curve is clearly visible at **3 clusters**. This point suggests that adding more clusters beyond this number yields diminishing returns in terms of WCSS reduction.

The **optimal number of clusters** is likely **3**, based on the elbow point in the scree plot. Beyond this number, the improvement in clustering quality becomes negligible.

## K-Means Clustering Algoritm

```
[165] from sklearn.cluster import KMeans

      kmeans = KMeans(n_clusters=3, random_state=42, n_init='auto')
      clusters = kmeans.fit_predict(pca_features)

      ev_data_only['Cluster'] = clusters
      sil_score = silhouette_score(pca_features, clusters)
      print("Silhouette Score for clustering:", sil_score)

      <ipython-input-165-bae00ed13cb5>:6: SettingWithCopyWarning:


      A value is trying to be set on a copy of a slice from a DataFrame.
      Try using .loc[row_indexer,col_indexer] = value instead

      See the caveats in the documentation: https://pandas.pydata.org/panda

      Silhouette Score for clustering: 0.8079379491524922
```

```
[170] pca_data = pd.DataFrame({
          'PC1': pca_features[:, 0],
          'PC2': pca_features[:, 1],
          'Cluster': clusters
      })

      sns.set(style='whitegrid')
      plt.figure(figsize=(12, 6))
      sns.scatterplot(x='PC1', y='PC2', hue='Cluster', palette='viridis', data=pca_data, s=100, edgecolor='w')
      plt.title('Customer Segmentation using PCA and KMeans', fontsize=20)
      plt.xlabel('PCA 1', fontsize=16)
      plt.ylabel('PCA 2', fontsize=16)
      plt.show()
```

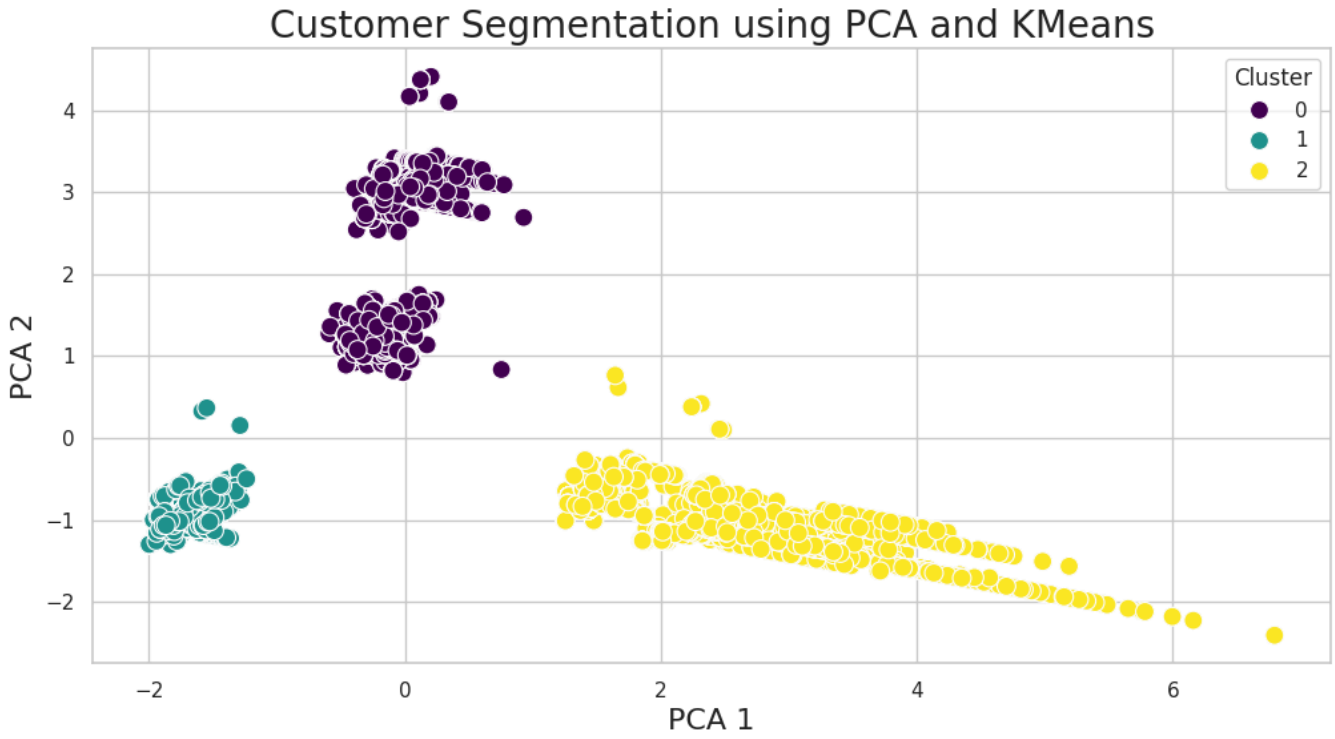
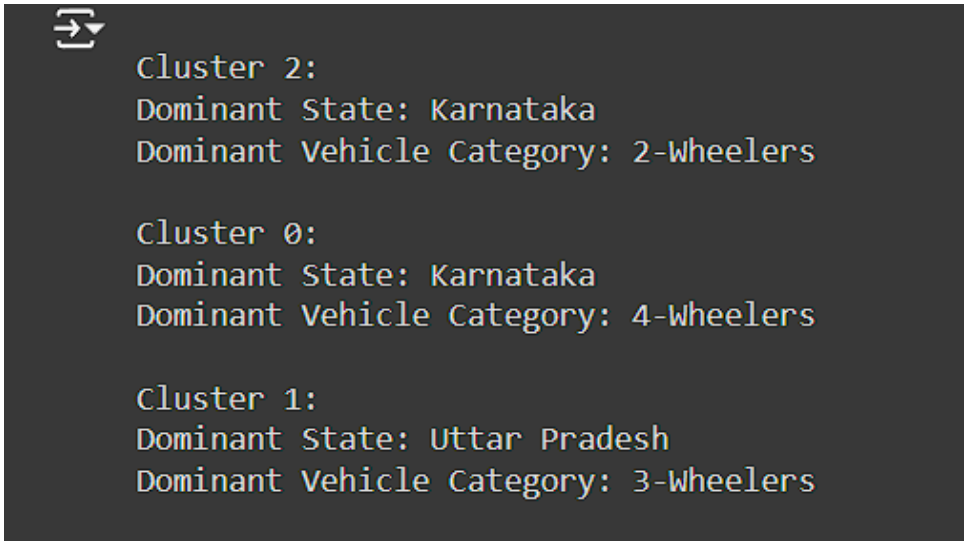


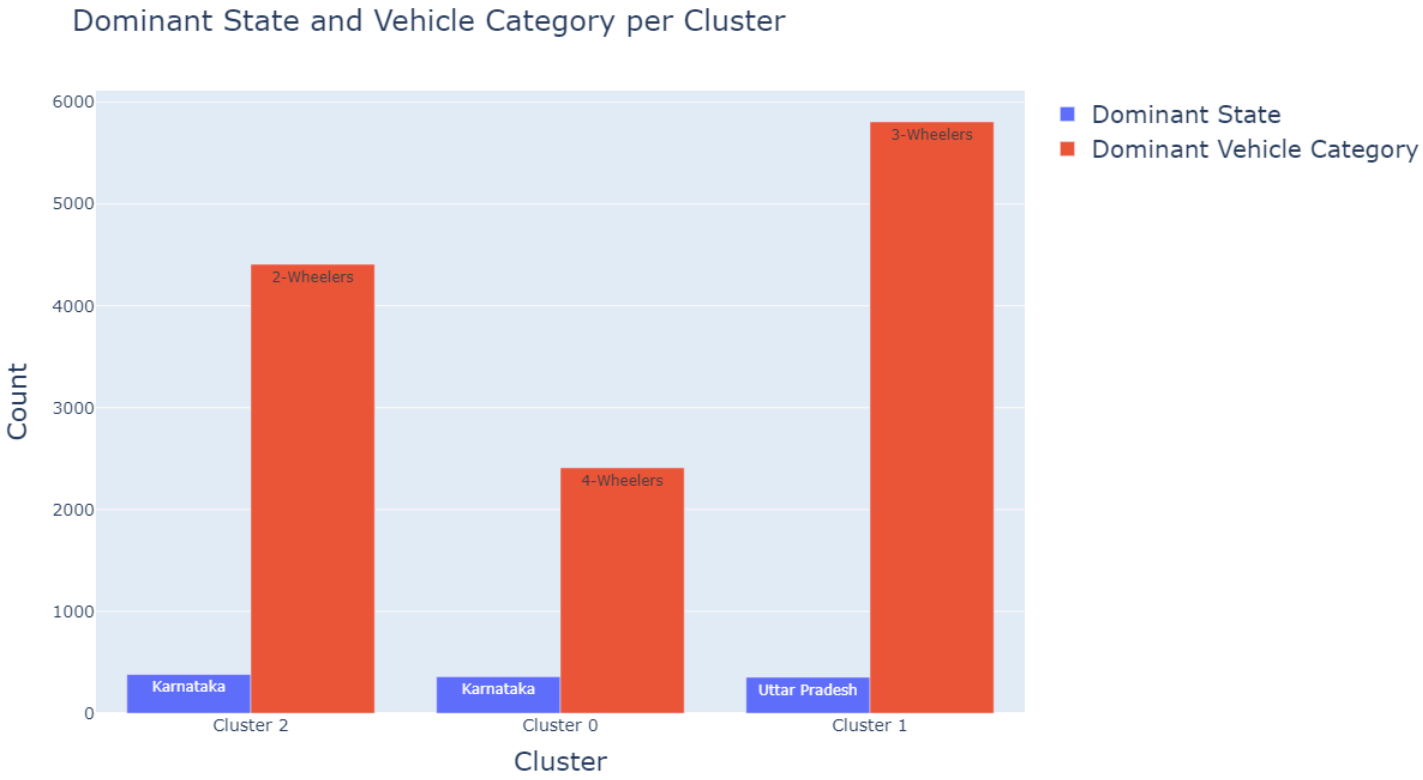

**Figure: Customer Segmentation Using PCA and KMeans**

The customer segmentation based on two principal components extracted from the data is depicted in the plot above, where KMeans clustering is used to separate the customers into three different groups. Using the elbow approach, these clusters were located, and it was discovered that three was the ideal number of clusters.

**Key Insights from the Plot:**

1. **Cluster Identification**:
    - **Cluster 0 (Purple)**: Located primarily in the upper-middle region of the plot, this cluster is highly compact, suggesting that the customers in this segment have similar characteristics.
    - **Cluster 1 (Teal)**: Situated in the lower-left corner, this cluster forms a tight group, suggesting a high degree of similarity among these customers.
    - **Cluster 2 (Yellow)**: Positioned towards the right side of the plot, this cluster is more spread out along the first principal component (PCA 1).
2. **Cluster Separation**:
    - The visualization demonstrates **clear segmentation** between the three customer groups, with minimal overlap between clusters. This separation implies that the clustering model has effectively identified meaningful divisions within the customer base, potentially representing different customer behaviors or preferences.
3. **Interpretation of Segmentation**:
    - The **distinct clusters** suggest the presence of different customer segments within the dataset. These segments could represent variations in customer demographics, purchasing behavior, or product preferences. Further analysis of the characteristics within each cluster can help in developing targeted marketing strategies or personalized recommendations.






## Recommendations

- **Focus on the 4-Wheeler SUV/Crossover Segment**: Based on the analysis, 4-wheelers, particularly SUVs and crossovers, represent the most profitable segment of the EV market in India. Startups should focus their efforts on this segment to capture high-revenue customers.
- **Geographic Targeting of Karnataka**: Karnataka have the highest number of EV registrations and one of the most developed charging infrastructure. Focusing on this regions will provide the best opportunities for growth in the short term.
- **Expand into the 2-Wheeler EV Market**: Once the startup has established itself in the SUV segment, expanding into 2-Wheeler can help capture a broader customer base, including lower-income families who may be looking for more affordable EV options.
- **Collaborate with Local Governments to Enhance Charging Infrastructure**: Partnerships with state governments in Maharashtra and Karnataka can help further develop the EV charging infrastructure, ensuring that the market continues to grow and that consumers have easy access to charging facilities.

## Conclusion

After completing the technical machine learning analysis and data analysis, we can firmly suggest **Bengaluru** as the main target geographic area. **Karnataka's** capital has great growth potential, particularly for businesses hoping to take advantage of the expanding market. Furthermore, we recommend concentrating on **4-wheelers**, especially **SUVs** and **crossovers**, as the favored category of electric vehicles (**EV**s), based on the customer segmentation and trends shown in the data. This market category is a significant prospect for market entry and expansion because it exhibits stronger demand and fits in well with Bengaluru's urban consumers' preferences.

**Github Link:**
**https://github.com/Baniya-sen/**