SYMBIOSIS
SCHOOL OF ECONOMICS
॥वसुधैव कुटुम्बकम्॥

Msc Economics Python mini Project

On

Opportunities and Challenges for EVs in India:- Exploring through EV sales forecasting in India

BY

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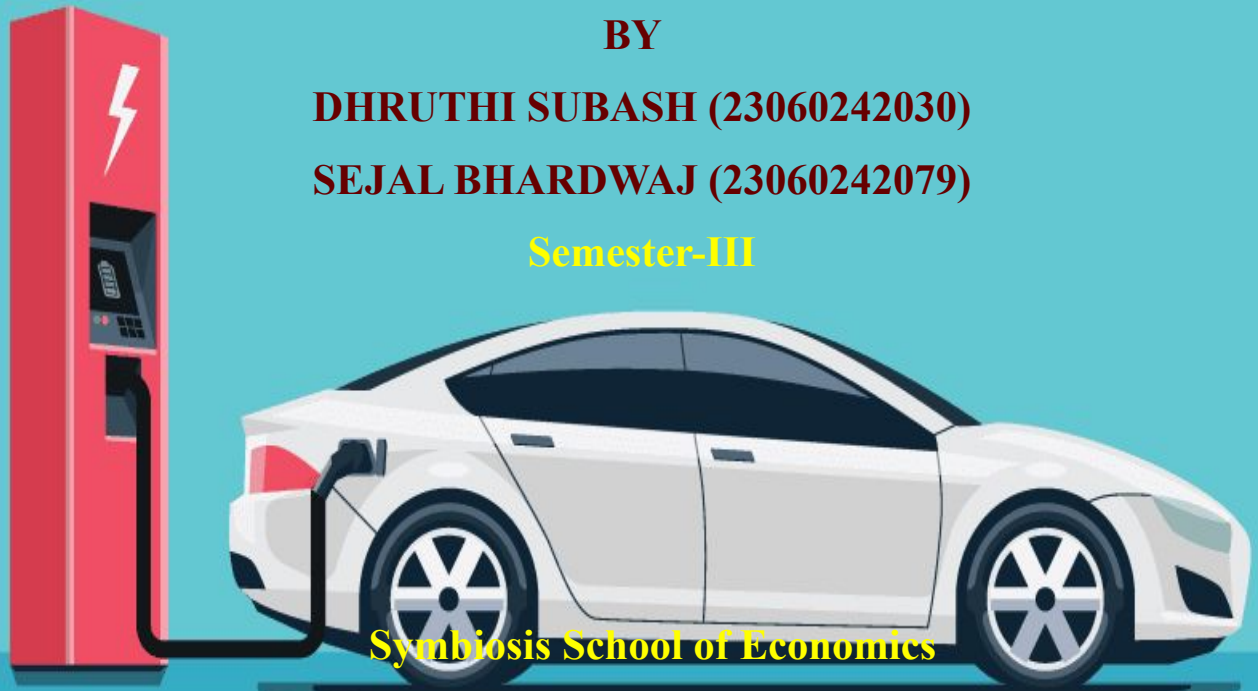
Semester-III



Symbiosis School of Economics

Senapati Bapat Rd, Pune, Maharashtra, India - 411004 .

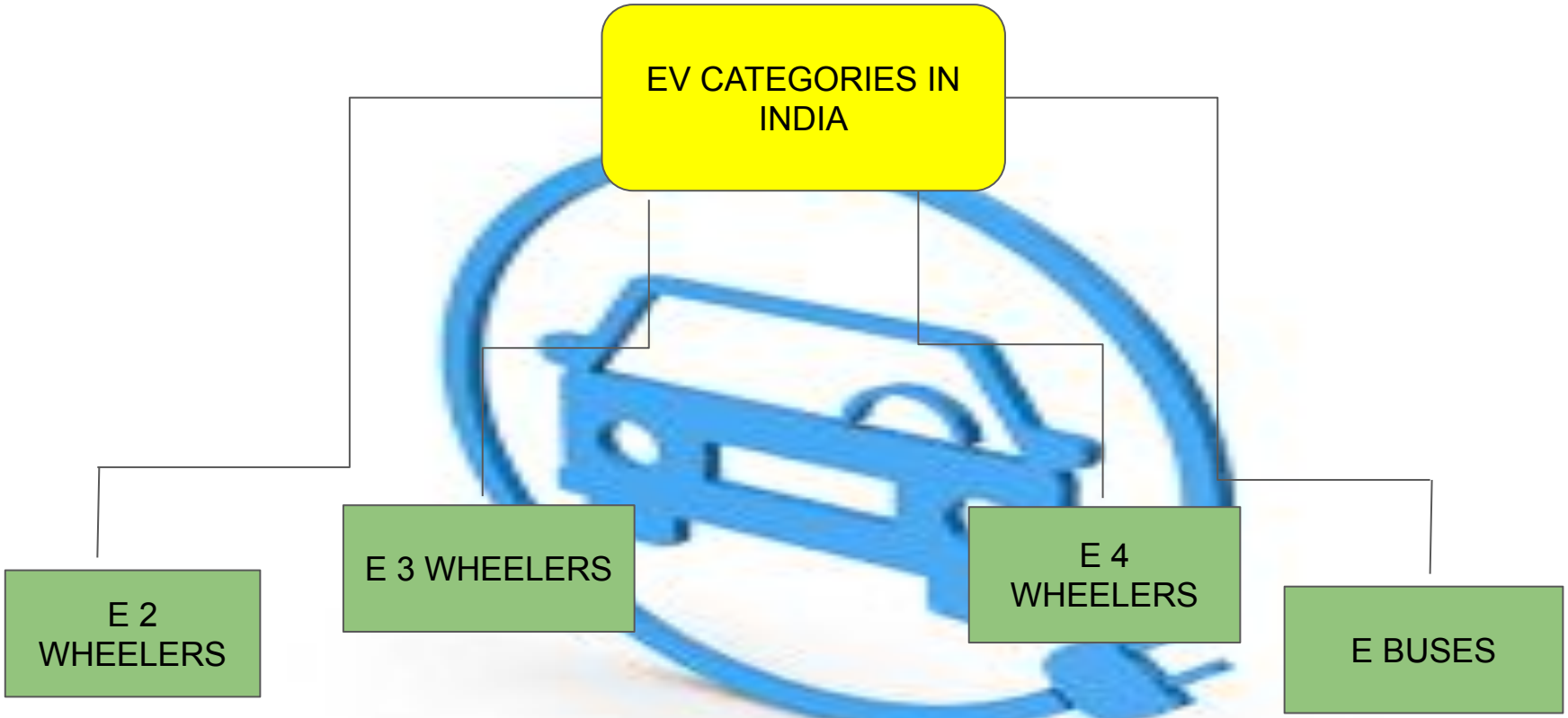
PROBLEM STATEMENT

EV Sales Forecasting

This project will leverage machine learning techniques and time series analysis to create an accurate and reliable sales forecasting model that can predict EV sales over a defined period, providing valuable insights into the future of electric mobility in India.

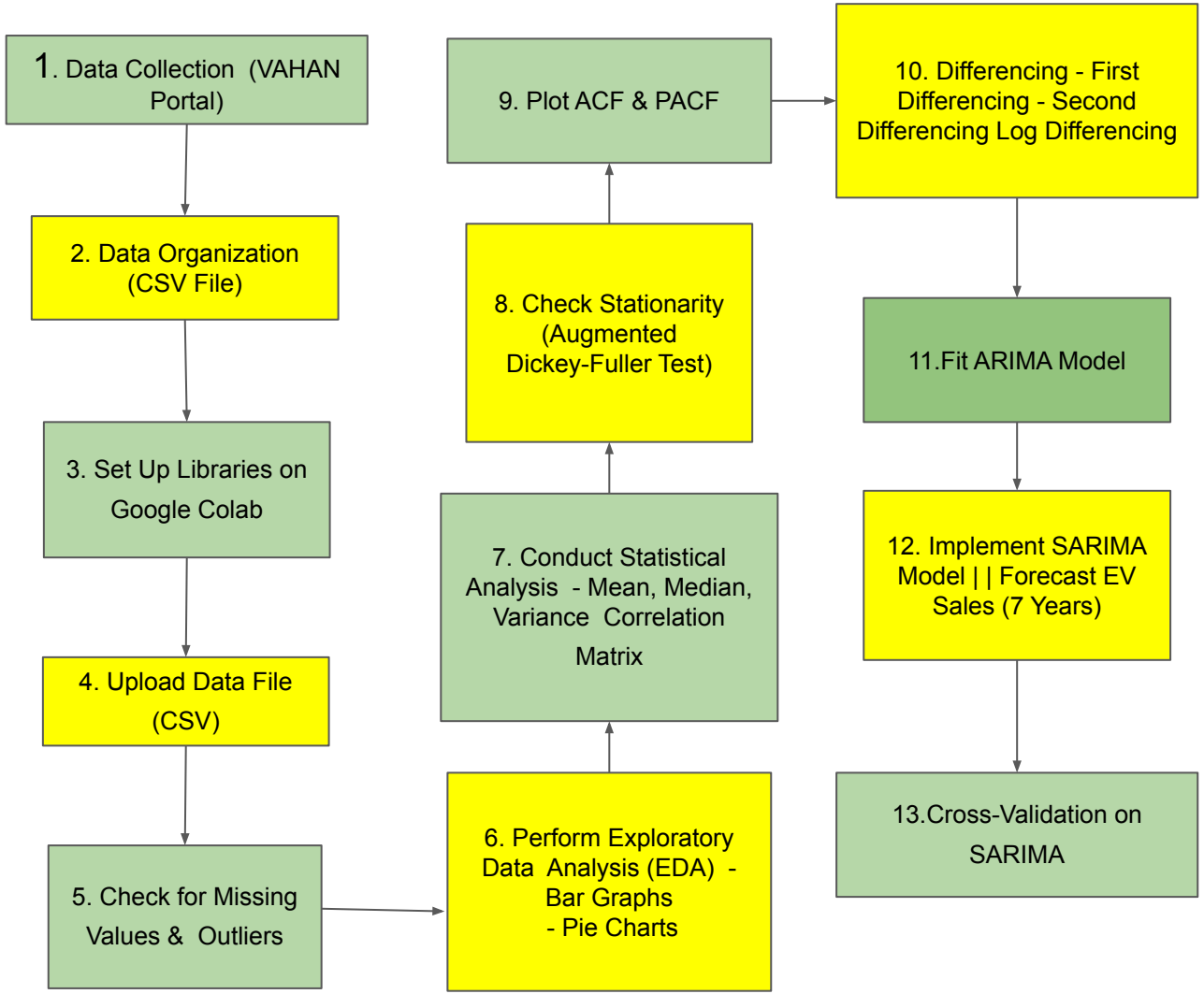
RESEARCH QUESTIONS

1) **What is the scope of the EV industry in India?**
2) **How has the demand for EV been in the recent years (2017-2023)?**
3) **Which time of the year has experienced the most number of EV sales?**
4) **How can predictive models (such as SARIMA or machine learning models) be leveraged to improve the accuracy of long-term EV sales forecasts in India?**


EV CATEGORIES IN INDIA
E 2 WHEELERS
E 3 WHEELERS
E 4 WHEELERS
E BUSES

DATA COLLECTION

The data has been retrieved from the **VAHAN PORTAL** , The data on the monthly sales of EVs - 2 wheeler , 3 wheeler , 4 wheeler and bus from the years 2017- 2023 has been collected and made into a CSV file which was then uploaded on google colab to perform the further analysis.



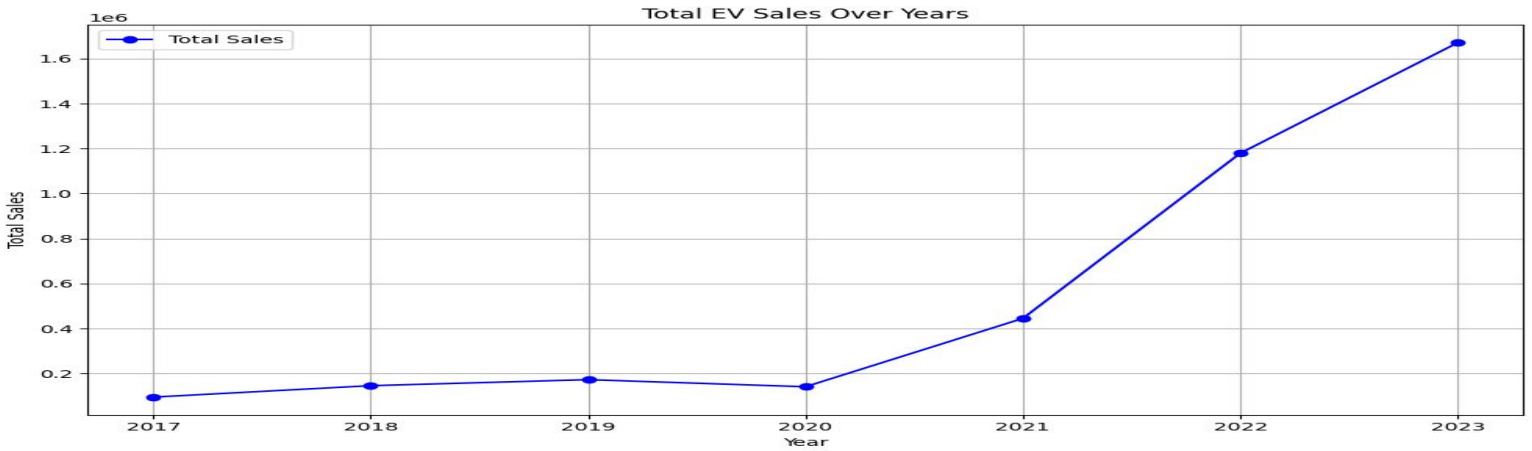
RESEARCH METHODOLOGY

SET UP THE DEVELOPMENT ENVIRONMENT

```
[ ]  import warnings
     warnings.filterwarnings('ignore')

     # Import packages
     import pandas as pd
     import numpy as np
     import itertools
     from statsmodels.tsa.seasonal import seasonal_decompose
     import math
     from sklearn.preprocessing import OneHotEncoder
     from sklearn.model_selection import train_test_split, cross_val_score, KFold, TimeSeriesSplit, GridSearchCV
     from sklearn.base import BaseEstimator, RegressorMixin
     from sklearn.svm import SVR
     from sklearn.linear_model import LinearRegression as LR
     from sklearn.linear_model import Ridge
     from sklearn.metrics import mean_squared_error, mean_absolute_percentage_error, mean_absolute_error
     import statsmodels.api as sm
     from statsmodels.tsa.stattools import acf, pacf
     from statsmodels.tsa.statespace.sarimax import SARIMAX
     from statsmodels.graphics.tsaplots import plot_acf, plot_pacf

     !pip install pmdarima
     from pmdarima import auto_arima, ARIMA
     from pmdarima.model_selection import SlidingWindowForecastCV
     from pmdarima.model_selection import cross_val_score as SARIMACV
```

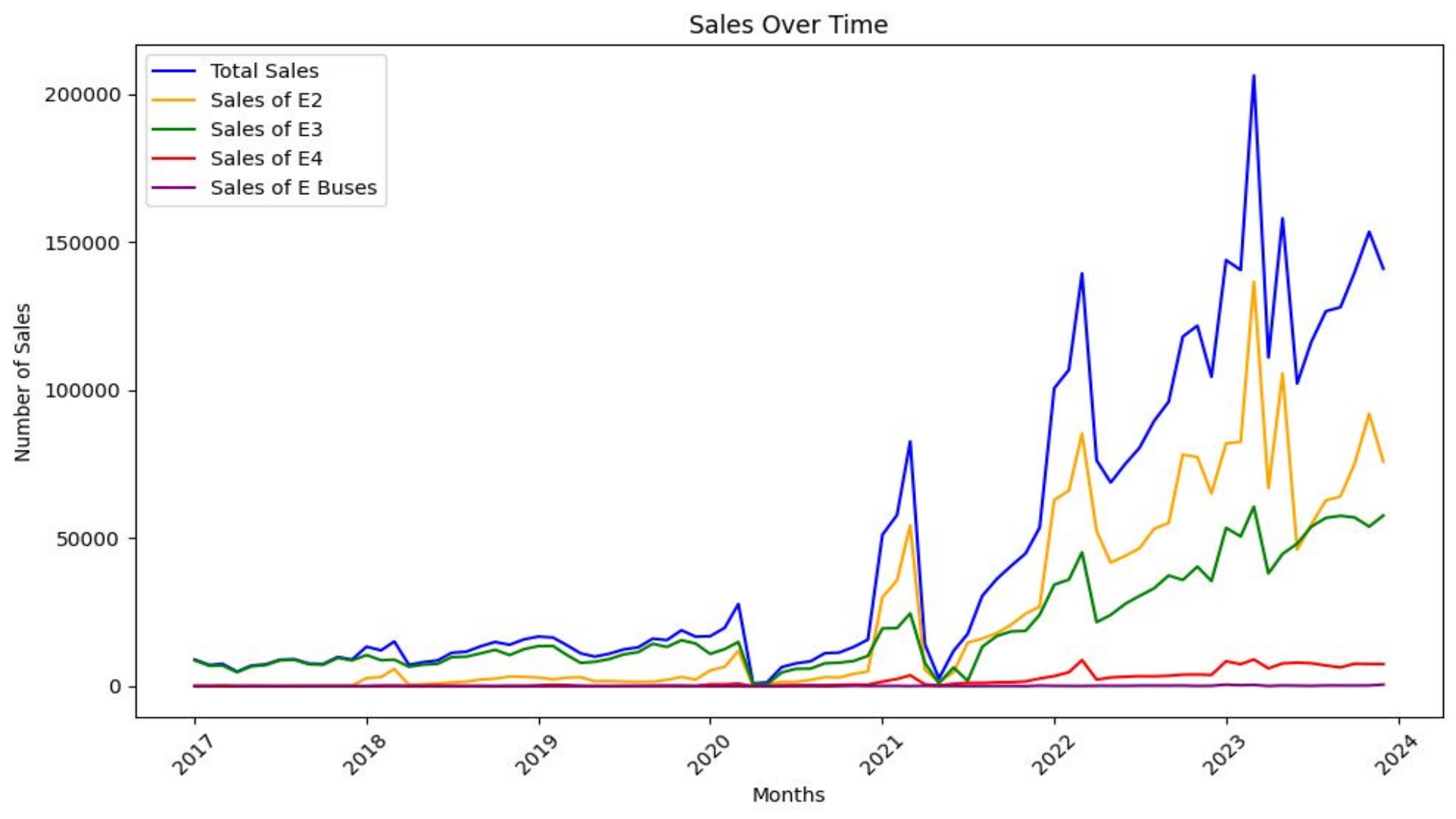
EXPLORATORY DATA ANALYSIS

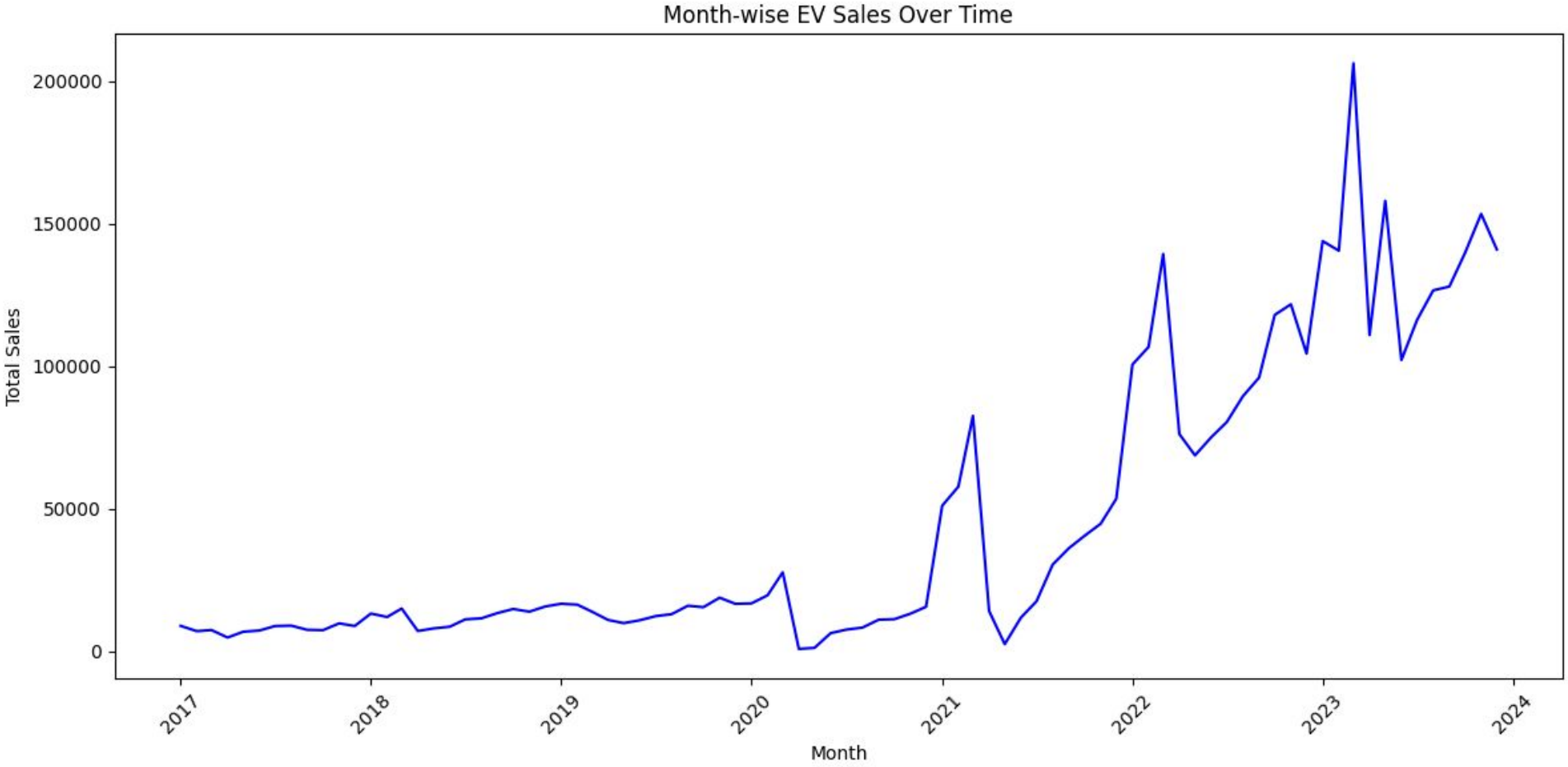
YEAR - WISE ANALYSIS OF TOTAL EV SALES OVER YEARS



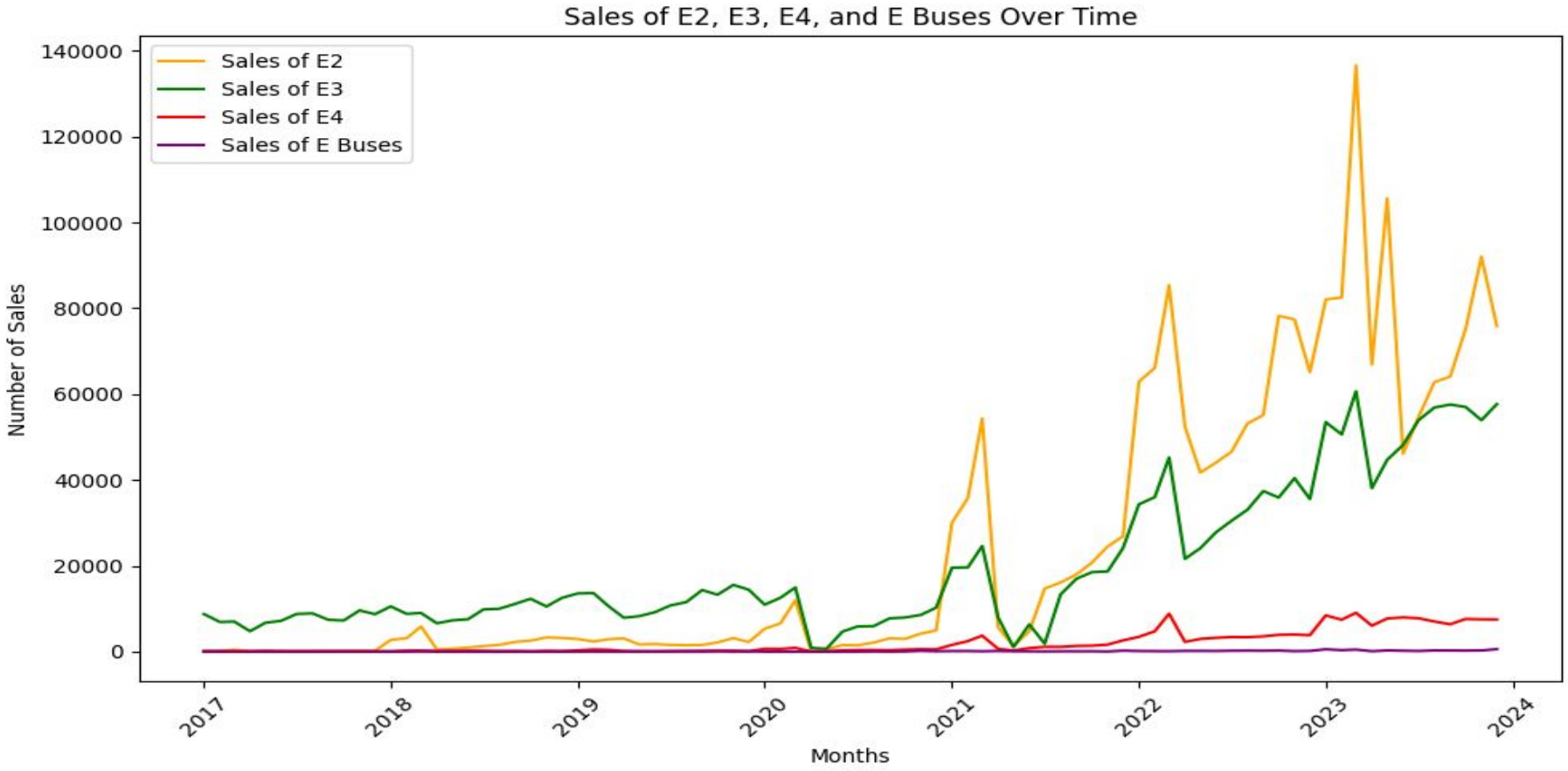
Overall Trend

- Significant **upward trend** with rapid acceleration, particularly from **2021 onward**.
- Reflects a strong shift toward **EV adoption in India**, fueled by **policy support** and **environmental awareness**.


Sales Over Time
Total Sales
Sales of E2
Sales of E3
Sales of E4
Sales of E Buses
200000
150000
100000
50000
0
Number of Sales
2017
2018
2019
2020
2021
2022
2023
2024
Months


Month-wise EV Sales Over Time
Total Sales
200000
150000
100000
50000
0
2017
2018
2019
2020
2021
2022
2023
2024
Month

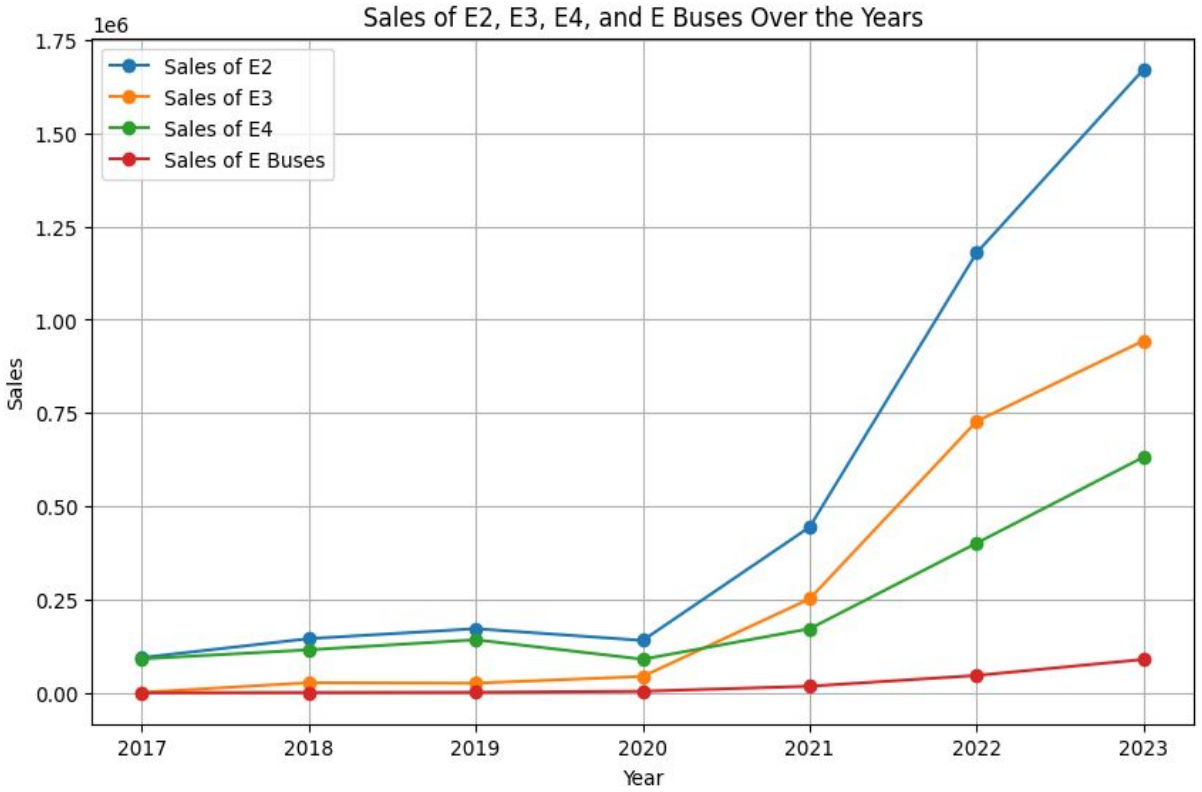
Category wise sales of E2,E3,E4 and E-Buses over the years



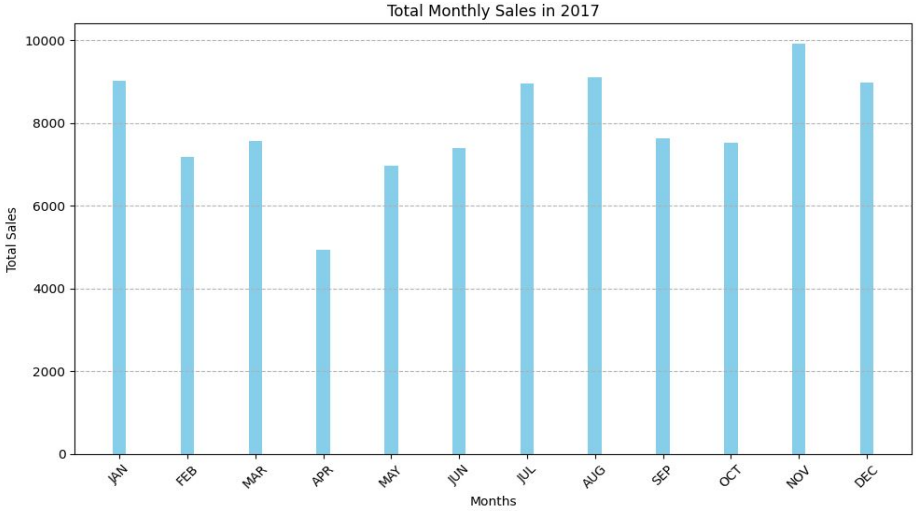
CATEGORY WISE EV SALES (2017-2023)

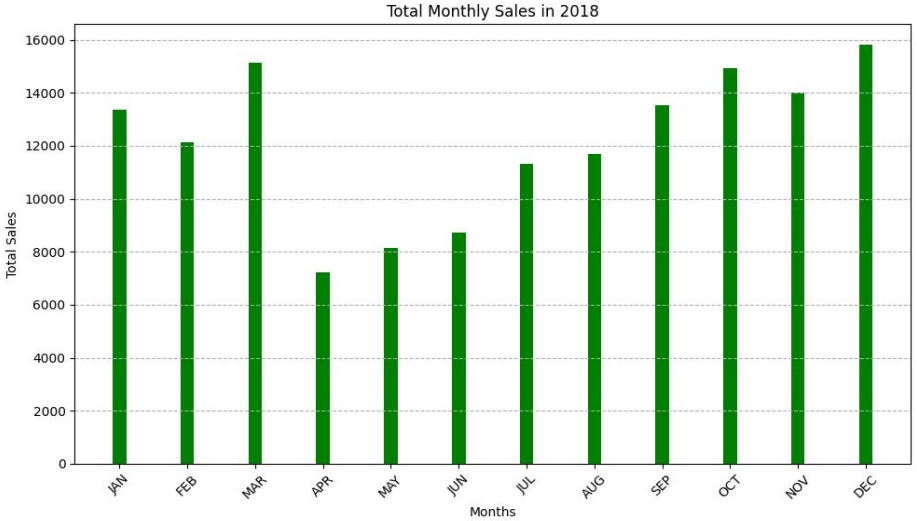
Key Insights from Category wise EV Sales (2017-2023)

1. **Exponential Growth Post-2021**
   - Sales surged significantly from 2021 onwards.
2. **Category Highlights**
   - **E2 & E3 Vehicles:** Saw the largest sales increases after 2020.
   - **E4 Vehicles:** Steady growth, similar upward trend.
   - **E Buses:** Notable growth in 2021-2022, driven by public transport electrification.
3. **Key Drivers**
   - **Government Incentives** and **Improved EV Infrastructure**.
   - **Increased Consumer Demand** for eco-friendly options.



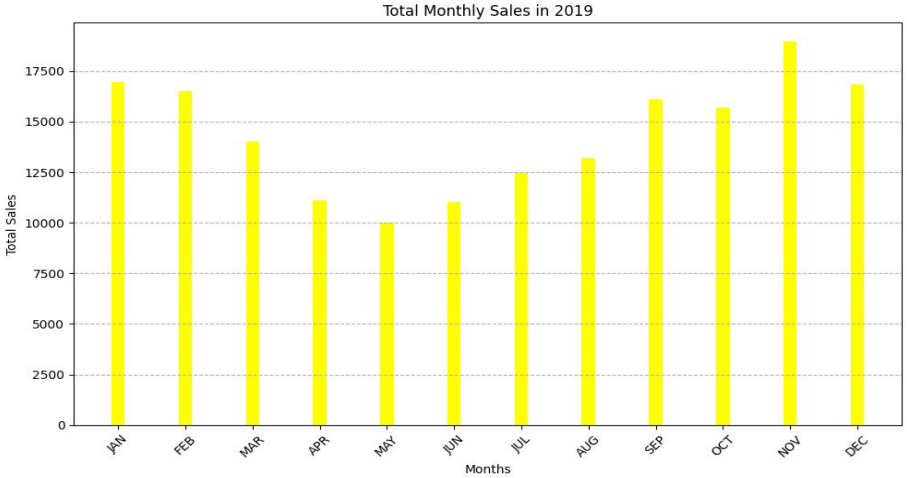
TOTAL MONTHLY SALES OF EVs FROM 2017 TO 2023



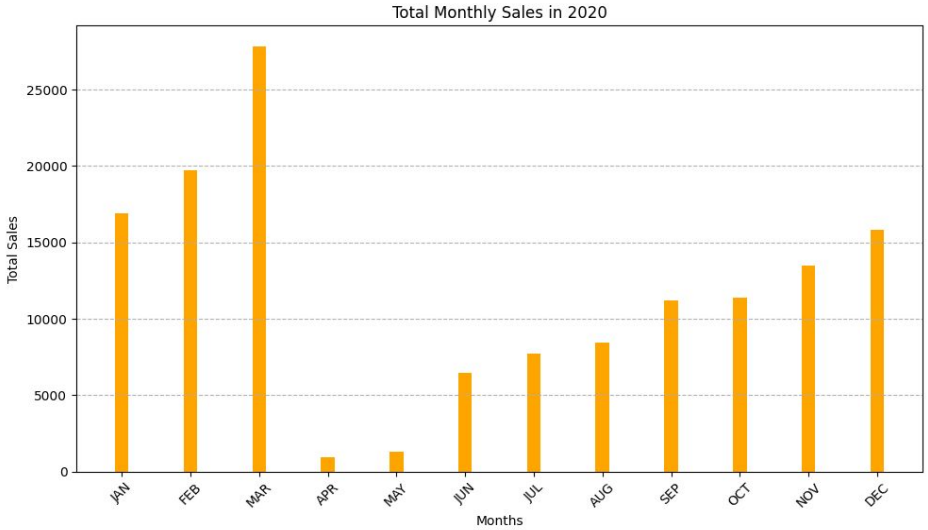


2017: November and December had the most sales.
April and May had the least sales.

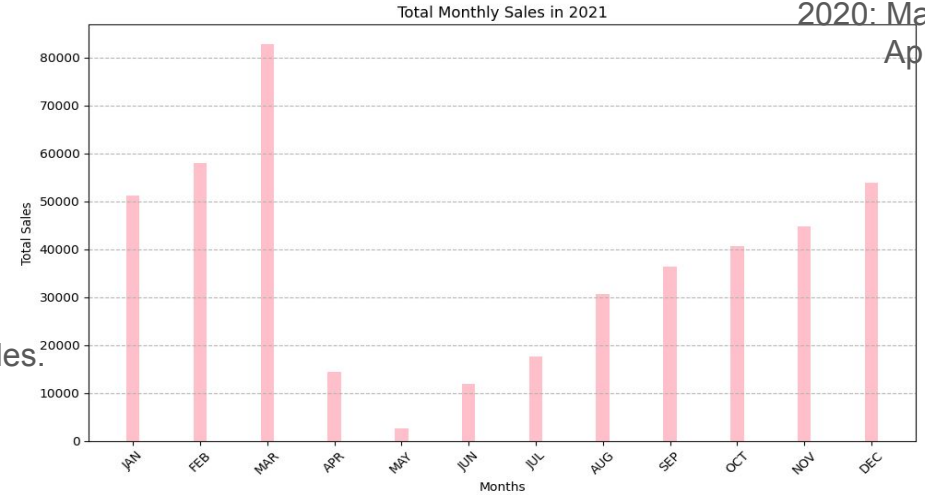
2018: December had the most sales.
April and May had the least sales.



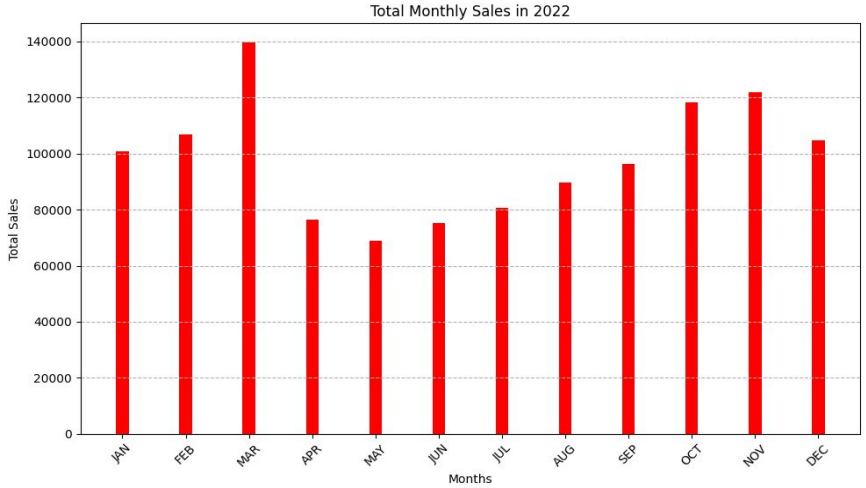
2019: November had the most sales.
May had the least sales.



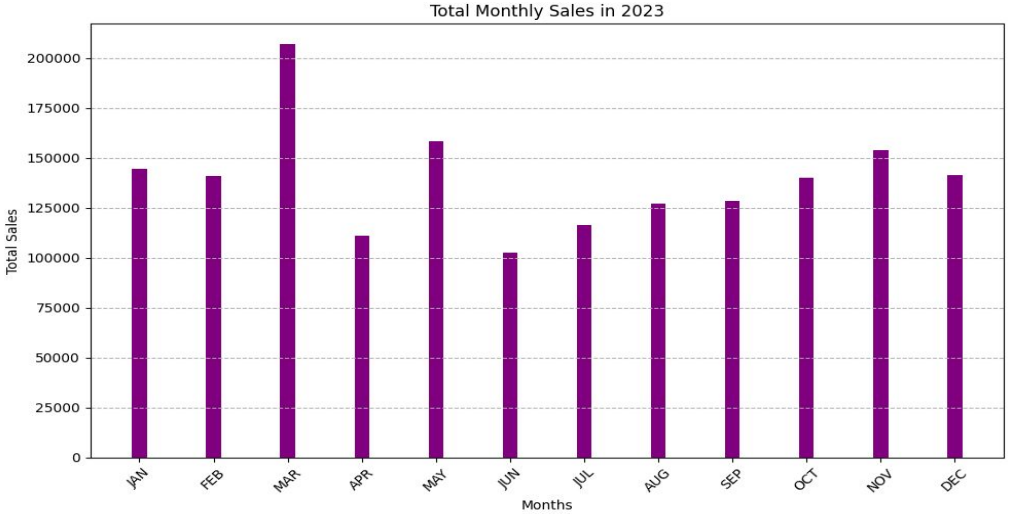
2020: March had the most sales.
April and May had the least sales.



2021: February had the most sales.
May had the least sales.



2022: March had the most sales.
May had the least sales.



2023: March had the most sales.
June had the least sales.

Breakdown of EV Sales over the years (2017-2023)

- **So we can see from the graphs that November and March have had the most number of sales and the sales have been the least in the month of May.**

REASON FOR THE SPIKE OF SALES DURING NOVEMBER AND MARCH

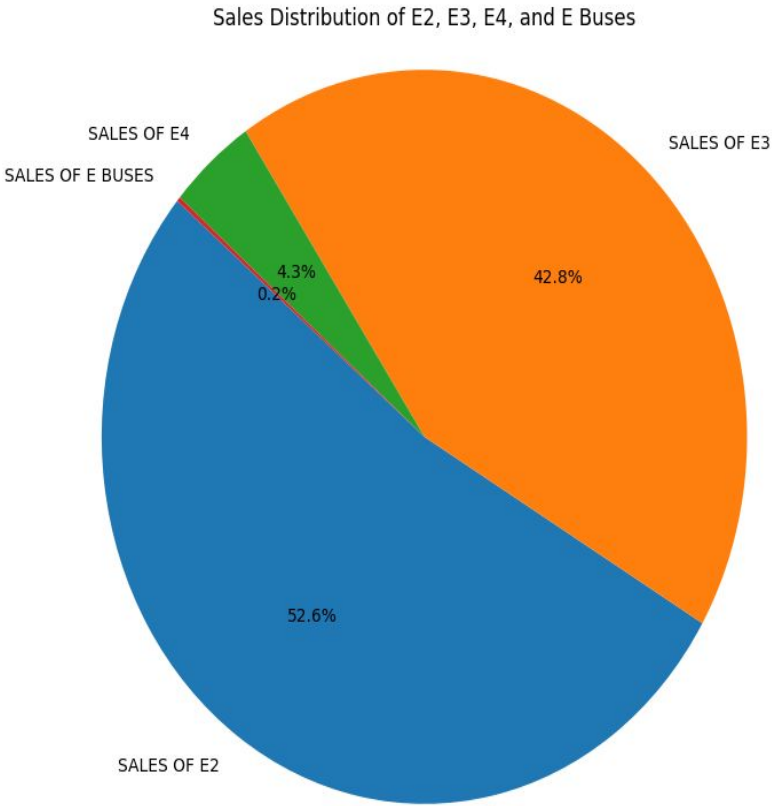
Festive Season and Year-End Offers (November):

- Diwali: November often sees a spike in consumer purchases due to Diwali, one of India's biggest festivals. People tend to buy new items, including cars, as a sign of prosperity during this time.
- Discounts and Promotions: Car manufacturers and dealerships typically offer substantial discounts, promotional offers, and year-end clearances in November to boost sales and clear out inventory before the end of the financial year.

Financial Year-End (March):

- Tax Planning: March marks the end of the financial year in India. Many buyers—especially businesses and professionals—tend to make large purchases, such as vehicles, to take advantage of tax-saving incentives, depreciation benefits, and fiscal planning.
- Bonus and Incentives: March is also a common month for employees to receive annual bonuses or incentives, which often drives higher consumer spending, including on vehicles.

E2,E3,E4 AND E BUS OVERALL SALES DISTRIBUTION



EV Sales Distribution by Category

- **E3 Vehicles:**
  - **52.63% of total sales**
  - Most popular category among consumers.
- **E2 Vehicles:**
  - **42.82% of total sales**
  - Strong market presence, close behind E3.
- **E4 Vehicles:**
  - **4.34% of total sales**
  - Smaller market share with potential for growth.
- **E Buses:**
  - **0.20% of total sales**
  - Minimal share, but potential to expand with targeted efforts.

Percentage_sales = (total_sales_per_category / total_sales) * 100

Electric two-wheelers (E-2Ws) and three-wheelers (E-3Ws) are popular in India for a number of reasons, including

Lower cost of ownership

Electric 3Ws are cheaper to own than their gasoline counterparts, even without subsidies.

Government subsidies

The Faster Adoption and Manufacturing of Electric Vehicles (FAME II) scheme has reduced the cost of ownership of electric 3Ws.

Favorable total cost of ownership

The total cost of ownership of electric 2Ws and 3Ws is favorable in India.

Less developed road infrastructure

Two-wheeled vehicles are more popular in developing countries like India because they are often used for short distances around cities.

Economical option

Three-wheelers are promoted as an economical option for short- to medium-distance public transportation.

Local manufacturing

Local manufacturing of batteries, critical components, and charging infrastructure can reduce costs and improve the acceptability of EVs.

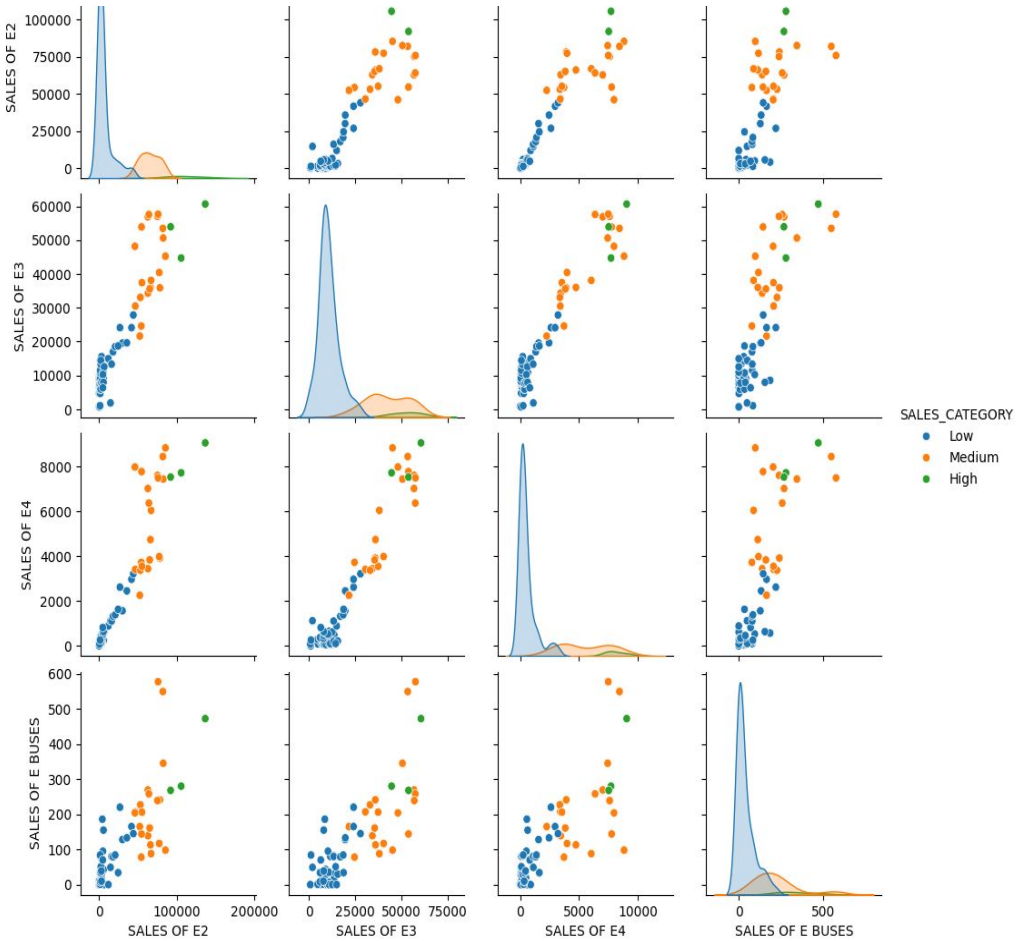
Renewable energy

India plans to install 500 gigawatts of clean energy by the end of the decade and reach net zero emissions by 2070.

India is the world's largest electric 3W market, and the second largest electric 2W market globally.

Key Insight:

- **E3 & E2 dominate the market**, while **E4 and E Buses** showroom for expansion, requiring **focused marketing** and **awareness campaigns**.



Pair Plot Analysis: EV Sales (E2, E3, E4, E-Buses)

1. **Sales Distribution**:
   - **E2 (Two-Wheelers)**: Skewed right, with most sales at lower values and a few high outliers.
   - **E3 (Three-Wheelers)**: Similar to E2, with lower sales concentrated and an upward trend.
   - **E4 (Four-Wheelers)**: Lower sales overall, with a strong right skew.
   - **E-Buses**: Lowest sales, with most data concentrated at very low values.
2. **Key Relationships**:
   - **E2 & E3**: Strong positive correlation, indicating higher E2 sales are associated with higher E3 sales.
   - **E2 & E4 / E3 & E4**: Positive but less concentrated correlation.
   - **E2/E3 & E-Buses**: Weaker, more scattered relationships.
   - **E4 & E-Buses**: Weakest correlation among all, with little connection.
3. **Summary**:
   - E2 and E3 dominate the market, showing strong interdependence.
   - E4 and E-Buses have lower sales and weaker correlations with other categories.

STATISTICAL ANALYSIS

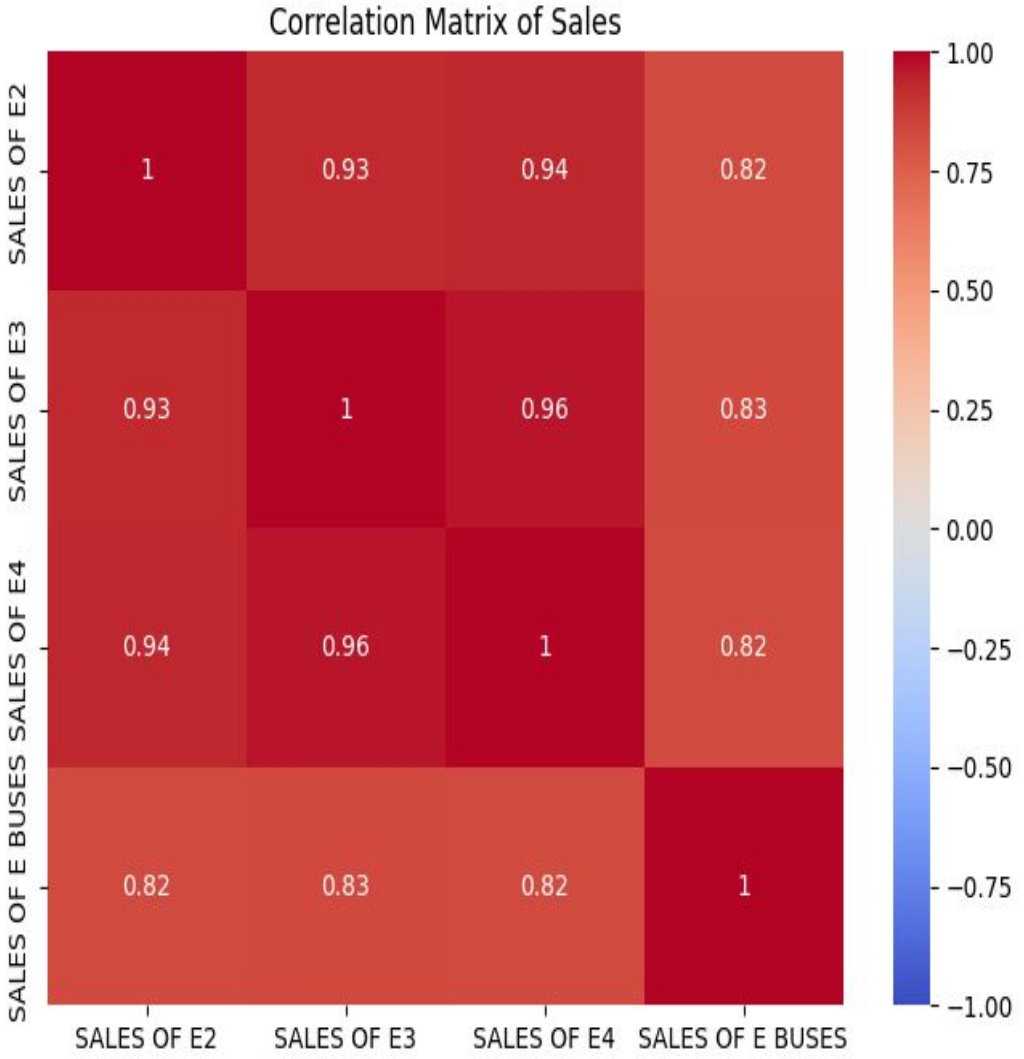
```python
import pandas as pd
# For the columns: 'SALES OF E2', 'SALES OF E3', 'SALES OF E4', 'SALES OF E BUSES'

# Calculate mean, median, and variance for each sales column
mean_sales = data[['SALES OF E2', 'SALES OF E3', 'SALES OF E4', 'SALES OF E BUSES']].mean()
median_sales = data[['SALES OF E2', 'SALES OF E3', 'SALES OF E4', 'SALES OF E BUSES']].median()
variance_sales = data[['SALES OF E2', 'SALES OF E3', 'SALES OF E4', 'SALES OF E BUSES']].var()
std_dev_sales = data[['SALES OF E2', 'SALES OF E3', 'SALES OF E4', 'SALES OF E BUSES']].std()


# Display the results
print("Mean Sales:\n", mean_sales)
print("\nMedian Sales:\n", median_sales)
print("\nVariance of Sales:\n", variance_sales)
print("\nStandard Deviation of Sales:\n", std_dev_sales)
```

```
Mean Sales:
 SALES OF E2         24124.642857
SALES OF E3          19629.285714
SALES OF E4           1990.154762
SALES OF E BUSES        92.380952
dtype: float64

Median Sales:
 SALES OF E2          3241.0
SALES OF E3          11916.0
SALES OF E4            443.5
SALES OF E BUSES        38.5
dtype: float64

Variance of Sales:
 SALES OF E2         1.042468e+09
SALES OF E3          2.788771e+08
SALES OF E4          7.434483e+06
SALES OF E BUSES     1.500988e+04
dtype: float64

Standard Deviation of Sales:
 SALES OF E2         32287.277239
SALES OF E3          16699.614667
SALES OF E4           2726.624770
SALES OF E BUSES       122.514804
dtype: float64
```

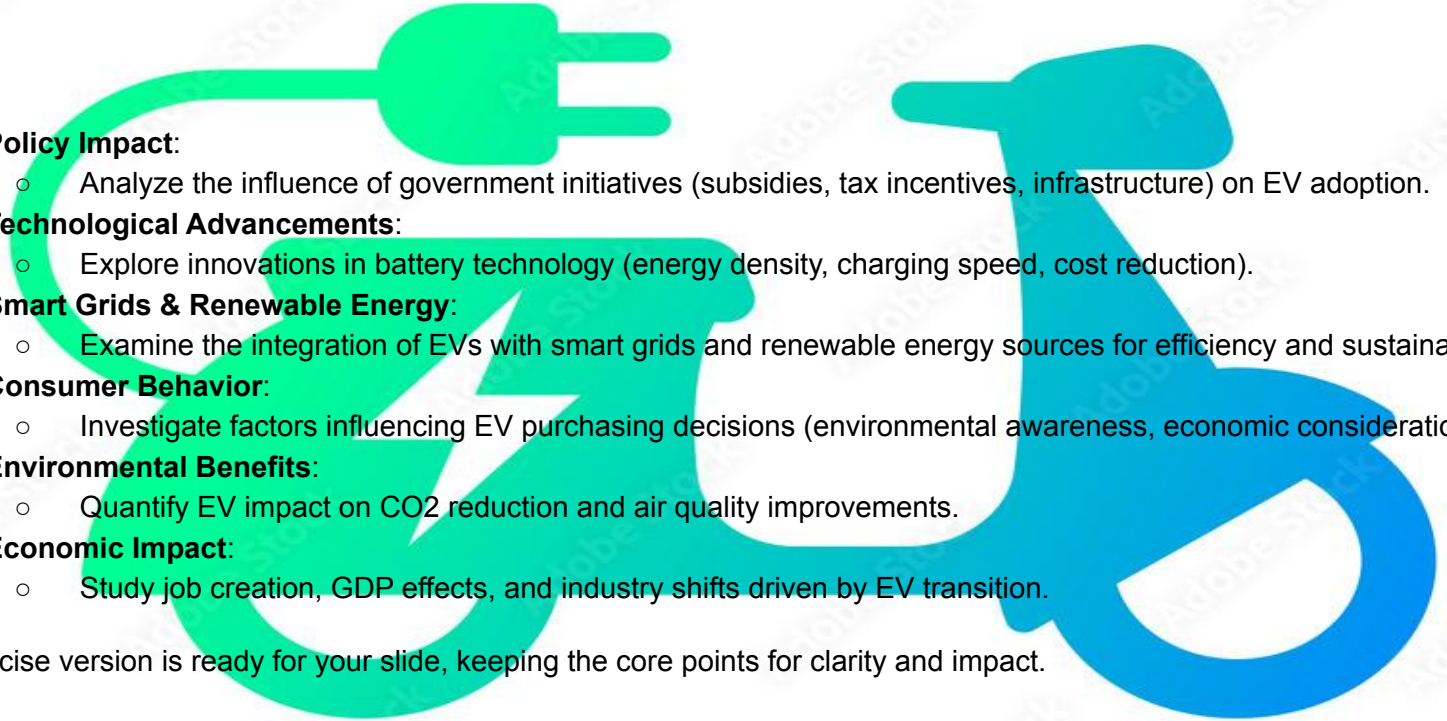
MEAN , MEDIAN , VARIANCE AND STANDARD DEVIATION

Correlation Matrix Analysis of EV Sales

- **Strong Positive Correlations:**
  - **E2 & E3 (0.926)** and **E2 & E4 (0.937)**: Strong linkage between sales of these categories.
  - **E3 & E4 (0.963):** Highest correlation, indicating synchronized sales trends.
- **Weaker Correlation with E Buses:**
  - **E Buses & E2 (0.822), E3 (0.833), E4 (0.824):** Strong, but weaker than among smaller EVs.
  - Suggests **different market drivers** for E Buses (e.g., public transport policies).
- **Key Insights:**
  - Strong sales correlation across all EV types indicates shared market factors like **government incentives** and **infrastructure development**.
  - **E Buses** may be influenced by **commercial** or **public sector** decisions, leading to a slightly **lower correlation** with other EVs.

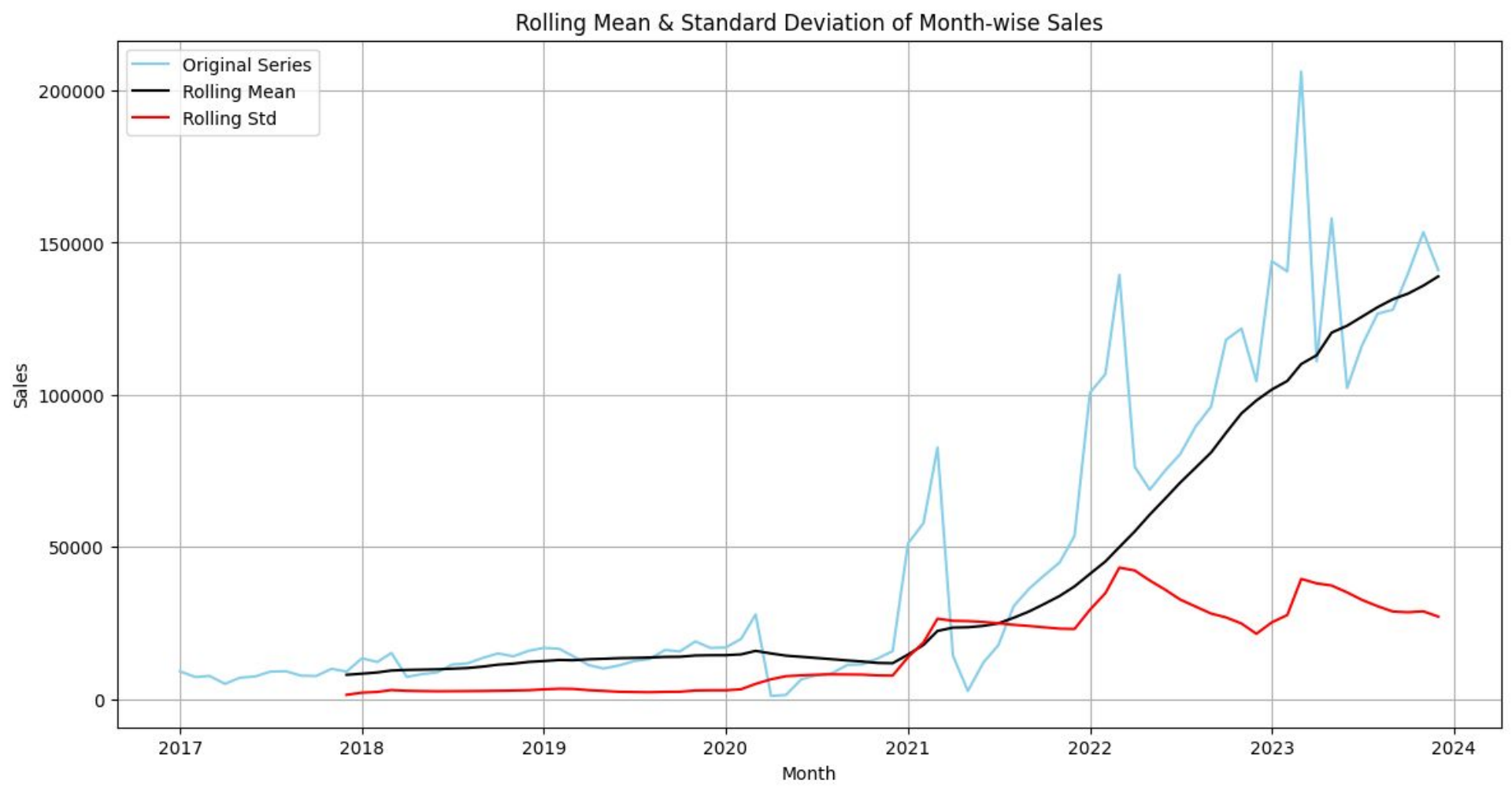


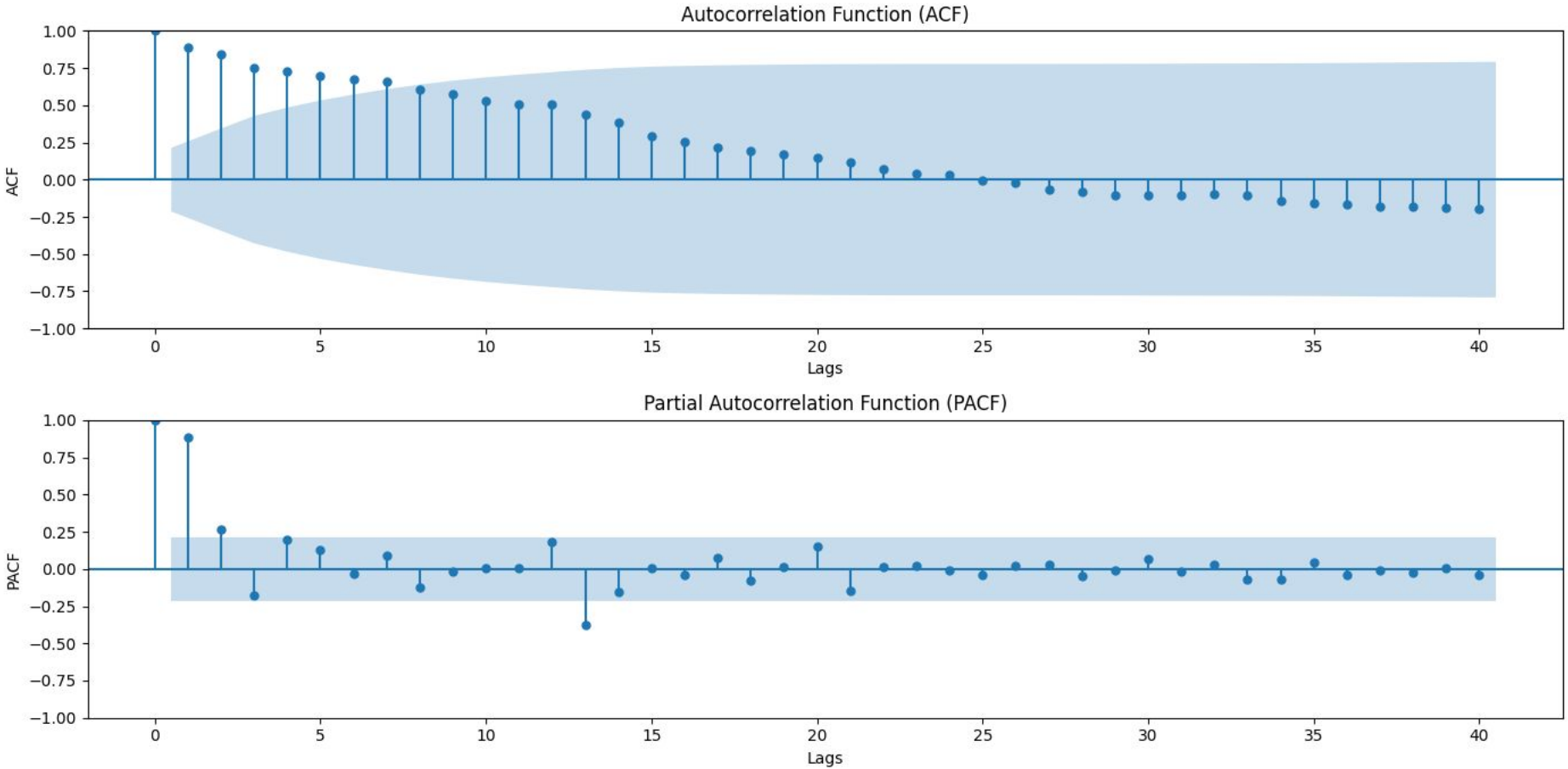
LIMITATIONS AND SCOPE

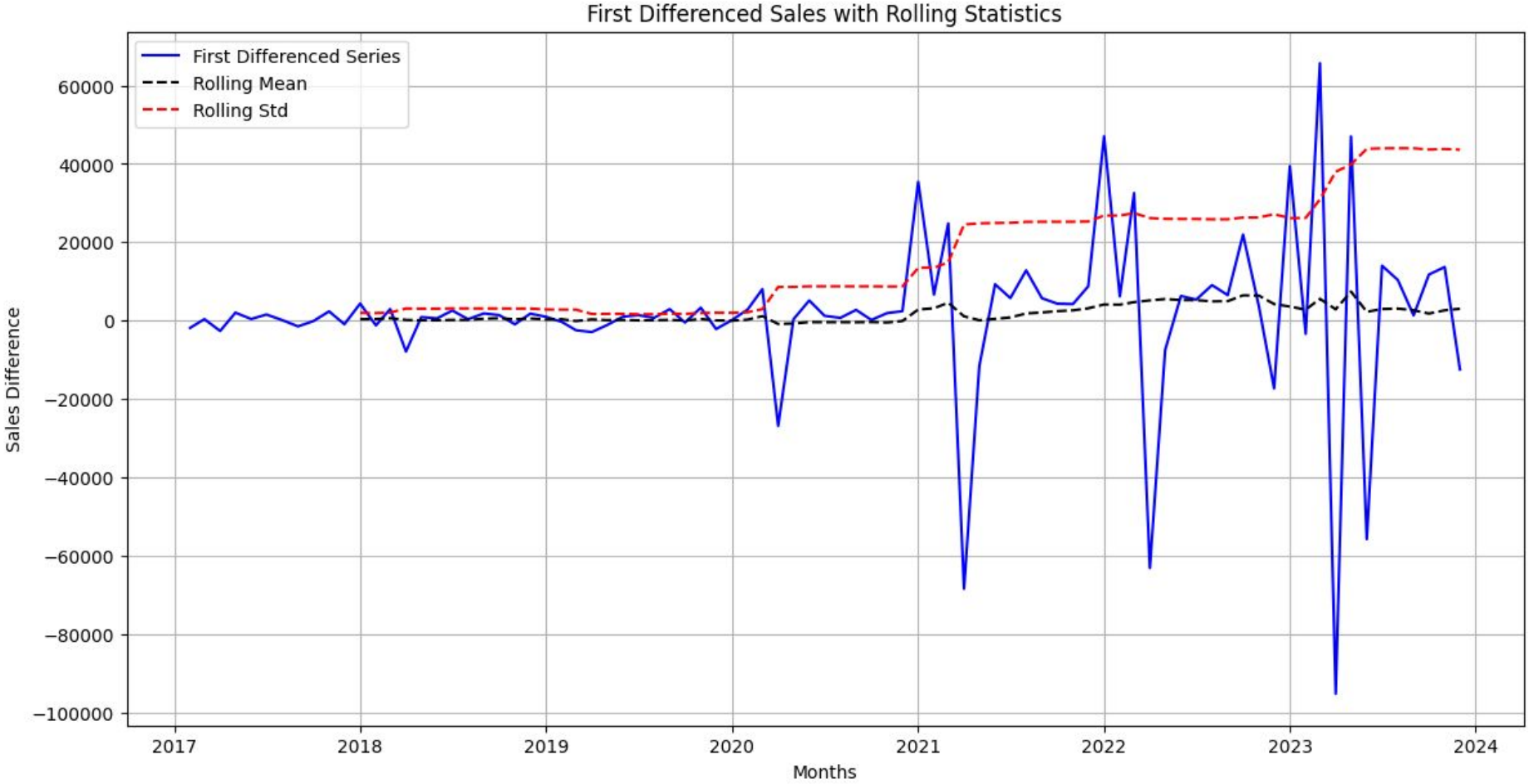


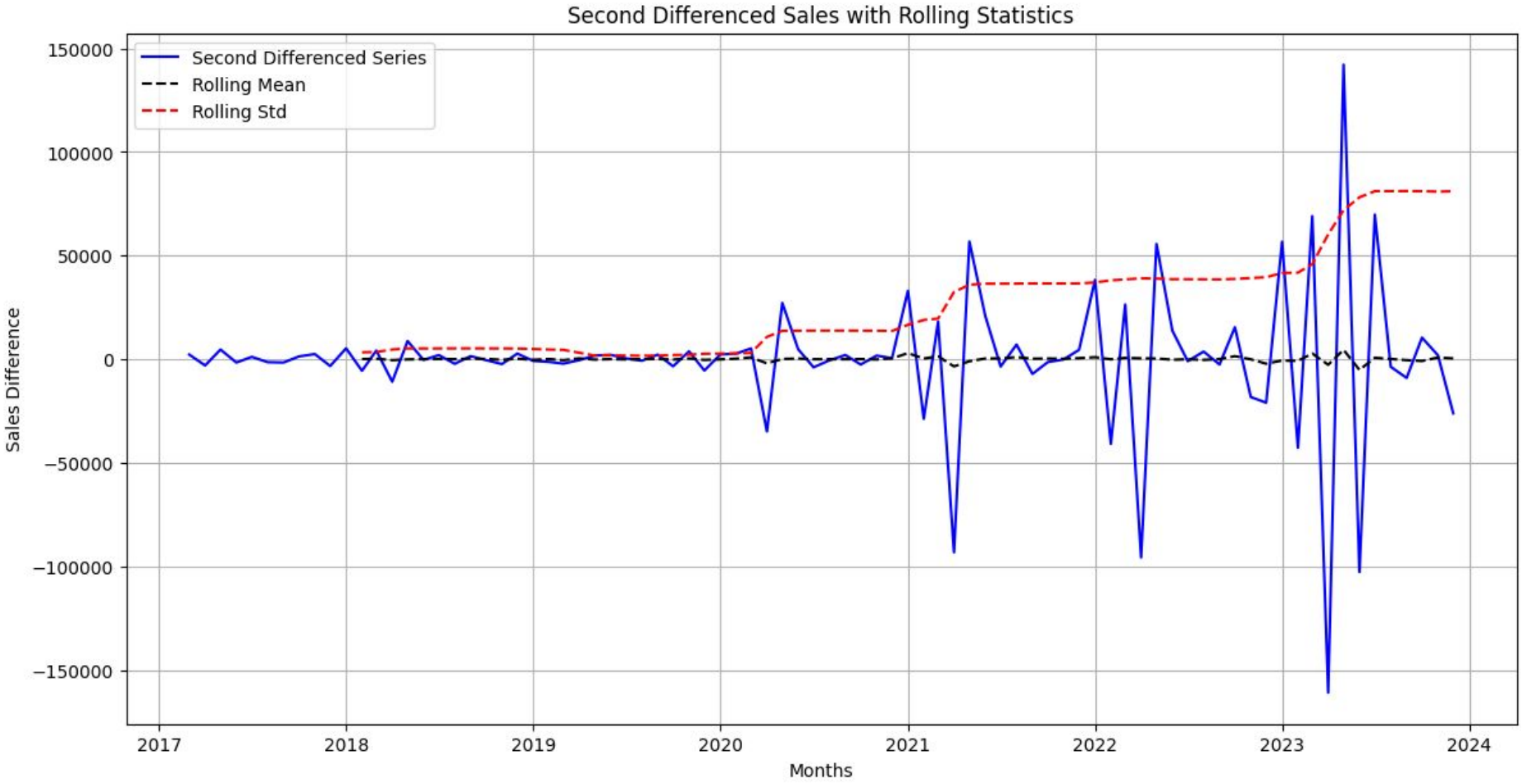
1. **Policy Impact**:
   - Analyze the influence of government initiatives (subsidies, tax incentives, infrastructure) on EV adoption.
2. **Technological Advancements**:
   - Explore innovations in battery technology (energy density, charging speed, cost reduction).
3. **Smart Grids & Renewable Energy**:
   - Examine the integration of EVs with smart grids and renewable energy sources for efficiency and sustainability.
4. **Consumer Behavior**:
   - Investigate factors influencing EV purchasing decisions (environmental awareness, economic considerations).
5. **Environmental Benefits**:
   - Quantify EV impact on CO_2 reduction and air quality improvements.
6. **Economic Impact**:
   - Study job creation, GDP effects, and industry shifts driven by EV transition.

This concise version is ready for your slide, keeping the core points for clarity and impact.


Rolling Mean & Standard Deviation of Month-wise Sales
Original Series
Rolling Mean
Rolling Std
200000
150000
100000
50000
0
Sales
2017
2018
2019
2020
2021
2022
2023
2024
Month


Autocorrelation Function (ACF)
ACF
Lags
Partial Autocorrelation Function (PACF)
PACF
Lags


First Differenced Sales with Rolling Statistics
First Differenced Series
Rolling Mean
Rolling Std
Sales Difference
60000
40000
20000
0
−20000
−40000
−60000
−80000
−100000
2017
2018
2019
2020
2021
2022
2023
2024
Months

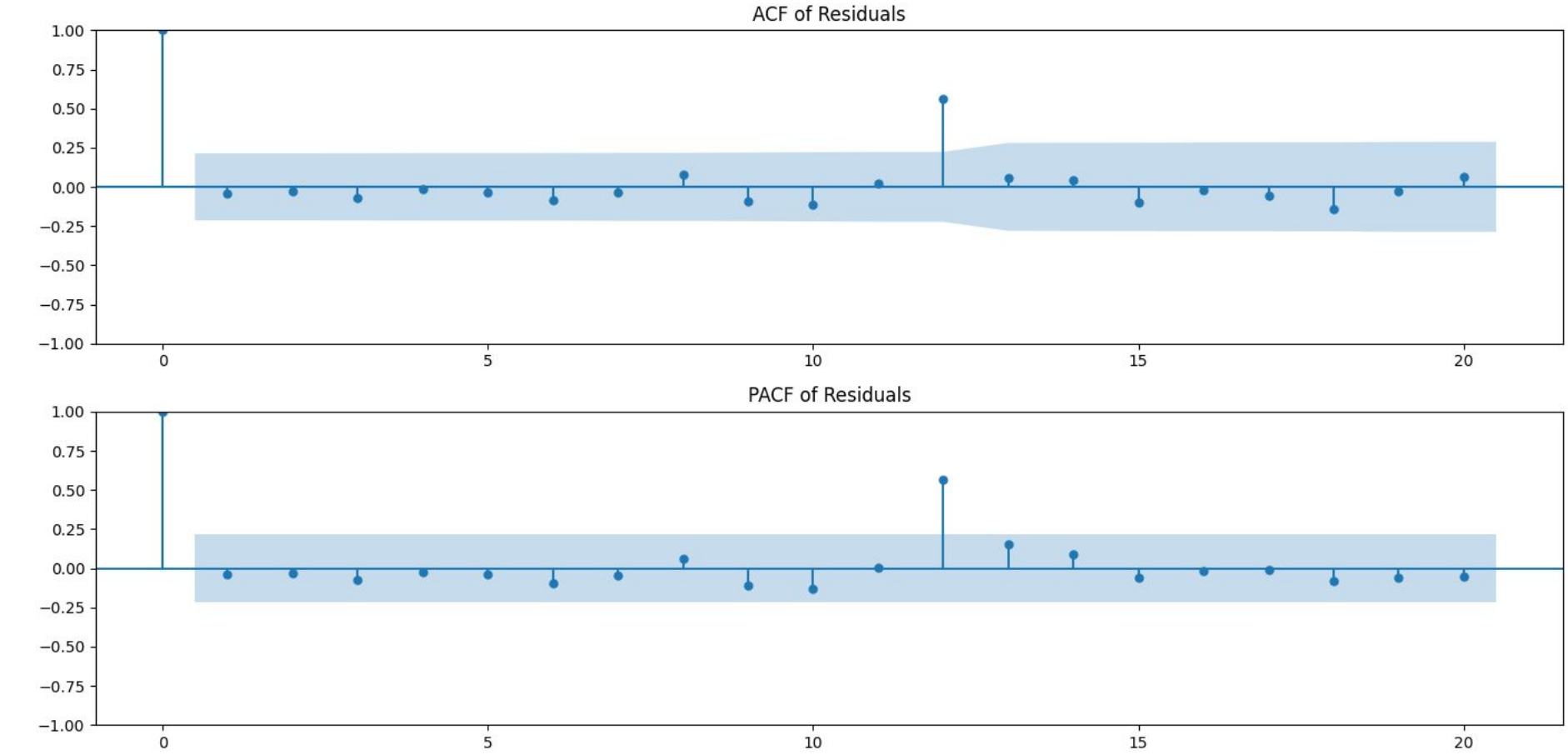

Second Differenced Sales with Rolling Statistics
Second Differenced Series
Rolling Mean
Rolling Std
150000
100000
50000
0
−50000
−100000
−150000
Sales Difference
2017
2018
2019
2020
2021
2022
2023
2024
Months

SARIMAX Results

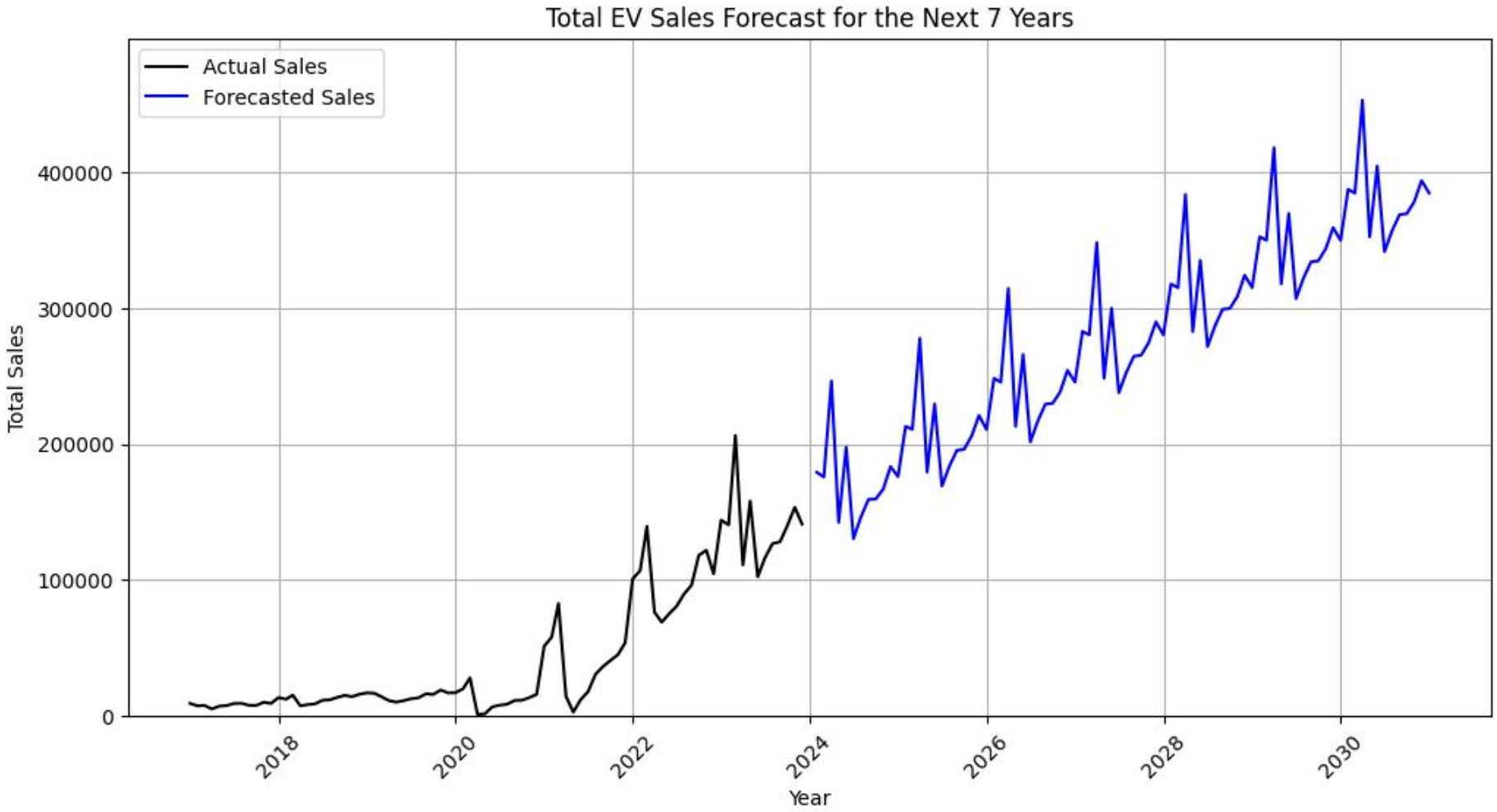
Dep. Variable:	Total Sales	No. Observations:	84
Model:	ARIMA(6, 1, 1)	Log Likelihood	-930.386
Date:	Fri, 18 Oct 2024	AIC	1876.771
Time:	18:28:30	BIC	1896.122
Sample:	01-01-2017 - 12-01-2023	HQIC	1884.545
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
ar.L1	0.2263	1.010	0.224	0.823	-1.754	2.206
ar.L2	0.3186	0.401	0.794	0.427	-0.468	1.105
ar.L3	-0.4001	0.139	-2.875	0.004	-0.673	-0.127
ar.L4	-0.0499	0.360	-0.139	0.890	-0.755	0.656
ar.L5	0.1461	0.281	0.520	0.603	-0.405	0.697
ar.L6	-0.0873	0.172	-0.507	0.612	-0.424	0.250
ma.L1	-0.5931	1.021	-0.581	0.561	-2.594	1.407
sigma2	3.472e+08	1.17e-08	2.98e+16	0.000	3.47e+08	3.47e+08

Ljung-Box (L1) (Q):	0.14	Jarque-Bera (JB):	30.07
Prob(Q):	0.70	Prob(JB):	0.00
Heteroskedasticity (H):	152.40	Skew:	-0.09
Prob(H) (two-sided):	0.00	Kurtosis:	5.94


ACF of Residuals
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0
5
10
15
20
PACF of Residuals
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0
5
10
15
20

```
  self._init_dates(dates, freq)
                                SARIMAX Results
==========================================================================================
Dep. Variable:                        Total Sales   No. Observations:                   84
Model:             SARIMAX(1, 1, 1)x(1, 1, 1, 12)   Log Likelihood                -772.784
Date:                            Fri, 18 Oct 2024   AIC                           1555.567
Time:                                    18:39:20   BIC                           1566.880
Sample:                                01-01-2017   HQIC                          1560.066
                                     - 12-01-2023
Covariance Type:                              opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1         -0.6609      0.197     -3.347      0.001      -1.048      -0.274
ma.L1          0.2684      0.282      0.953      0.341      -0.284       0.821
ar.S.L12      -0.5701      0.921     -0.619      0.536      -2.374       1.234
ma.S.L12       0.7726      0.904      0.854      0.393      -1.000       2.545
sigma2      1.805e+08   2.19e-08   8.23e+15      0.000    1.81e+08    1.81e+08
===================================================================================
Ljung-Box (L1) (Q):                   0.03   Jarque-Bera (JB):                 9.96
Prob(Q):                              0.86   Prob(JB):                         0.01
Heteroskedasticity (H):              43.82   Skew:                            -0.18
Prob(H) (two-sided):                  0.00   Kurtosis:                         4.80
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
[2] Covariance matrix is singular or near-singular, with condition number 2.8e+31. Standard errors may be unstable.
            Forecasted Total Sales
2024-01-31           179169.213272
2024-02-29           175702.073054
2024-03-31           246376.804092
2024-04-30           142302.145561
2024-05-31           197581.295038
...                            ...
2030-08-31           368865.540468
2030-09-30           369491.742224
2030-10-31           378412.971901
2030-11-30           393959.556917
2030-12-31           384786.394157
```


Total EV Sales Forecast for the Next 7 Years
Actual Sales
Forecasted Sales
Total Sales
0
100000
200000
300000
400000
2018
2020
2022
2024
2026
2028
2030
Year

12s

```
Performing stepwise search to minimize aic
 ARIMA(2,0,2)(1,1,1)[12] intercept   : AIC=979.699, Time=0.77 sec
 ARIMA(0,0,0)(0,1,0)[12] intercept   : AIC=1001.845, Time=0.01 sec
 ARIMA(1,0,0)(1,1,0)[12] intercept   : AIC=973.646, Time=0.15 sec
 ARIMA(0,0,1)(0,1,1)[12] intercept   : AIC=987.070, Time=0.12 sec
 ARIMA(0,0,0)(0,1,0)[12]             : AIC=1009.735, Time=0.02 sec
 ARIMA(1,0,0)(0,1,0)[12] intercept   : AIC=976.772, Time=0.03 sec
 ARIMA(1,0,0)(2,1,0)[12] intercept   : AIC=975.199, Time=0.25 sec
 ARIMA(1,0,0)(1,1,1)[12] intercept   : AIC=974.938, Time=0.16 sec
 ARIMA(1,0,0)(0,1,1)[12] intercept   : AIC=973.421, Time=0.13 sec
 ARIMA(1,0,0)(0,1,2)[12] intercept   : AIC=975.242, Time=0.31 sec
 ARIMA(1,0,0)(1,1,2)[12] intercept   : AIC=976.932, Time=0.42 sec
 ARIMA(0,0,0)(0,1,1)[12] intercept   : AIC=1003.480, Time=0.07 sec
 ARIMA(2,0,0)(0,1,1)[12] intercept   : AIC=974.622, Time=0.14 sec
 ARIMA(1,0,1)(0,1,1)[12] intercept   : AIC=975.344, Time=0.16 sec
 ARIMA(2,0,1)(0,1,1)[12] intercept   : AIC=976.388, Time=0.37 sec
 ARIMA(1,0,0)(0,1,1)[12]             : AIC=973.113, Time=0.08 sec
 ARIMA(1,0,0)(0,1,0)[12]             : AIC=976.785, Time=0.02 sec
 ARIMA(1,0,0)(1,1,1)[12]             : AIC=974.306, Time=1.02 sec
 ARIMA(1,0,0)(0,1,2)[12]             : AIC=974.767, Time=1.99 sec
 ARIMA(1,0,0)(1,1,0)[12]             : AIC=972.442, Time=0.99 sec
 ARIMA(1,0,0)(2,1,0)[12]             : AIC=974.339, Time=0.42 sec
 ARIMA(1,0,0)(2,1,1)[12]             : AIC=976.198, Time=0.48 sec
 ARIMA(0,0,0)(1,1,0)[12]             : AIC=1011.915, Time=0.05 sec
 ARIMA(2,0,0)(1,1,0)[12]             : AIC=974.212, Time=0.16 sec
 ARIMA(1,0,1)(1,1,0)[12]             : AIC=973.436, Time=0.34 sec
 ARIMA(0,0,1)(1,1,0)[12]             : AIC=990.091, Time=0.09 sec
 ARIMA(2,0,1)(1,1,0)[12]             : AIC=976.250, Time=0.39 sec
```

```
Best model:  ARIMA(1,0,0)(1,1,0)[12]
Total fit time: 9.213 seconds
Mean Absolute Error (Set 1): 44554.05720416259
Forecast for the next 84 months: [178306.88154851 175873.0951826  241166.58712275 146098.52413031
 193014.78758505 137283.41946636 151298.69386203 161686.63412514
 163029.57114257 174793.92294467 188497.32634678 176039.58964645
 213348.35499154 210914.61991029 276208.08921671 181140.03621334
 228056.29525955 172324.9290865  186340.20262349 196728.14326557
 198071.08011574 209835.43199166 223538.8353612  211081.09867523
 248389.86401399 245956.12893553 311249.59824072 216181.54523789
 263097.80428386 207366.43811092 221381.71164786 231769.65228996
 233112.58914012 244876.94101604 258580.34438558 246122.60769962
 283431.37303837 280997.63795992 346291.10726511 251223.05426227
 298139.31330825 242407.9471353  256423.22067225 266811.16131435
 268154.09816451 279918.45004043 293621.85340997 281164.11672401
 318472.88206276 316039.1469843  381332.61628949 286264.56328666
 333180.82233263 277449.45615969 291464.72969663 301852.67033873
 303195.60718889 314959.95906482 328663.36243435 316205.62574839
 353514.39108714 351080.65600869 416374.12531388 321306.07231105
 368222.33135702 312490.96518407 326506.23872102 336894.17936312
 338237.11621328 350001.4680892  363704.87145874 351247.13477278
 388555.90011153 386122.16503308 451415.63433827 356347.58133543
 403263.84038141 347532.47420846 361547.7477454  371935.6883875
 373278.62523767 385042.97711359 398746.38048312 386288.64379716]
```

FORECASTS OF EV SALES DONE WITH AUTHENTIC SOURCES

1. Electric vehicle sales in India are projected to reach 10 million units by 2030 - Economic times
2. The EV market is expected to grow at a CAGR of 49% from 2022 to 2030, with major contributions from the e-2W and e-3W segments - Clean Mobility shift
3. Union Minister Nitin Gadkari forecasts that India's EV sales will reach 10 million units per year by 2030. Business Standard projects that EV sales will reach 27.2 million units by 2032. - Business standard

ETPrime

EV sales in India to reach 10 mn units by 2030, to create 5 mn jobs: Nitin Gadkari

By Sharmistha Mukherjee, ET Bureau • Last Updated: Sep 10, 2024, 11:35:00 PM IST

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Synopsis

Electric vehicle sales in India are projected to reach 10 million units by 2030, creating 5 million jobs, according to Union Minister Nitin Gadkari. The market potential is expected to touch Rs 20 lakh crore, with the EV finance market growing to Rs 4 lakh crore. Battery costs are likely to decrease, boosting affordability and adoption.

While addressing a gathering on 'Sustainable Mobility Journey Towards Viksit Bharat' at the Inaugural Session of the 64th SIAM Annual Convention 2024, in New Delhi, Union Minister Nitin Gadkari also urged automakers to take measures to promote scrappage of old vehicle scrappage.

Electric vehicle sales in the local market will grow to 10 million units by the turn of the decade, generating employment for 5 million people, Union Minister for Road, Transport & Highways Nitin Gadkari said on Tuesday.

Gadkari, who was speaking at the 64th Annual Convention of the Society of Indian Automobile Manufacturers (SIAM), said the market potential for

CLEAN MOBILITY SHIFT

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instrumental in managing lithium-ion batteries, extending their lifespan, improving energy efficiency, and reducing waste – crucial factors for sustainable mobility. However, EVs require up to three times more semiconductor content than conventional vehicles.

Given their huge role in the digitisation drive of the country, as per PwC, the semiconductor market in India is expected to reach $32 billion by 2025. The EV market accounts for a significant share of this growth. The Economic Survey of India 2023 forecasts a 49% compound annual growth rate (CAGR) in India's domestic EV market between 2022 to 2030, with an estimated 10 million annual sales by 2030. On the demand side, therefore, semiconductor technology is on the upswing.

Conclusion - Opportunities and Challenges for EVs in India

1. Economic Opportunities

- **Lower Operating Costs:** Electricity is cheaper than gasoline, and government subsidies can reduce the cost of EVs over time.
- **Job Creation:** Expansion in EV manufacturing and infrastructure development can generate employment opportunities in India.

2. Technological Opportunities

- **Advancements in Battery Tech:** As battery costs decrease, EVs will become more affordable, leading to wider adoption.
- **Innovation in Charging Infrastructure:** Development of faster charging stations and renewable energy-based grids can enhance EV convenience.

3. Environmental Opportunities

- **Reduced Emissions:** EVs contribute to a significant reduction in emissions compared to traditional gasoline vehicles, helping combat global warming.
- **Sustainable Energy Integration:** EVs can integrate with renewable energy sources, reducing dependency on fossil fuels.

4. Social Opportunities

- **Health & Safety:** Reduction in air pollution due to fewer emissions from EVs can improve public health outcomes.
- **Growing Acceptance:** As more people adopt EVs, social acceptance and infrastructure will improve, fostering more widespread use.

Challenges of Electric Vehicles (EVs)

1. Economic Challenges

- **High Initial Cost:** EVs have a high upfront cost due to expensive components and manual assembly.
- **Battery Costs:** Lithium-ion batteries, which make up a significant part of the EV cost, are expensive and linked to ethical concerns such as child labor in cobalt mining.
- **Infrastructure Costs:** Charging infrastructure, both public and private, requires significant investment. Profitability is low in developing countries like India.

2. Technological Challenges

- **Battery Safety & Cost:** Li-ion batteries are prone to safety risks like overheating and require costly maintenance.
- **Energy Storage Systems:** One-third of the EV cost comes from energy storage, which includes expensive materials and labor.
- **Charging Technology:** Slow charging times and reliance on renewable energy sources can limit adoption.

3. Environmental Challenges

- **Greenhouse Gas Emissions:** EV charging still relies on power grids that emit greenhouse gases, contributing to global warming.
- **Battery Disposal:** Improper disposal of EV batteries can lead to health risks and environmental harm.

4. Social Challenges

- **Consumer Attitudes:** Range anxiety and reluctance to adopt new technologies are major hurdles in EV adoption.

REFERENCES

DATASET

https://docs.google.com/spreadsheets/d/1t1c66c6eOTflskxCFB2OUWnUyQDLZxmsoKoA9j69nPc/edit?usp=sharing

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https://economictimes.indiatimes.com/industry/renewables/ev-sales-in-india-to-reach-10-mn-units-by-2030-to-create-5-mn-jobs-nitin-gadkari/articleshow/113230568.cms?from=mdr

https://www.bain.com/insights/india-electric-vehicle-report-2023/#:~:text=India's%20electric%20vehicle%20(EV)%20market,%2Dwheeler%20(3W)%20categories.