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CHAPTER 1
INTRODUCTION

India's Electric Vehicle (EV) scenario is speeding up pushed by eco goals, smart tech, and solid government backing. Several government programs are helping India hit the accelerator on EV adoption, pushing the country toward cleaner, smarter transport.

Big targets are on the table: by **2030**, the aim is to make **30% of private cars, 70% of commercial vehicles, 40% of buses**, and a massive **80% of two- and three-wheelers** fully electric. That's about **80 million EVs** zipping through Indian roads! And yep, '**Make in India**' is in full swing to keep all that EV production local and self-reliant.

Globally, EVs are crushing it. In **2023**, the EV market was worth **$255.54 billion**, and it's set to skyrocket to around **$2,108.80 billion by 2033**, growing at a strong **CAGR of 23.42%**.

Back home, India's momentum is building. **January 2025** saw a solid **19.4% MoM** and **17.1% YoY** jump in EV sales—**1,69,931 units** sold in just one month. In **2023**, sales surged **49.25%** to hit **1.52 million units**. It's early days, but theSe shift is gaining serious traction.

Indian automakers are gearing up to launch nearly **a dozen new EVs in 2025**, mostly in the **premium segment**, as domestic demand grows—even while global demand cools off. The **30% EV sales goal by 2030** is looking more achievable by the day.This global shift is opening new doors—especially for suppliers. India's **EV battery market** is expected to jump from **$16.77B in 2023** to **$27.70B by 2028**.

On the infrastructure side, things are also ramping up. India has **11,000+ public charging stations** online and expected to grow 30% by end of 2025. **Maharashtra** leads the pack, followed by **Delhi** and other states.

But it doesn't stop there—the **Confederation of Indian Industry (CII)** says we need **1.32 million charging points by 2030**, which means installing over **4 lakh** every year.

Major automotive manufacturers are rapidly expanding their ultra-fast charging networks, adding new stations in key cities such as Mumbai, Pune, Hyderabad, Gurugram, Bangalore, and along major highways to enhance EV access nationwide.

Meanwhile, state-level EV plans are also in play:

- **Maharashtra** is aiming for **10% EVs in all new vehicle registrations** by **Dec 2025**
- **Karnataka** has set a goal to **electrify 100% of cargo three- and four-wheelers** by **2030**

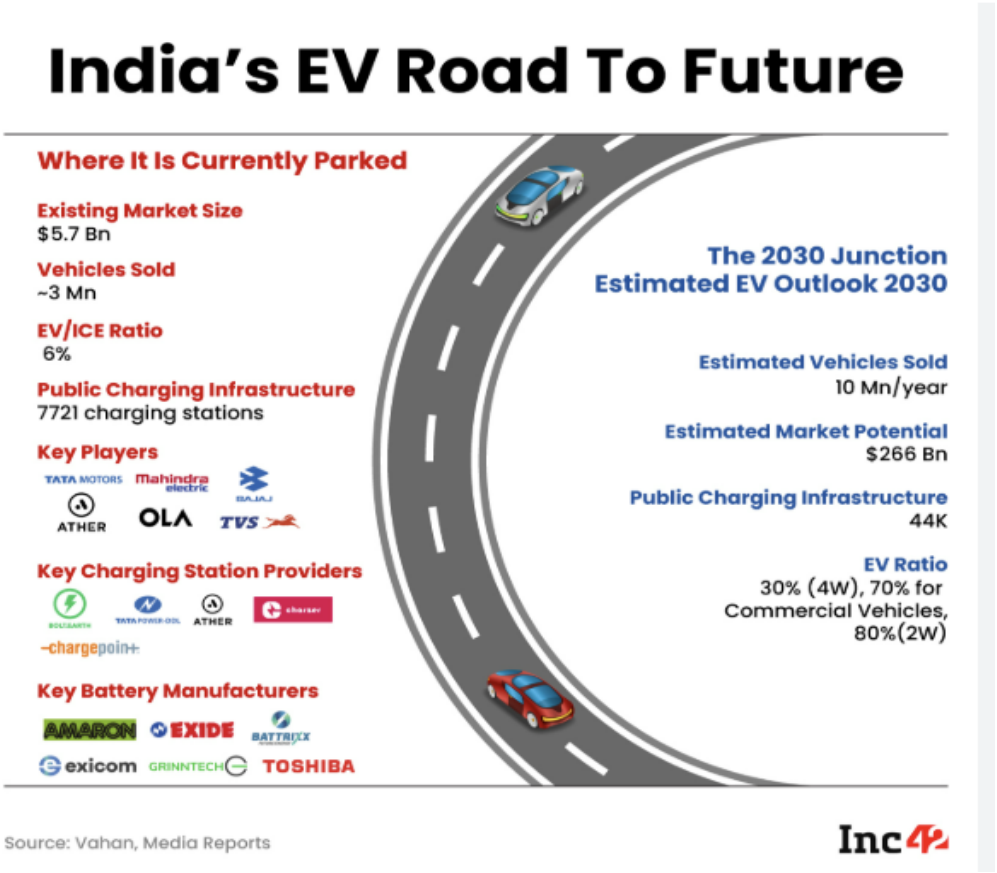


Figure 1: Infographics of EV Industry in India

India's electric mobility future is already here and charging ahead at full speed.

CHAPTER 1.1
INDUSTRY PROFILE

The Indian electric vehicle (EV) market is experiencing rapid growth which is leading to transformation of indian automobile industry. This change has been triggered by pollution and other threats to environment, limited availability of oil etc. This fast-paced growth is further being driven by new breakthroughs in chemical and battery technologies, supported by government support and initiatives.

The market has grown exponentially in past ten years with sales of 2000+ EVs recorded in 2013 to 1.7 million EVs sold in 2024.
With Covid years as an exception, the market has witnessed a 20% growth YOY and further expected to grow with CAGR of 22.4% from 2024 to 2032.

Presently, the two-wheeler segment currently dominates, however 3-wheeler segment has shown sharp growth since past few years. The market is diversifying across various vehicle types, including electric buses and trucks.

Key Trends and Growth Drivers:

- **Government Support:**

  Favorable PESTEL environment, subsidies and FAME scheme are playing key role.

- **Rising Fuel Prices:**

- Increased awareness of rising fuel costs is prompting consumers to consider EVs as a cost-effective alternative.
- **Environmental Concerns:**

  Growing awareness of environmental issues and the need for sustainable transportation is also a key factor.
- **Technological Advancements:**

  Improvements in battery technology and decreasing costs are making EVs more accessible and appealing to consumers.
- **Localization of Manufacturing:**
  Efforts to localize EV component manufacturing, especially batteries, are reducing reliance on imports and boosting domestic production.

Challenges and Opportunities:

- **Charging Infrastructure:**

  Expanding the charging infrastructure to support the growing EV fleet is a key challenge.
- **Battery Technology:**

  Further advancements in battery technology, including energy density and cost reduction, are crucial for market growth.
- **Import Dependency:**

  Reducing reliance on imported components, particularly battery cells, is a priority for the Indian government.
- **Competitive Landscape:**
  The market is becoming increasingly competitive, with both domestic and international players vying for market share.

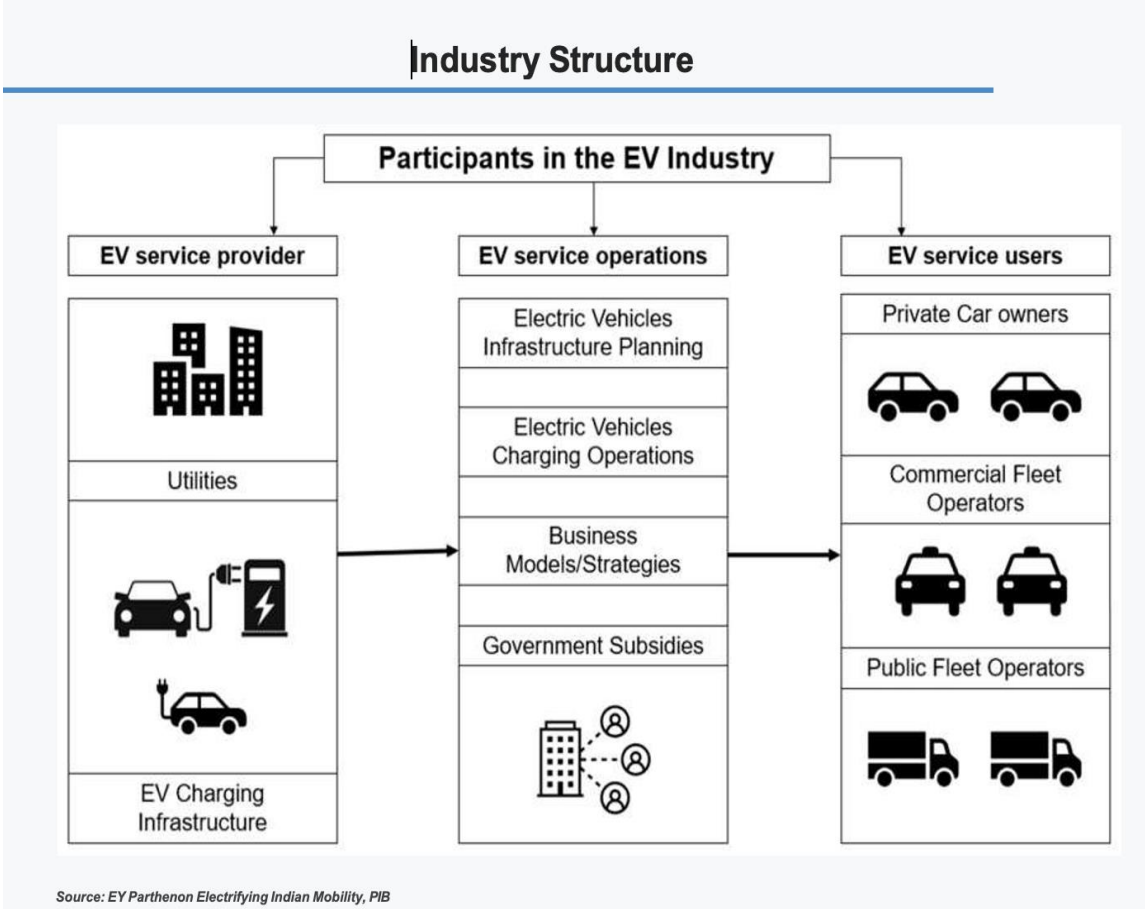


Figure 2: Structure of Indian EV Industry

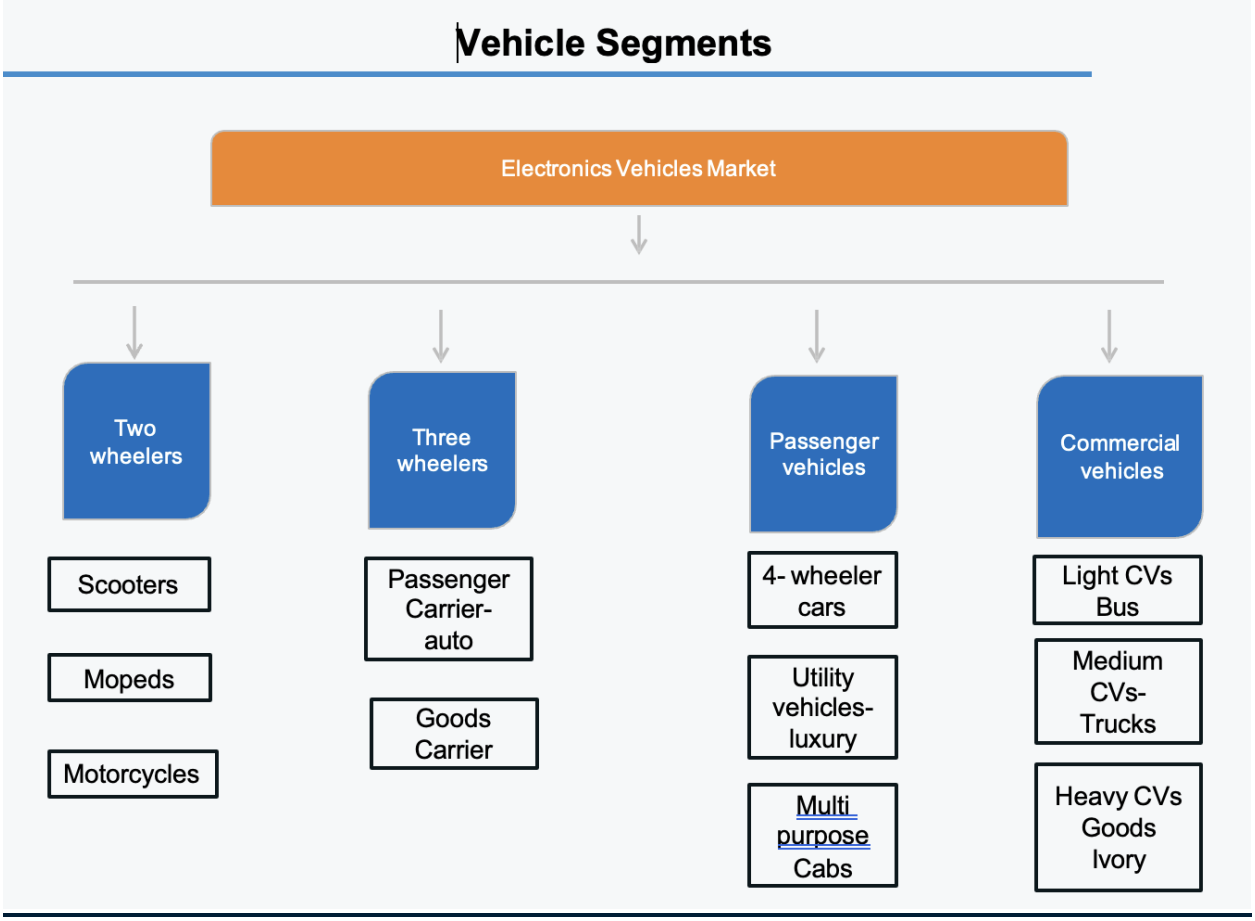


Figure 3: Segmentation of EV market (types of vehicles)

Future Outlook

The Indian EV market is set for significant growth in the following years, with projections indicating a massive increase in EV adoption across various segments. The government's commitment to achieving net-zero emissions by 2070 and its various initiatives to promote EVs are expected to further accelerate market growth.

CHAPTER 1.2
ORGANIZATION PROFILE: ELECTRIC VEHICLE INDUSTRY IN INDIA

Introduction

India's electric vehicle (EV) industry is rapidly becoming a cornerstone of the nation's push for sustainable transportation and economic resilience. As urbanization accelerates and environmental consciousness deepens, the adoption of EVs has gained significant momentum. Government initiatives and private sector investments are propelling the industry forward, positioning it as a vital contributor to India's energy security and environmental goals.

Industry Landscape and Segmentation

The Indian EV sector is defined by a complex ecosystem of stakeholders, each playing a pivotal role across the value chain. The principal segments include:

- Original Equipment Manufacturers (OEMs): Key players such as Maruti Suzuki, Tata Motors, Mahindra Electric, and Ashok Leyland are actively manufacturing electric cars, buses, and commercial vehicles. International automakers like Hyundai and MG have also expanded their presence in the Indian market. (https://www.spglobal.com/automotive-insights/en/blogs/2025/02/electric-vehicle-industry-in-india-shows-promising-growth)
- Two- and Three-Wheeler Producers: Companies including Ola Electric, Ather Energy, Hero Electric, and Bajaj Auto dominate this segment, which represents the largest share of India's EV adoption.
- Battery Manufacturers: Firms like Exide Industries and Amara Raja, alongside emerging startups, are focusing on the production and assembly of lithium-ion batteries and related technologies.
- Component and Technology Providers: A range of enterprises supply core components such as electric motors, controllers, battery management systems, and software solutions, tailored specifically for Indian applications.

- Charging Infrastructure Developers: Organizations such as Tata Power, Fortum India, and state-run entities are constructing public and private charging networks, often partnering with local authorities for deployment.
- Research and Development Institutes: Esteemed institutions, including IITs and the Indian Institute of Science (IISc), are engaged in R&D to advance battery science, lightweight materials, and indigenous technology solutions.

Leading Organizations in the Indian EV Ecosystem

The industry features a blend of established conglomerates, public sector organizations, and agile startups:

- Tata Motors: A pioneer in the large-scale production of electric passenger vehicles with popular models like the Nexon EV and Tigor EV.
- Mahindra Electric: An early leader offering a diverse portfolio, including electric cars and commercial vehicles.
- Ola Electric: Transforming the two-wheeler market with high-performance e-scooters and a focus on localized manufacturing.
- Ather Energy: Recognized for its smart, connected scooters and proprietary fast-charging network.
- Hero Electric: Boasts an extensive national footprint in the electric two-wheeler segment.
- MG Motor, Hyundai: Prominent international OEMs bringing successful global EV models to India.
- Innovative Startups: Numerous startups are introducing electric cycles, cost-effective mobility solutions, and affordable charging technologies suited for the Indian environment.

Market Dynamics and Growth Trends

India’s EV market is witnessing robust growth, with two- and three-wheelers, as well as electric buses, outpacing electric car adoption. The Ministry of Heavy Industries recorded sales exceeding 1.2 million electric vehicles in 2023, driven largely by the demand for affordable urban transport solutions. Key factors fueling market expansion include:

- Declining Battery Prices: Indigenous manufacturing and technological advancements are reducing battery costs, making EVs more accessible.

- Expansion of Charging Infrastructure: Substantial investments are being made to establish fast and accessible charging facilities in urban areas and along strategic corridors.
- Government Incentives: Policies such as FAME II (Faster Adoption and Manufacturing of Electric Vehicles) and state-level initiatives offer financial support to both manufacturers and consumers.
- Fleet Electrification: Public transportation agencies, ride-hailing services, and delivery companies, particularly in metropolitan areas, are increasingly transitioning to electric fleets.

Policy and Regulatory Environment

India's policy framework is instrumental in shaping the sector's trajectory:

- FAME II: A central scheme providing financial support for EV adoption, local manufacturing, and infrastructure development.
- State-specific Policies: States such as Maharashtra, Delhi, Tamil Nadu, and Karnataka implement tailored policies to promote manufacturing, innovation, and workforce development.
- Localization Initiatives: The 'Make in India' campaign encourages domestic production of vehicles and components, aiming to strengthen the local supply chain.
- Standardization and Safety: Ongoing efforts to establish national standards for batteries, charging connectors, and safety protocols. (https://www.nhtsa.gov/battery-safety-initiative)

Innovation and Research Focus

Innovation is central to the advancement of India's EV sector, with active research in the following domains:

- Next-generation Battery Technologies: Exploration of solid-state, sodium-ion, and locally developed lithium-ion batteries.
- Smart Mobility Solutions: Integration of IoT, artificial intelligence, and advanced fleet management systems.
- Urban Mobility Innovation: Development of electric rickshaws, affordable scooters, and shared mobility platforms tailored to Indian cities. (http://wri-india.org/research/enabling-shift-electric-auto-rickshaws-guidebook-electrification-auto-rickshaw-fleets)
- Battery Recycling and Reuse: Initiatives targeting end-of-life management and secondary applications for batteries.

Key Challenges

Despite strong progress, the industry faces several challenges:

- Charging Network Gaps: Limited accessibility in rural and semi-urban regions.
- Battery Supply Chain Dependencies: Continued reliance on imported materials and cells poses strategic risks.
- Affordability Barriers: High upfront costs, even after subsidies, remain a hurdle for widespread consumer adoption.
- Public Awareness: Misconceptions about vehicle range, battery longevity, and charging infrastructure persist.
- Human Capital: A growing need for skilled workforce in engineering, research, and technical roles.

Opportunities and Outlook

The Indian electric vehicle market holds significant promise:

- Projections indicate EVs could comprise 30% of new vehicle sales by 2030, with two- and three-wheelers leading the sector.
- India is well positioned to become a global leader in affordable electric mobility tailored for developing markets.
- Ancillary sectors such as battery recycling, software development, and charging infrastructure are set for rapid expansion.
- The industry will contribute to national objectives of lowering oil imports, improving urban air quality, and fostering job creation.

Corporate Social Responsibility and Sustainability

Firms in the Indian EV sector are increasingly committed to:

- Ethical sourcing and processing of raw materials.
- Skill development through vocational and STEM education programs.
- Community engagement via public outreach and sustainable mobility campaigns.
- Environmental responsibility through eco-friendly manufacturing and circular economy practices. (https://www.mdpi.com/2071-1050/14/24/17010)

CHAPTER 1.3
OBJECTIVE OF STUDY

The primary objective of this study is to gain more insights about the EV market in India.The effort is to make the study data driven and applying the knowledge gained during our EMBA course.

This includes data collection from primary and secondary sources and further understanding the data handling process, evaluating historical trends, identifying key market drivers, and quantifying the influence of various factors on EV adoption and pricing.

To achieve this, the study integrates descriptive and analytical methodologies. It conducts **trend analysis** to uncover the growth trajectory, market segmentation, and sales performance across different types of EVs—such as two-wheelers, three-wheelers, passenger vehicles, and commercial fleets. This analysis helps in understanding the pace and direction of EV penetration in the broader Indian automobile market.

In addition, the study employs **multivariable linear regression modeling** to determine the statistical relationship between EV prices and influencing features like range, top speed, efficiency, acceleration, and seating capacity. Code generation through Python to perform the desired tasks

The goal is to provide empirical insights that can guide manufacturers in product development and pricing strategies, and support policymakers in crafting targeted strategies.

CHAPTER 2
LITERATURE REVIEW: THE EVOLUTION AND ADOPTION OF ELECTRIC VEHICLES IN INDIA

Introduction

Electric Vehicles (EVs) are central to India's clean mobility transition, offering a sustainable alternative to fossil fuel-based transport. This review draws from consumer insights, historical perspectives, and recent statistical data to understand the trajectory, adoption patterns, and challenges of EVs in the Indian context. It leverages consumer studies, government policy evaluations, and industry performance from FY2012 to FY2025.

Consumer Behavior & Perception

A comprehensive 2021 survey (Indian Automotive Consumer Canvass - IACC) with over 200,000 responses revealed pivotal consumer insights:
- Post-COVID Mobility Shift: 54% of respondents intended to purchase a vehicle in 2021. However, 77% postponed their decision due to pandemic-related uncertainties.
- EV Interest: 37% of two-wheeler buyers and 33% of four-wheeler buyers showed increased interest in EVs post-2020. Product variety and improved affordability were cited as key factors driving this trend.
- Barriers to Adoption: The primary barriers were charging infrastructure (50%), high upfront cost, and limited vehicle options.

Table 1: Key Drivers & Barriers for EV Adoption (Based on IACC 2021)

Factors	Positive Influence (%)	Barrier (%)
Better product options	55	
Improved affordability	31	33 (4W), 28 (2W)
Charging infrastructure	20	50
Attractive technologies	39	
Safety concerns		~13

Historical Context and Infrastructure Gaps

As per a 2013 research study, India's EV industry faced foundational gaps including weak consumer awareness, high battery costs, and inadequate policy support. Hypotheses focused on range anxiety, price sensitivity, and skepticism over total cost of ownership (TCO). Over the last decade, these have been partially addressed.

Current Market Landscape (FY2024–25)

India's EV market reached 2.04 million units sold in FY24-25, a 15.7% YoY increase. The chart below illustrates EV sales growth and their share in total vehicle sales.

Battery Ecosystem & Growth

India's EV battery market is poised for exponential growth, projected to rise from US$ 16.77 billion in 2023 to US$ 27.70 billion by 2028. This surge is driven by demand for lithium-ion cell manufacturing, localizing supply chains, and large-scale energy storage requirements.

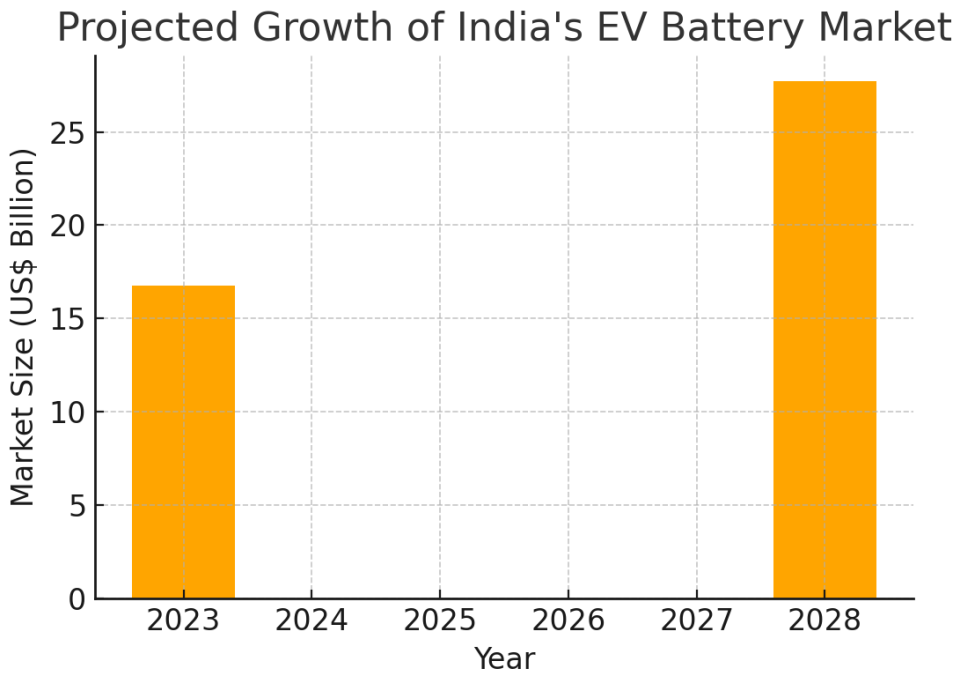


Figure 4: Projected Growth of India's EV Battery Market

Two-Wheeler (E2W) OEM Market Share

The E2W segment continues to dominate the Indian EV market. In FY24-25, Ola Electric remained the market leader despite a slight decline in share, followed by TVS Motor and Bajaj Auto. The pie chart below presents the current distribution of market share among leading OEMs.

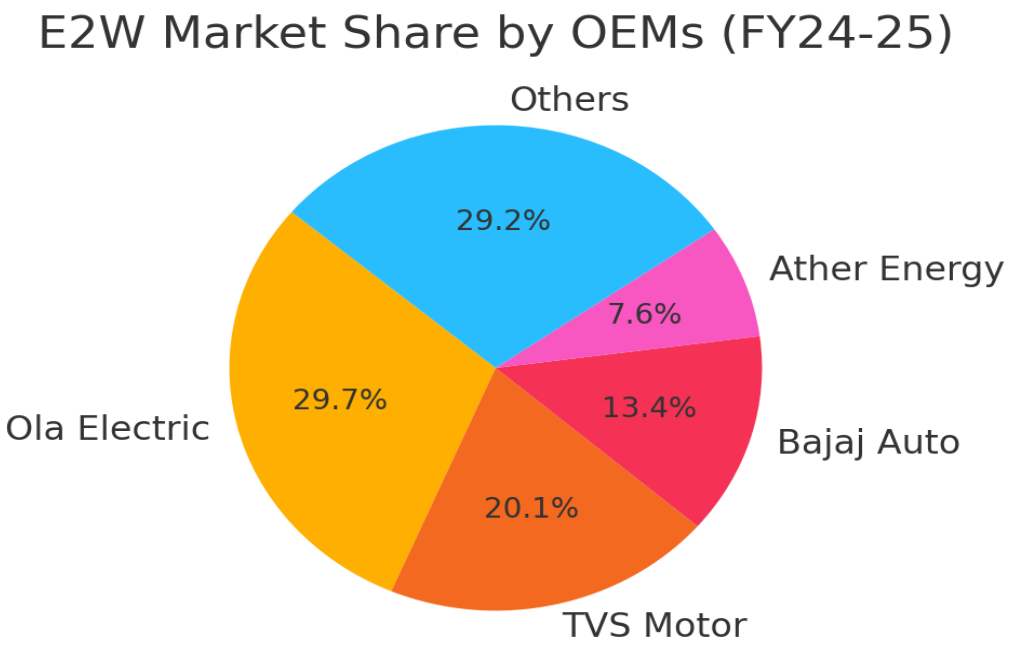


Figure 5: E2W Market Share

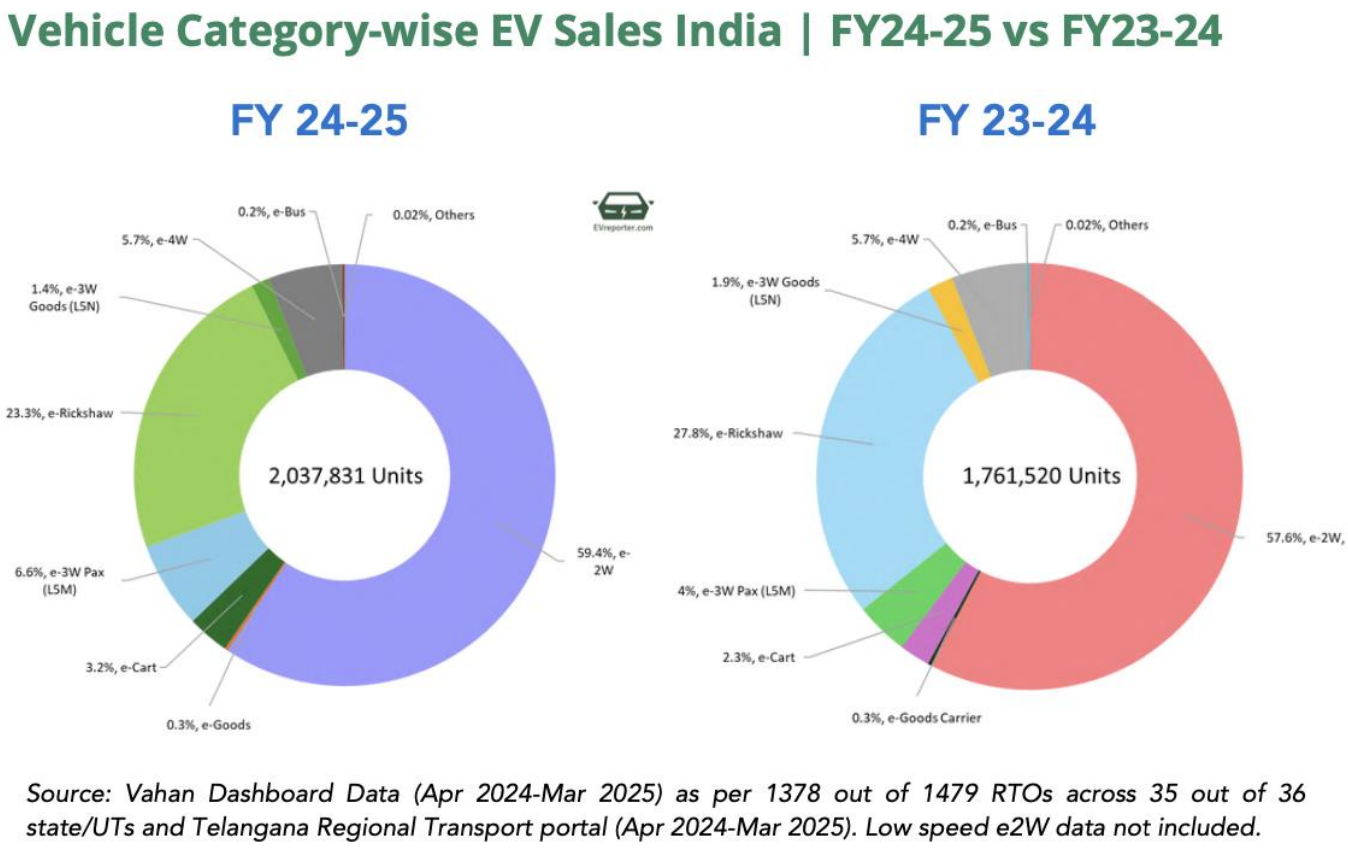


Figure 6: Vehicle Category-wise EV Sales

Category	EV Sales	Total Sales	% EV Penetration
Two-Wheelers	1,209,772	19,551,949	6.2%
3W Passenger	135,260	593,849	22.8%
3W Goods	28,023	130,150	21.5%
Four-Wheelers	115,800	4,282,486	2.7%
Buses	3,493	73,852	4.7%
Goods Carrier	5,465	803,339	0.7%

Figure 7: Segment-wise EV Penetration (FY 2024-25)

SWOT Analysis of the Indian EV Sector

Strengths

- • Strong government policy support (FAME-II, PM E-DRIVE).
- • Large consumer base with rising EV awareness.
- • Growing startup ecosystem and OEM investments.

Weaknesses

- • Limited rural EV penetration and high upfront costs.
- • Underdeveloped EV charging infrastructure.
- • Battery disposal and recycling systems still evolving.

Opportunities

- Potential to become a global EV manufacturing hub.
- Massive scope for charging station expansion (1.32 million by 2030).
- Growing export demand and technology innovation.

Threats

- • Global supply chain disruptions (e.g., lithium shortage).
- • Dependence on imports for key battery materials.
- • Competition from established global OEMs entering India.

Policy Framework Supporting EV Adoption

India's push for EV adoption is strongly backed by both central and state-level initiatives:
- FAME II: ₹10,000 crore subsidy covering vehicles and infrastructure.
- PM E-DRIVE (2024–2026): ₹10,900 crore for public chargers and manufacturing.
- 100% FDI permitted in the auto component sector under the automatic route.
- GST on EVs reduced to 5%; incentives for battery manufacturing under PLI scheme.
- State policies (Delhi, Maharashtra, Tamil Nadu) offer road tax waivers, capital subsidies, and EV mandates.

CHAPTER 3
RESEARCH METHODOLOGY FOR THE ANALYSIS OF THE ELECTRIC VEHICLE (EV) MARKET IN INDIA: TREND AND REGRESSION ANALYSIS

The research methodology used is mix of quantitative and qualitative data to offer a holistic view of the EV market. The quantitative component focuses on statistical analysis and model building, whereas the qualitative component offers insights into consumer behavior, government policies, and industry perspectives.

- Descriptive Research: To identify and describe prevailing trends, market size, growth rates, and segment performance within the EV sector.
- Analytical Research: To examine causal relationships, especially through regression analysis, to determine the impact of various factors such as pricing, policy initiatives, and technological developments on EV adoption.

Objectives of the Methodology

- To identify and analyze key trends shaping the Indian EV market.
- To quantify the relationship between influencing factors and market performance through regression analysis.
- To provide recommendations based on empirical evidence for future market strategies and policymaking.

Data Sources

The research utilizes majorly secondary data sources to enhance comprehensiveness and reliability.

Secondary Data

- Market Reports: Data from credible and reliable sources such as the Society of Indian Automobile Manufacturers (SIAM), NITI Aayog, EV reporter, IBEF
- Academic Publications: Review of published research, white papers, and case studies relevant to the Indian EV sector.

- Online Databases: Utilization of data from databases like Census, VahanStatista, IEA, Kaggle and for market statistics, international comparisons.
- News and Media Reports: Analysis of recent news articles, press releases, and policy announcements.

Analytical Framework

Trend Analysis

Trend analysis constitutes the core of the descriptive research phase. Historical data on EV sales, market shares, price fluctuations, and charging infrastructure development are collected and analyzed using:

- Time Series Analysis: To observe patterns, seasonality, and cyclical movements in EV adoption over time.
- Growth Rate Calculations: Annual compound growth rates and market penetration rates are computed to evaluate the pace of market expansion.
- Segmental Analysis: Examination of market sub-segments such as two-wheelers, three-wheelers, passenger cars, and commercial EVs.

Regression Analysis

Regression analysis is employed to identify and quantify the impact of various independent variables on the adoption and sales of EVs in India.

- Model Selection: Multiple linear regression is used to analyze the relationship between the dependent variable (e.g., EV sales volume) and independent variables such as government subsidies, fuel prices, battery cost, charging infrastructure, GDP per capita, and policy changes.
- Variable Selection: Variables are chosen based on theoretical relevance and data availability. Dummy variables are included for policy interventions to capture their discrete impact.
- Model Validation: Diagnostic tests such as multicollinearity checks, residual analysis, and model fit statistics (R^2, adjusted R^2, F-statistic) are conducted to ensure robustness.
- Software Tools: Analytical work is carried out using statistical packages such as R, Python (with Pandas and statsmodels), Colab.

Limitations

The methodology acknowledges certain limitations:

- Data availability and reliability, particularly regarding recent EV sales and charging infrastructure deployment.
- Potential respondent bias in surveys and interviews.
- Constraints in generalizing findings due to the diversity of the Indian market.

Activity 1

In this activity, multivariable linear regression was performed to showcase the procedure of model building using MVR and understand the influence of independent variables on dependent variable.

Dataset considered was https://www.kaggle.com/datasets/vanillatyy1/electric-vehicle-dataset?select=cars_data_cleaned.csv

Multivariable Linear Regression

The price in Euro is taken as the **dependent variable**, and analyze how it's influenced by independent variables such as:

- AccelSec
- TopSpeed_KmH
- Range_Km
-
- Efficiency_WhKm
- Seats

Assumptions of Multivariable Linear Regression

Before running the regression, we check the key assumptions:

- **Linearity**: Relationship between predictors and target should be linear.
- **Independence**: Observations should be independent.
- **Homoscedasticity**: Constant variance of residuals.
- **Normality of Residuals**: Residuals should follow a normal distribution.
- **No Multicollinearity**: Predictors should not be highly correlated.

Python Code for running MVR on dataset

```
import pandas as pd
import matplotlib.pyplot as plt
from statsmodels.tsa.seasonal import seasonal_decompose
from sklearn.linear_model import LinearRegression
import numpy as np

# Step 1: Create the dataset
data = {
    'Year': list(range(2013, 2025)),
    'Sales': [
        18423223, 19724371, 20468971, 21863281, 24981312, 26266179,
        21545551, 18620233, 17617606, 21206846, 23853463, 26107679
    ]
}

df = pd.DataFrame(data)
df.set_index('Year', inplace=True)

# Step 2: Plot the original data
plt.figure(figsize=(10, 5))
plt.plot(df.index, df['Sales'], marker='o', linestyle='-', label='Vehicle Sales')
plt.title('Yearwise Vehicle Sales')
plt.xlabel('Year')
plt.ylabel('Sales')
plt.grid(True)
plt.legend()
plt.tight_layout()
plt.show()
```

Figure 8: Python Code for running MVR

In next step **multivariable regression** is run, including assumption diagnostics and graphs.

Multivariable Linear Regression Results – Summary

Model Overview

- **Dependent Variable**: PriceEuro
- **R^2 = 0.733** → About **73.3%** of the variability in EV price is explained by the model.
- **Adjusted R^2 = 0.719** → Good fit, accounting for number of predictors.
- **F-statistic p-value < 0.001** → Model is statistically significant.

Coefficient Insights

Variable	Coefficient	P-value	Interpretation
Intercept	**-79,500**	**0.001**	**Base price offset**
AccelSec	**1,436**	**0.154**	**Slower acceleration → slightly higher price (not significant)**
TopSpeed_KmH	**574**	**<0.001**	**Higher top speed → higher price**
Range_Km	**57**	**0.015**	**Each additional km of range increases price**
Efficiency_WhKm	**194**	**0.005**	**Higher energy usage → higher price**
Seats	**-6,996**	**0.006**	**More seats → lower price (unusual but significant)**

Table 2: Coefficient Insights

Assumption Checks

Linearity & Residuals

- **Residuals vs Fitted**: Mostly centered around zero with no clear pattern → acceptable linearity and homoscedasticity.

Normality of Residuals

- Histogram shows a moderately skewed residual distribution, but sufficient for linear regression.

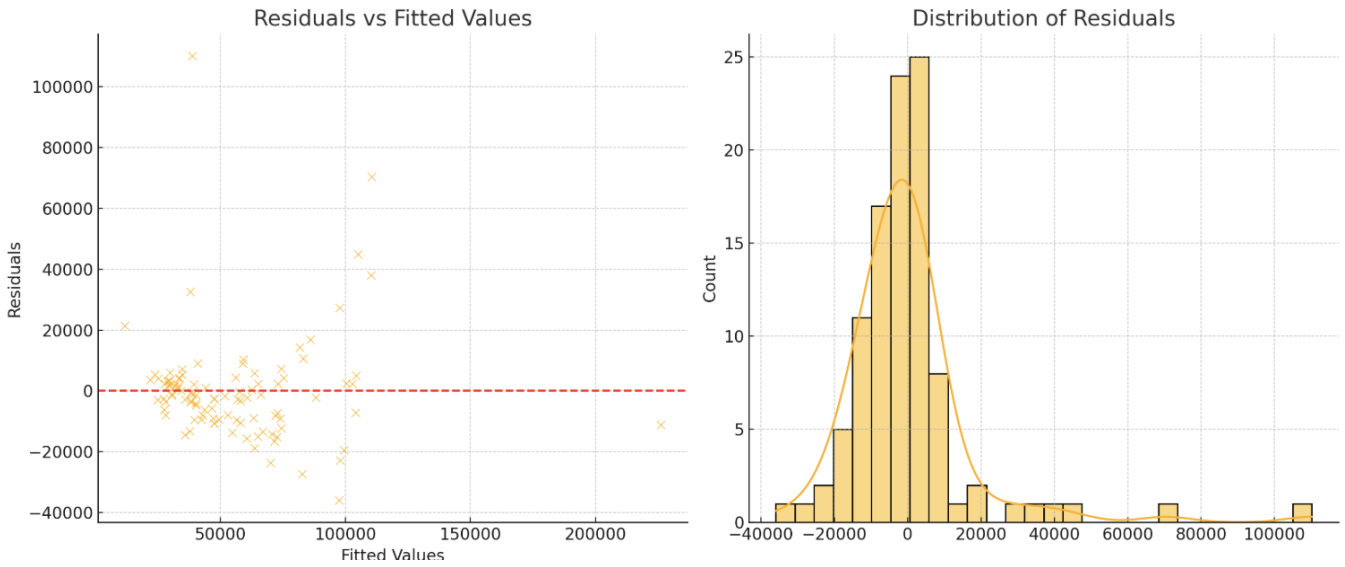


Figure 9: Linearity and Normality Residuals

Multicollinearity (VIF > 10 is a concern):

Feature	VIF
AccelSec	8
TopSpeed_KmH	39
Range_Km	**21.58**
Efficiency_WhKm	**44.97**
Seats	**40.52**

Table 3: Multicollinearity Results

High VIF values indicate **multicollinearity**, especially among top speed, efficiency, and seats. A dimension reduction (PCA) or variable exclusion may be needed for better modeling.

Conclusion

- **Key Predictors** of EV price are: **Top Speed**, **Range**, **Efficiency**, and **Seats**.
- The model explains a substantial portion of price variance but suffers from **multicollinearity**, potentially impacting coefficient stability.
- For actionable insights or deployment, reducing multicollinearity or applying regularization (like Ridge or Lasso regression) is recommended.

Activity 2

This activity involved executing a multivariable linear regression on the dataset car_dataset_india using Python and plot various graphs. This is the latest dataset from Kaggle comprising of 10000 tuples. A small section of dataset is shown below.

Data Preparation

Data is prepared by selecting the independent and dependent variables. Dataset is then split into training and testing sets.

)	Brand	Model	Year	Fuel_Type	Transmission	Price	Mileage	Engine_CC	Seating_Capacity	Service_Cost
1	Toyota	Innova	2024	CNG	Manual	2020000.0	27.3	800	4	24100.0
2	Kia	EV6	2023	Diesel	Manual	1770000.0	16.4	2500	7	18800.0
3	Maruti Suzuki	Dzire	2016	Petrol	Manual	3430000.0	17.6	2000	6	24700.0
4	Honda	Amaze	2019	Petrol	Manual	1610000.0	19.2	2500	6	23300.0
5	Honda	City	2015	Electric	Manual	1840000.0	15.8	1000	5	5800.0

```
[4]  from sklearn.model_selection import train_test_split

     features = ['Year', 'Mileage', 'Engine_CC', 'Seating_Capacity', 'Service_Cost']
     target = 'Price'

     X = ds[features]
     y = ds[target]

     X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

     print("Shape of X_train:", X_train.shape)
     print("Shape of X_test:", X_test.shape)
     print("Shape of y_train:", y_train.shape)
     print("Shape of y_test:", y_test.shape)
```

```
Shape of X_train: (8000, 5)
Shape of X_test: (2000, 5)
Shape of y_train: (8000,)
Shape of y_test: (2000,)
```

Model Building

Train a multivariable linear regression model on the training data. Writing/generating the python code to run the regression.

```
[5]  from sklearn.linear_model import LinearRegression

     model = LinearRegression()
     model.fit(X_train, y_train)
```

```
▾ LinearRegression
LinearRegression()
```

Model Evaluation

Import the necessary evaluation metrics and calculate the MSE and R-squared score on the test set.

```
[6]  from sklearn.metrics import mean_squared_error, r2_score

     y_pred = model.predict(X_test)

     mse = mean_squared_error(y_test, y_pred)
     r2 = r2_score(y_test, y_pred)

     print(f"Mean Squared Error (MSE): {mse}")
     print(f"R-squared (R2) Score: {r2}")
```

```
Mean Squared Error (MSE): 779733375883.0509
R-squared (R2) Score: -0.0019836884282684597
```

Results and Visualization

Create plots to visualize the relationship between the features and the target variable, as well as the model's predictions.

```python
import matplotlib.pyplot as plt
import numpy as np

# Scatter plots of features vs. target
fig, axes = plt.subplots(nrows=1, ncols=len(X_test.columns), figsize=(20, 5))
for i, col in enumerate(X_test.columns):
    axes[i].scatter(X_test[col], y_test, alpha=0.5)
    axes[i].set_title(f'{col} vs. Price')
    axes[i].set_xlabel(col)
    axes[i].set_ylabel('Price')
plt.tight_layout()
plt.show()

# Scatter plot of actual vs. predicted prices
plt.figure(figsize=(8, 8))
plt.scatter(y_test, y_pred, alpha=0.5)
plt.plot([y_test.min(), y_test.max()], [y_test.min(), y_test.max()], 'k--', lw=2)
plt.xlabel('Actual Price')
plt.ylabel('Predicted Price')
plt.title('Actual vs. Predicted Prices')
plt.show()
```

ACTIVITY 3

In this activity, a small dataset of Electric Vehicle Industry of India was created which showed the overall automobile sales, EV sales over the year, YOY growth. Trend analysis and MVR was performed.

DATASETS CONSIDERED (Table 4 & 5)

Year	Yearwise Vehicle Sales	Yearwise EV Sales	Annual Share of EV Mkt (%)	YOY Growth of Automobile Sales (%)	YOY Growth EV Sales (%)	Yearwise GDP ($ Trillion)
2013	18423223.00	2443.00	0.01	-	-	1.86
2014	19724371.00	16000.00	0.08	7.06	554.93	2.04
2015	20468971.00	22000.00	0.11	3.78	37.50	2.10
2016	21863281.00	20000.00	0.09	6.81	-9.09	2.30
2017	24981312.00	55867.00	0.22	14.26	179.34	2.65
2018	26266179.00	96508.00	0.37	5.14	72.75	2.70
2019	21545551.00	147623.00	0.69	-17.97	52.96	2.84
2020	18620233.00	176202.00	0.95	-13.58	19.36	2.68
2021	17617606.00	148382.00	0.84	-5.38	-15.79	3.17
2022	21206846.00	490697.00	2.31	20.37	230.70	3.35
2023	23853463.00	1248866.00	5.24	12.48	154.51	3.57
2024	26107679.00	1752406.00	6.71	9.45	40.32	3.91

S.No	Company	Battery Capacity kwh	Motor Power kw	Max Power bhp	Max Torque Nm	Range (km)	Sales 25	Sales 24
1	Tata Motors (Nexon)	46.08	110	148	215	489	61350	69645
2	MG Motor	50.3	129	174.33	280	461	32762	13893
3	Mahindra & Mahindra	39.4	100	147.51	310	456	8859	6948
4	BYD Automobiles	71.7	70	93.87	180	465	3778	2278
5	PCA Automobiles	29.2	57	108	143	320	2218	2518
6	Hyundai Creata	42	99	134.1	395	430	2654	2016

TREND ANALYSIS

Generating python code to perform the Trend Analysis on overall automobile sales.

```
import pandas as pd
import matplotlib.pyplot as plt
from statsmodels.tsa.seasonal import seasonal_decompose
from sklearn.linear_model import LinearRegression
import numpy as np

# Step 1: Create the dataset
data = {
    'Year': list(range(2013, 2025)),
    'Sales': [
        18423223, 19724371, 20468971, 21863281, 24981312, 26266179,
        21545551, 18620233, 17617606, 21206846, 23853463, 26107679
    ]
}

df = pd.DataFrame(data)
df.set_index('Year', inplace=True)
```

PLOTTING THE GRAPH

```
# Step 2: Plot the original data
plt.figure(figsize=(10, 5))
plt.plot(df.index, df['Sales'], marker='o', linestyle='-', label='Vehicle Sales')
plt.title('Yearwise Vehicle Sales')
plt.xlabel('Year')
plt.ylabel('Sales')
plt.grid(True)
plt.legend()
plt.tight_layout()
plt.show()
```

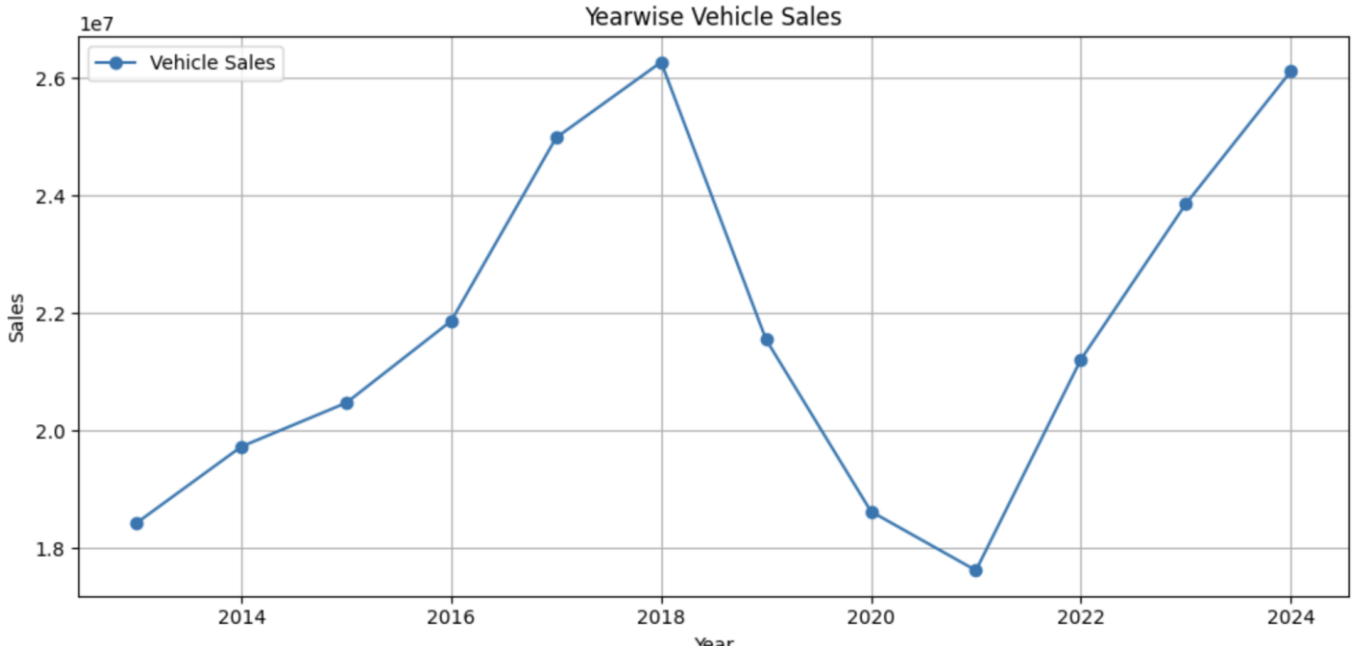


Figure 10: Yearwise Vehicle Sales

```
# Step 3: Add data for EV sales
data['EV Sales'] = [
    62198, 89974, 114037, 157134, 236841, 361307,
    327474, 231459, 472481, 806327, 1128546, 1171011
]
df['EV Sales'] = data['EV Sales']

# Step 4: Plot bar graph for Total Sales and EV Sales
df[['Sales', 'EV Sales']].plot(kind='bar', figsize=(10, 6))
plt.title('Yearwise Total Vehicle Sales and EV Sales')
plt.xlabel('Year')
plt.ylabel('Sales')
plt.xticks(rotation=45)
plt.legend(['Total Sales', 'EV Sales'])
plt.tight_layout()
plt.show()
```

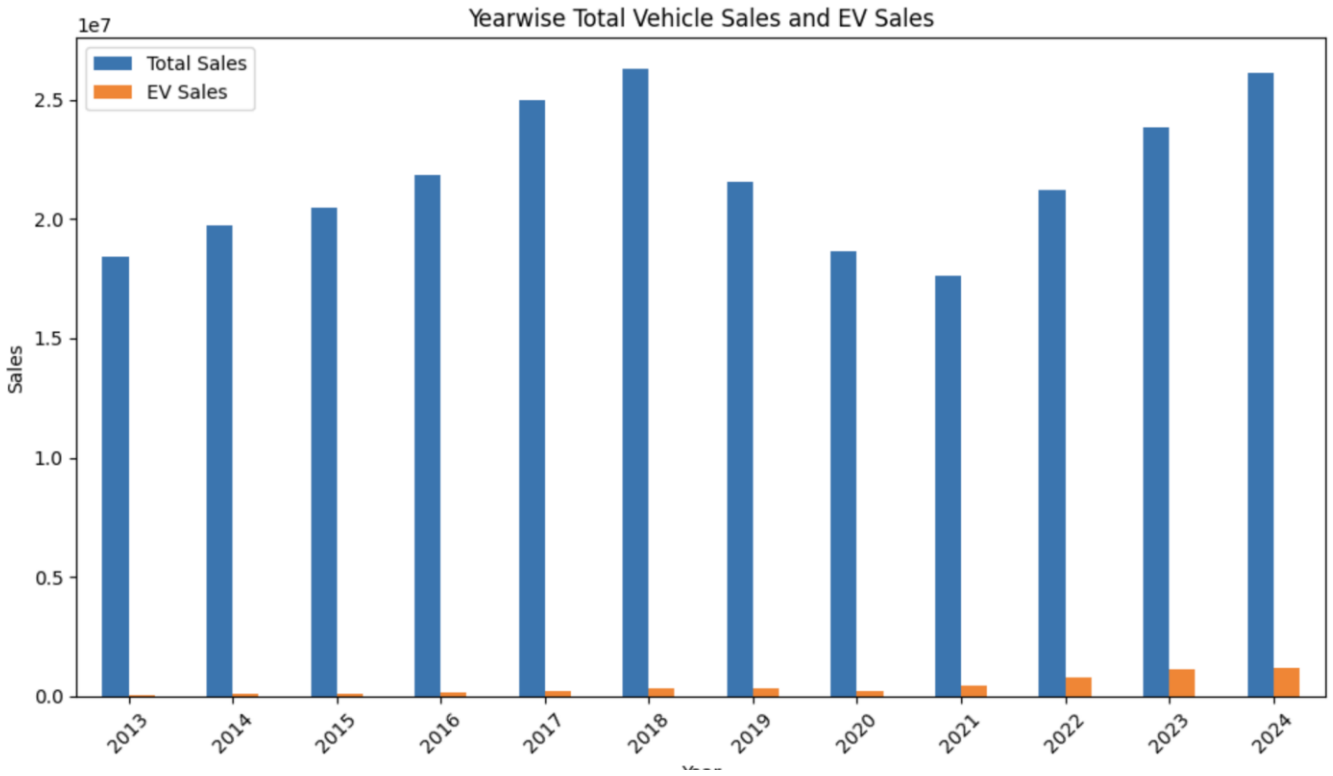


Figure 11: Yearwise Total Vehicle Sales and EV Sales

Plot the trend of EV sales over time as requested by the subtask instructions.

```
[ ] plt.figure(figsize=(10, 5))
    plt.plot(df.index, df['EV Sales'], marker='o', linestyle='-', label='EV Sales')
    plt.title('Trend of EV Sales Over Time')
    plt.xlabel('Year')
    plt.ylabel('EV Sales')
    plt.grid(True)
    plt.legend()
    plt.tight_layout()
    plt.show()
```

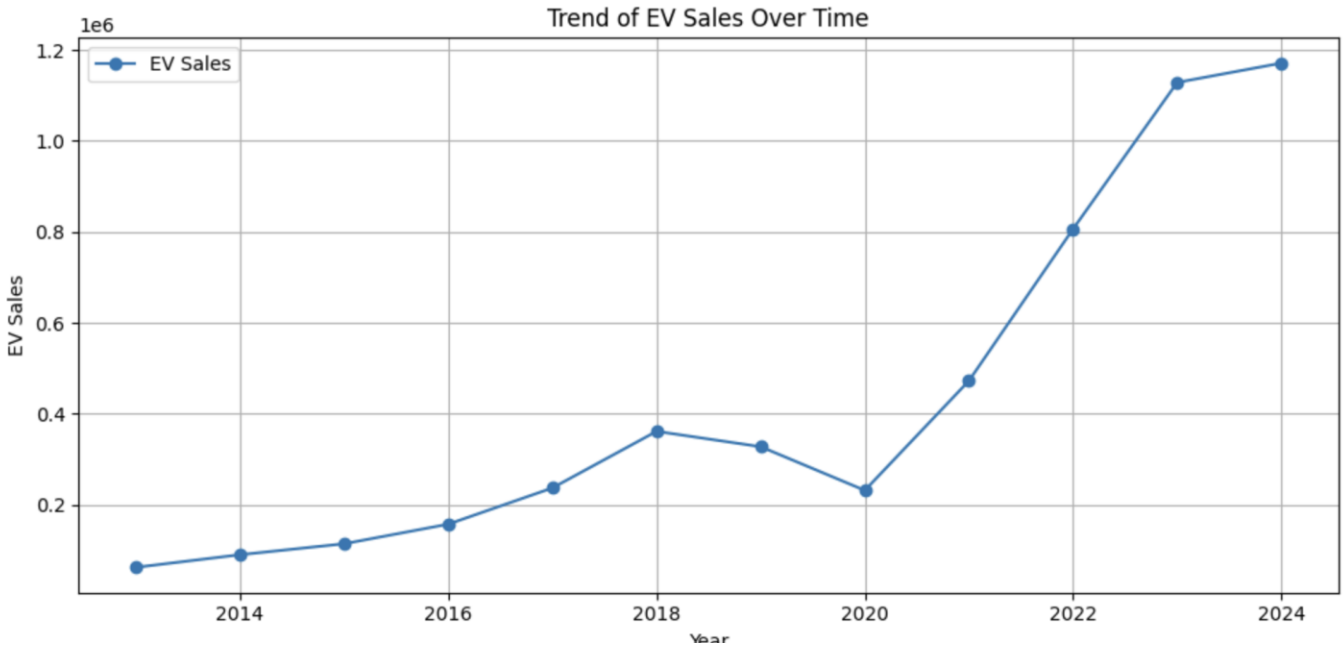


Figure 12: Trend of EV Sales Over Time

REGRESSION ANALYSIS

GENERATING PYTHON CODE TO PERFORM REGRESSION AND PREDICT FUTURE VALUES

```
# Define the future years
future_years = range(2025, 2031)
X_future_years = np.array(future_years).reshape(-1, 1)

# Assume a simple linear growth for future EV Sales based on the last few years
# Calculate the average growth rate of EV Sales over the last 3 years
recent_ev_sales_growth = df['EV Sales'].diff().tail(3).mean()
last_ev_sales = df['EV Sales'].iloc[-1]
future_ev_sales_assumption = [last_ev_sales + recent_ev_sales_growth * (i + 1) for i in range(len(future_years))]

# Assume future Total Sales follow a linear trend based on the last few years
# This is a simplification to create the X_future structure for prediction
recent_sales_growth = df['Sales'].diff().tail(3).mean()
last_sales = df['Sales'].iloc[-1]
future_sales_assumption = [last_sales + recent_sales_growth * (i + 1) for i in range(len(future_years))]

X_future_data = {
    'Year': future_years,
    'Sales': future_sales_assumption,
    'EV Sales': future_ev_sales_assumption
}
X_future = pd.DataFrame(X_future_data)

# Ensure the columns in X_future match the order and names of the columns used to train the model (X)
# The original X had 'Year', 'Sales', 'EV Sales'
X_future = X_future[['Year', 'Sales', 'EV Sales']]
```

Visualize the results

Plot the actual sales, total sales and EV sales regression results, and future predictions.

Generate Python Code

```
# 1. Reset the index of the original DataFrame df to include 'Year' as a column.
df_reset = df.reset_index()
# 2. Create a new DataFrame df_future from the X_future_data dictionary.
df_future = pd.DataFrame(X_future_data)
# 3. Plot the actual 'Sales' from the original data (df_reset) against 'Year' .
plt.figure(figsize=(12, 6))
plt.plot(df_reset['Year'], df_reset['Sales'], marker='o', linestyle='-', label='Actual Sales')
# Use the fitted linear regression model to predict sales for the historical years
# Ensure the columns in df_reset used for prediction match the training data columns
X_historical = df_reset[['Year', 'Sales', 'EV Sales']]
y_historical_pred = model.predict(X_historical)
# 4. Plot these predicted values against 'Year' as a line plot, labeling it 'Regression Fit'.
plt.plot(df_reset['Year'], y_historical_pred, color='red', linestyle='--', label='Regression Fit')
# 5. Plot the predicted future sales (y_future) against the future years .
plt.plot(df_future['Year'], y_future, color='green', linestyle='--', label='Future Predictions')
# 6. Add a title to the plot
plt.title('Vehicle Sales: Actual, Regression Fit, and Future Predictions')
# 7. Add labels to the x and y axes
plt.xlabel('Year')
plt.ylabel('Sales')
# 8. Include a legend
plt.legend()
# 9. Add a grid
plt.grid(True)

# 10. Use plt.tight_layout()
plt.tight_layout()

# 11. Display the plot
plt.show()
```

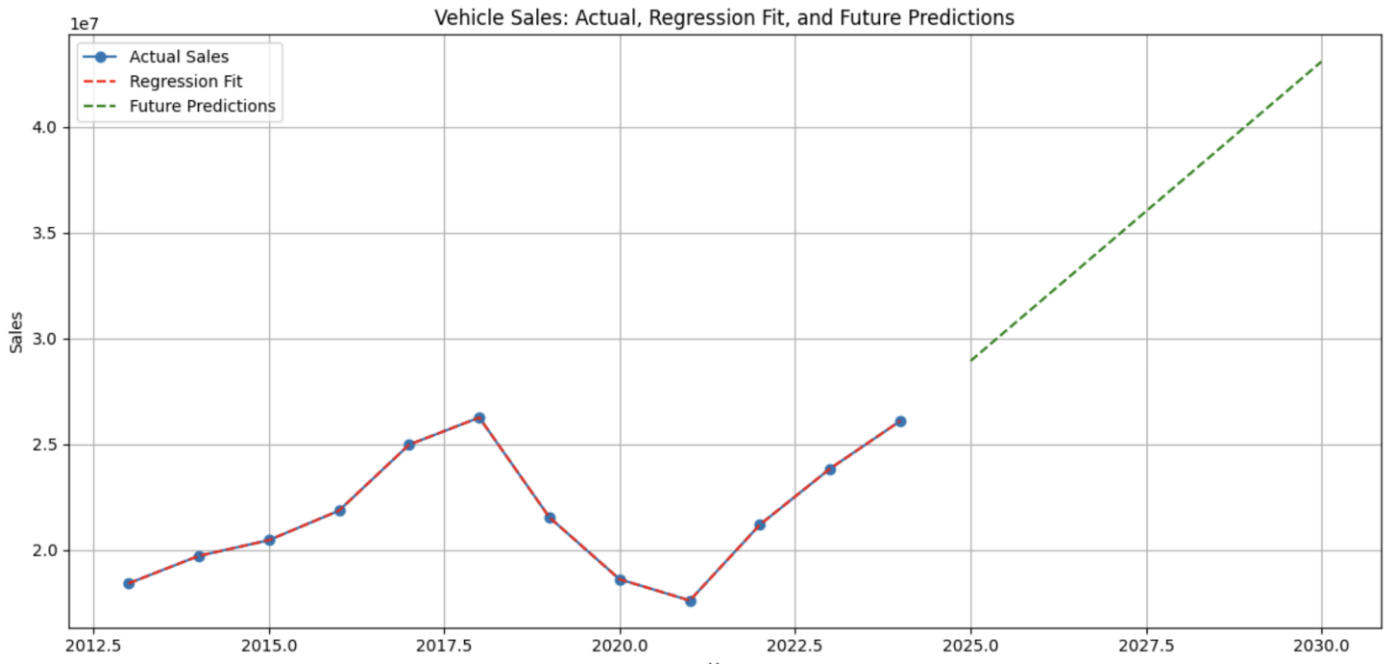


Figure 13: Vehicle Sales: Actual, Regression Fit and Future Predictions

Data Analysis Key Findings

- The analysis successfully loaded the EV sales data, visualized the historical trend of EV sales, fitted a multivariable linear regression model using Year, Sales, and EV Sales as predictors for Sales, and made predictions for future sales.
- The historical data shows a generally increasing trend in both total sales and EV sales.
- The linear regression model was successfully fitted to the historical data.
- Future sales predictions were generated for the years 2025 through 2030.
- The visualization shows the actual historical sales, the regression model's fit to this historical data, and the predicted future sales.

CHAPTER 4
RESULTS

This study conducted a multifaceted analysis of the Indian Electric Vehicle (EV) market using a combination of trend analysis and multivariable linear regression modeling. The data-driven exploration yielded several critical findings:

1. **Market Growth Trends**
   EV sales in India have grown significantly, with total units rising from just a few thousand in 2013 to over 1.75 million in 2024. The annual market share of EVs expanded from under 0.1% in 2013 to over 6.7% in 2024, signaling a strong upward trajectory.
2. **Regression Model Performance**
   A multivariable linear regression model was applied to estimate EV prices based on performance characteristics (acceleration, range, efficiency, top speed, seating capacity). The model achieved an R^2 of **0.733**, indicating that 73.3% of price variance could be explained by the selected features.
3. **Key Influencing Factors on Price**
   - **Top Speed**, **Range**, and **Efficiency** were positively correlated with price.
   - **Number of Seats** had a statistically significant negative correlation, suggesting that higher seating may be offered in lower-cost vehicle categories.
   - **Acceleration** (AccelSec) had an insignificant effect, indicating a weaker relationship with price in the current Indian market.
4. **Multicollinearity Analysis**
   The analysis revealed **high Variance Inflation Factor (VIF)** scores (>10) for several features, including Efficiency and Top Speed, suggesting multicollinearity. This could impact model interpretability and suggests the need for dimension reduction techniques in future models.
5. **Forecasting Trends**
   Using regression-based forecasting, vehicle sales are projected to continue rising through 2030, with EV sales increasing disproportionately due to policy support, declining battery costs, and infrastructure improvements.

CHAPTER 5
CONCLUSION

The findings of this study reinforce the strategic significance of the electric vehicle sector within India's automotive and clean energy transition. EV adoption is accelerating, driven by policy incentives, environmental awareness, and technological advancements.

Through quantitative trend analysis, the research captured a consistent and compelling growth pattern in EV market penetration. Furthermore, multivariable regression illuminated the factors most closely tied to EV pricing, offering actionable insights for manufacturers and policymakers.

Despite the encouraging trends, certain structural challenges persist—namely, infrastructure inadequacies, affordability barriers, and dependence on imported battery components.

Addressing these barriers will be crucial to achieving the government’s ambitious EV adoption targets for 2030 and beyond.

In conclusion, the Indian EV industry is evolving into a high-potential market characterized by rapid innovation and policy momentum. However, realizing its full potential will require coordinated investments in manufacturing, R&D, charging infrastructure, and consumer awareness.

CHAPTER 6
FUTURE WORK

While the current study offers meaningful insights into the Indian EV landscape, several avenues exist for further research and refinement:

1. **Advanced Regression Techniques**
   Future studies can apply **Ridge**, **Lasso**, or **ElasticNet** regression models to overcome multicollinearity and improve predictive accuracy.
2. **Time Series Forecasting**
   Building **ARIMA** or **Prophet models** for EV sales forecasting can provide seasonality-aware projections for manufacturers and governments.
3. **Consumer Behavior Modeling**
   Integrating more granular survey data (e.g., income, education, urban/rural split) could enrich the understanding of purchase intent and affordability constraints.
4. **Real-time Policy Impact Assessment**
   Ongoing evaluation of FAME-II, state EV policies, and PLI schemes through quasi-experimental designs could reveal the true effectiveness of interventions.
5. **Lifecycle Cost Analysis**
   Incorporating total cost of ownership (TCO), including maintenance, battery replacement, and resale value, could yield a more complete consumer value framework.
6. **Integration with Renewable Energy**
   Future research can examine the intersection of EV charging and renewable power sources to assess grid stability and carbon offset potential.
7. **Segmentation, Targetting and Positioning**
   By incorporating STP into future research, this study moves beyond technical modeling into strategic decision-making. This will not only help manufacturers optimize their product-market fit but also aid governments in crafting **inclusive and targeted EV adoption policies**.

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