Problem Statement / Objective

Market Size Analysis is the process of estimating the potential sales for a product or service within a particular market segment. In the context of electric vehicles (EVs), it involves assessing the total volume of EV registrations to understand the growth of the market, forecast future trends, and help stakeholders make informed decisions regarding production, infrastructure development, and policy-making

The provided dataset contains the following columns, each representing different aspects of the electric vehicle (EV) population in the United States:

- VIN (1-10): Partial Vehicle Identification Number.
- County: The county in which the vehicle is registered.
- City: The city in which the vehicle is registered.
- State: The state in which the vehicle is registered. It appears that this dataset may be focused on Washington (WA) state.
- Postal Code: The postal code where the vehicle is registered.
- Model Year: The year of the vehicle model
- Make: The manufacturer of the vehicle.
- Model: The model of the vehicle.
- Electric Vehicle Type: The type of electric vehicle, e.g., Battery Electric Vehicle (BEV).
- Clean Alternative Fuel Vehicle (CAFV) Eligibility: Eligibility status for clean alternative fuel vehicle programs.
- Electric Range: The maximum range of the vehicle on a single charge (in miles).
- Base MSRP: The Manufacturer's Suggested Retail Price.

- Legislative District: The legislative district where the vehicle is registered.
- DOL Vehicle ID: Department of Licensing Vehicle Identification.
- Vehicle Location: Geographic coordinates of the vehicle location.
- Electric Utility: The electric utility service provider for the vehicle’s location.
- 2020 Census Tract: The census tract for the vehicle’s location.

The primary objective of this analysis is to leverage historical EV registration data to understand the current market penetration of EVs, predict future market growth, and identify key trends and factors driving market expansion.

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Data Dictionary

- `6-Electric_Vehicle_Population_Data New.csv`

The top 5 rows

Observation

	0	1	2	3	4
VIN (1-10)	5YJYGDEE1L	7SAYGDEE9P	5YJSA1E4XK	5YJSA1E27G	5YJYGDEE5M
County	King	Snohomish	King	King	Kitsap
City	Seattle	Bothell	Seattle	Issaquah	Suquamish
State	WA	WA	WA	WA	WA
Postal Code	98122.0	98021.0	98109.0	98027.0	98392.0
Model Year	2020	2023	2019	2016	2021
Make	TESLA	TESLA	TESLA	TESLA	NaN
Model	MODEL Y	MODEL Y	MODEL S	MODEL S	MODEL Y
Electric Vehicle Type	Battery Electric Vehicle (BEV)	Battery Electric Vehicle (BEV)	Battery Electric Vehicle (BEV)	Battery Electric Vehicle (BEV)	Battery Electric Vehicle (BEV)
Clean Alternative Fuel Vehicle (CAFV) Eligibility	Clean Alternative Fuel Vehicle Eligible	Eligibility unknown as battery range has not b...	NaN	Clean Alternative Fuel Vehicle Eligible	Eligibility unknown as battery range has not b...
Electric Range	291	0	270	210	0
Base MSRP	0	0	0	0	0
Legislative District	37	1	36	5	23
DOL Vehicle ID	125701579	244285107	156773144	165103011	205138552
Vehicle Location	POINT (-122.30839 47.610365)	POINT (-122.179458 47.802589)	POINT (-122.34848 47.632405)	POINT (-122.03646 47.534065)	POINT (-122.55717 47.733415)
Electric Utility	CITY OF SEATTLE - (WA)|CITY OF TACOMA - (WA)	PUGET SOUND ENERGY INC	CITY OF SEATTLE - (WA)|CITY OF TACOMA - (WA)	PUGET SOUND ENERGY INC||CITY OF TACOMA - (WA)	PUGET SOUND ENERGY INC
2020 Census Tract	53033007800.0	53061051938.0	53033006800.0	53033032104.0	53035940100.0

The last 5 rows

Observation

	177861	177862	177863	177864	177865
VIN (1-10)	7SAYGDEE3N	KM8K23AG1P	5YJYGDEE6M	WVGKMPE27M	5YJ3E1EA8M
County	Pierce	Mason	Grant	King	Pierce
City	Bonney Lake	Shelton	Quincy	Black Diamond	Tacoma
State	WA	WA	WA	WA	WA
Postal Code	98391.0	98584.0	98848.0	98010.0	98422.0
Model Year	2022	2023	2021	2021	2021
Make	TESLA	HYUNDAI	TESLA	VOLKSWAGEN	TESLA
Model	MODEL Y	KONA ELECTRIC	MODEL Y	ID.4	MODEL 3
Electric Vehicle Type	Battery Electric Vehicle (BEV)	Battery Electric Vehicle (BEV)	Battery Electric Vehicle (BEV)	Battery Electric Vehicle (BEV)	Battery Electric Vehicle (BEV)
Clean Alternative Fuel Vehicle (CAFV) Eligibility	Eligibility unknown as battery range has not b...	Eligibility unknown as battery range has not b...	Eligibility unknown as battery range has not b...	Eligibility unknown as battery range has not b...	Eligibility unknown as battery range has not b...
Electric Range	0	0	0	0	0
Base MSRP	0	0	0	0	0
Legislative District	31.0	35.0	13.0	5.0	27.0
DOL Vehicle ID	195224452	228454180	168797219	182448801	211464683
Vehicle Location	POINT (-122.183805 47.18062)	POINT (-123.105305 47.211085)	POINT (-119.8493873 47.2339933)	POINT (-122.00451 47.312185)	POINT (-122.38578 47.28971)
Electric Utility	PUGET SOUND ENERGY INC||CITY OF TACOMA - (WA)	BONNEVILLE POWER ADMINISTRATION||CITY OF TACOM...	PUD NO 2 OF GRANT COUNTY	PUGET SOUND ENERGY INC||CITY OF TACOMA - (WA)	BONNEVILLE POWER ADMINISTRATION||CITY OF TACOM...
2020 Census Tract	53053070308.0	53045960900.0	53025010500.0	53033031603.0	53053940005.0

Shape of Dataset

Observation

- The dataset is having 17766 rows and 17 columns

Datatypes of each feature

Observation

- Postal Code is numerical type but should be Object
- Electric Range is Object type but should be Numerical
- DOL Vehicle ID is numerical type but should be Object
- 2020 Census Tract is numerical type but should be Object
- All these columns need to be checked

Statistical Summary

Observation

- Data set contains numerical datatypes of columns Postal code, DOL Vehicle ID and 2020 Census Tract which should be statistical types

Null values

Observation

Columns –

- County [5],
- City [5],
- Postal Code [5],
- Make [7],
- Model [4],
- Electric Vehicle Type [6],
- Clean Alternative Fuel Vehicle (CAFV) [2],
- Electric Range [3],
- Legislative District [389],
- Vehicle Location [9],
- Electric Utility [5],
- 2020 Census Tract [5]

contains null values as shown respectively

Duplicate values

Observation

- Data set contains no duplicate values

Anomalies or wrong entry

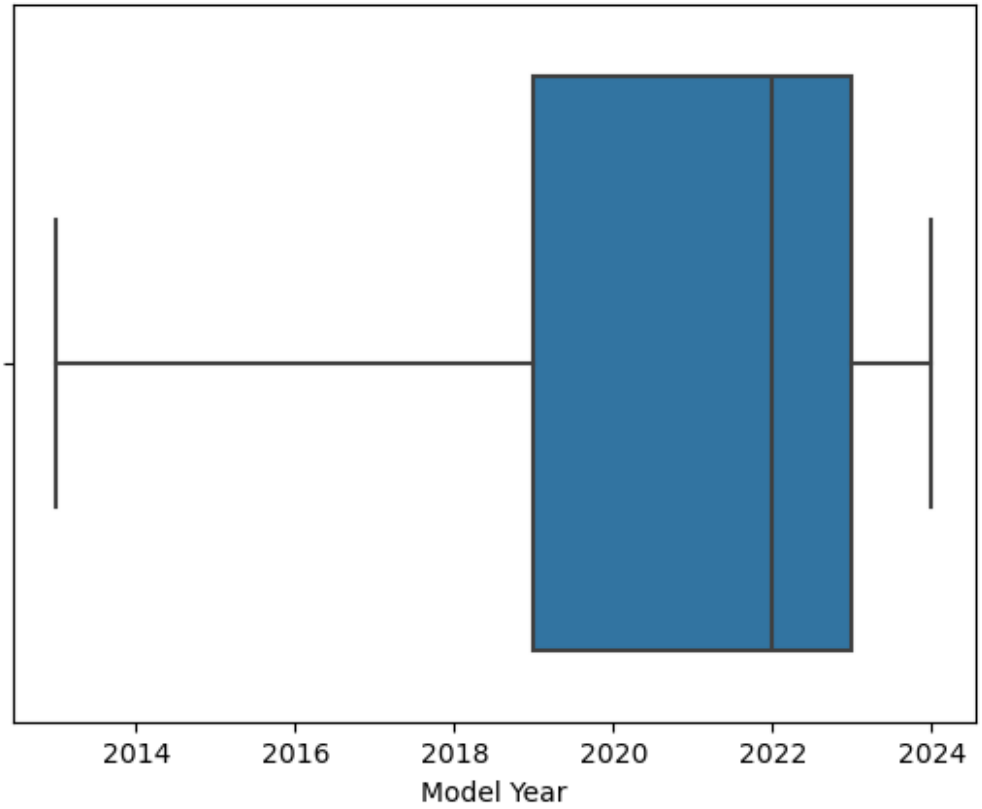
Observation

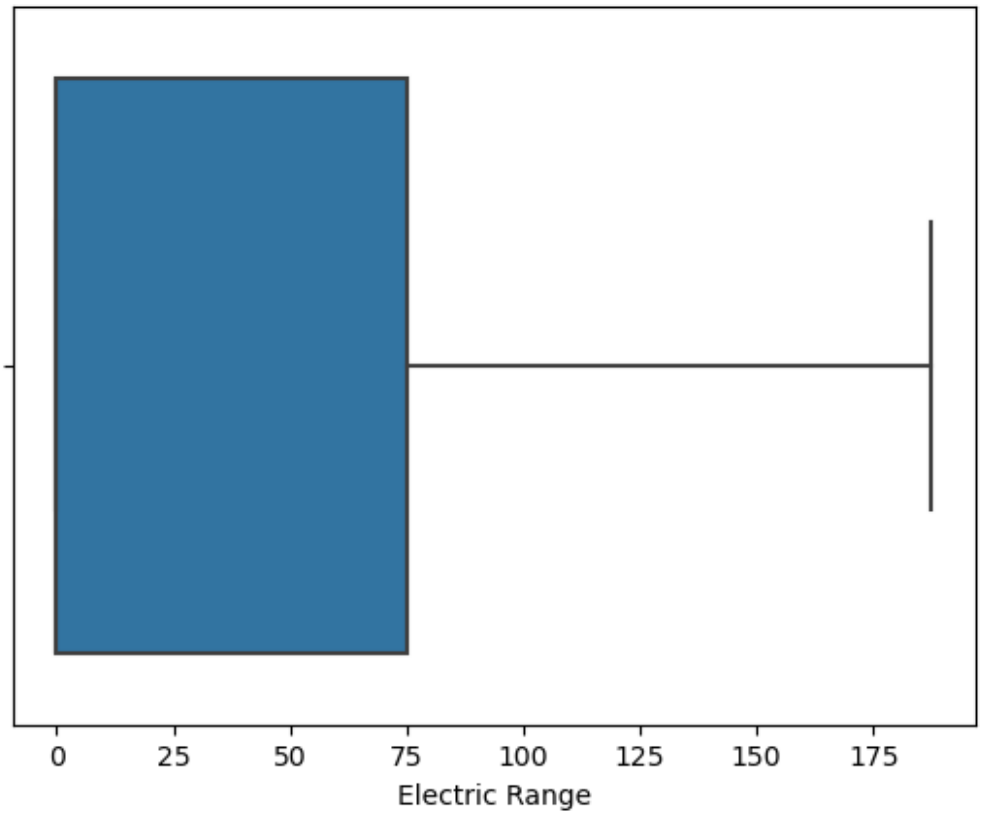
- Electric Range contains '?'
- Legislative District contains '?'
- For row 6, Country and City are both the same name, Yakima. Further checking is to be done.

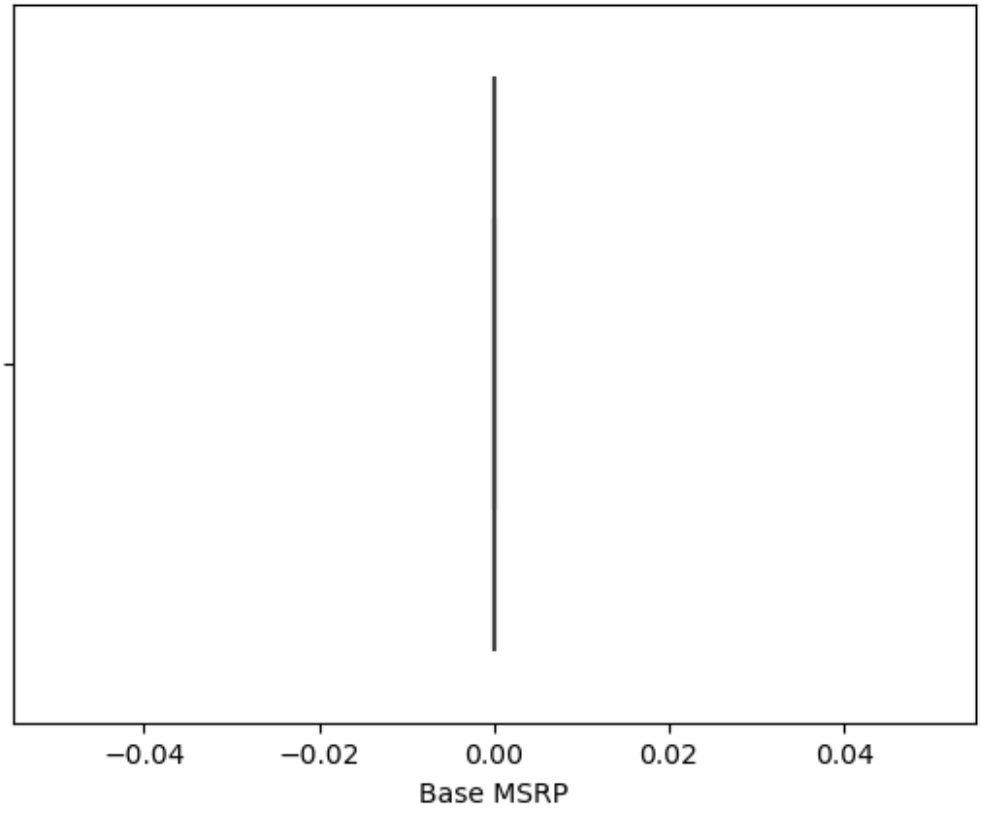
Check the outliers and their authenticity

Observation

- After removing anomalies and converting datatypes of each column with wrong entries, the outliers representation through box plot are




0
25
50
75
100
125
150
175
Electric Range


−0.04
−0.02
0.00
0.02
0.04
Base MSRP

Cleaning Data

Observation

- Updated '?' to null value in columns- Electric Range and Legislative District
- Null values of columns Electric Range and Base MSRP are replaced by median
- Columns –
- [County, City, Postal Code, Make, Model, Electric Vehicle Type, Clean Alternative Fuel Vehicle (CAFV) Eligibility, Electric Range, Legislative District, Vehicle Location, Electric Utility, 2020 Census Tract]
- contains null values, all has been replaced by their respective Mode as they are of statistical datatype
- Outliers of every column has been removed

1. Descriptive Statistics:

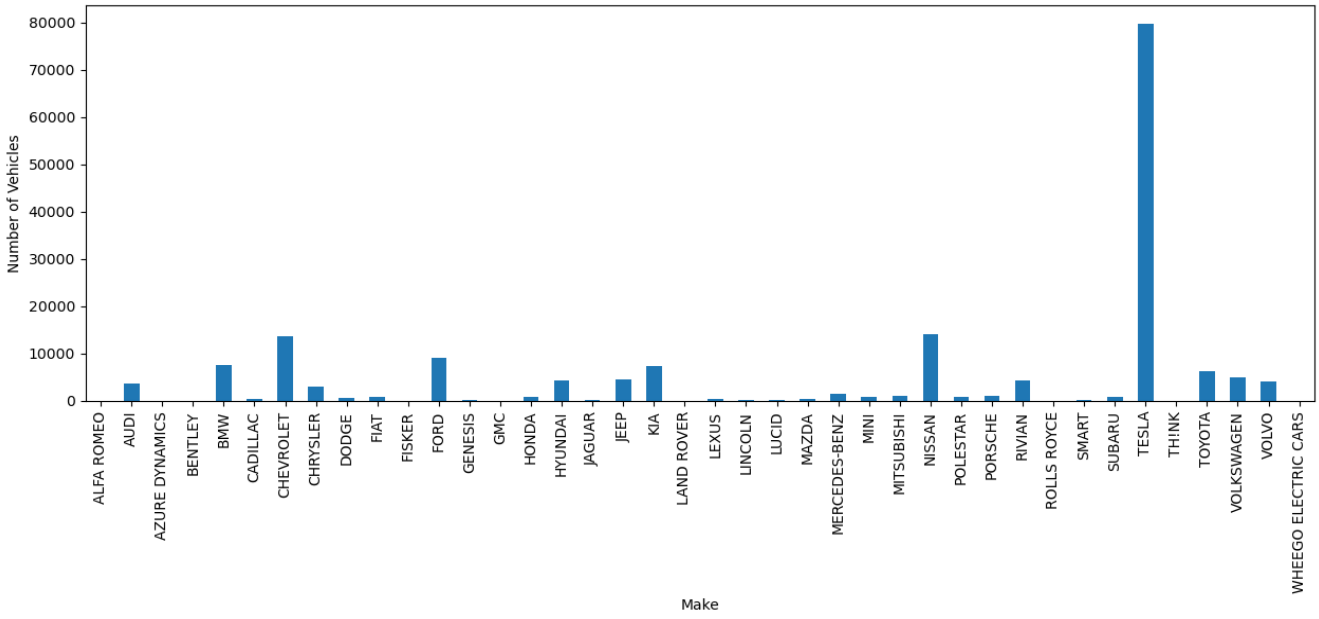
• What are the mean, median, and standard deviation of the base MSRP for the vehicles in the dataset?

Observation

- The Mean of Base MSRP is 0.00
- The Median of Base MSRP is 0.0
- The Standard Deviation of Base MSRP is 0.00

2. Data Distribution:

• What is the distribution of vehicle makes in the dataset? Represent it using a bar chart.



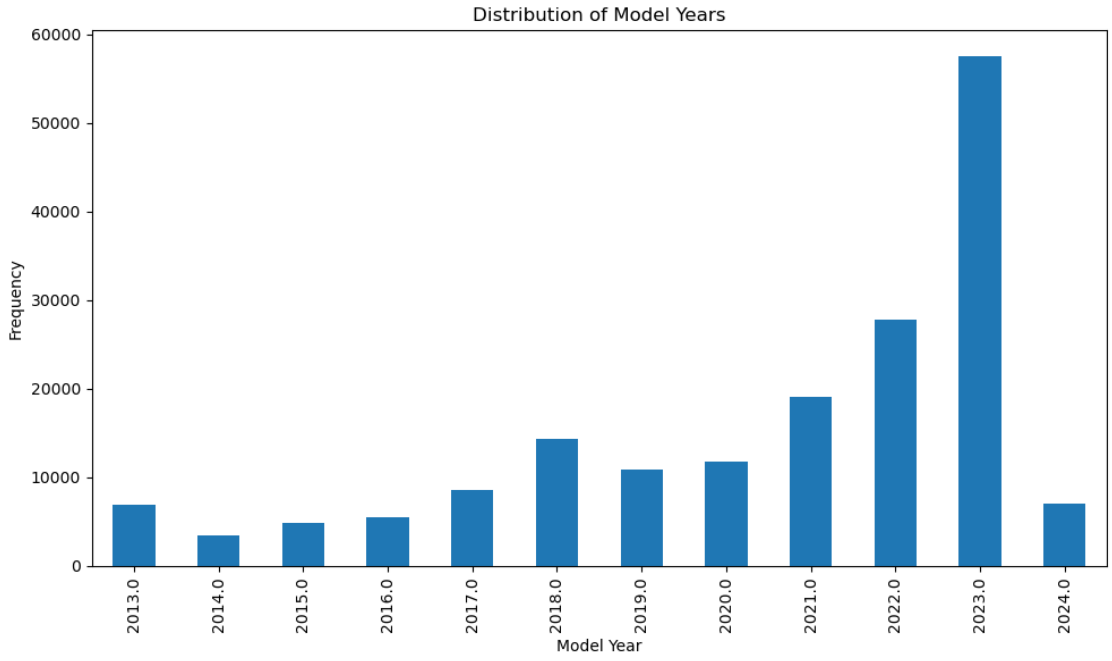
3. Model Year Analysis:

• What are the most common model years in the dataset? Provide

1. A frequency table
2. histogram.

Observation

- ```
  Model Year
  2013.0     6862
  2014.0     3509
  2015.0     4844
  2016.0     5483
  2017.0     8562
  2018.0    14323
  2019.0    10940
  2020.0    11768
  2021.0    19132
  2022.0    27776
  2023.0    57587
  2024.0     7080
  ```



Observation

- The year between 2023 had seen the most common modles in a year.
  ```

4. Electric Vehicle Type:

• What is the proportion of Battery Electric Vehicles (BEV) versus other types of electric vehicles?

Observation

- The raito of Battery Electric Vehicles (BEV) to other types of electric vehicles is 13921 : 177866.
- Or Battery Electric Vehicles (BEV) is 78.26% more compared to other electric vehicles.

5. Electric Range Analysis:

• What is the average electric range for vehicles of different makes? Provide a summary tabe.

Observation

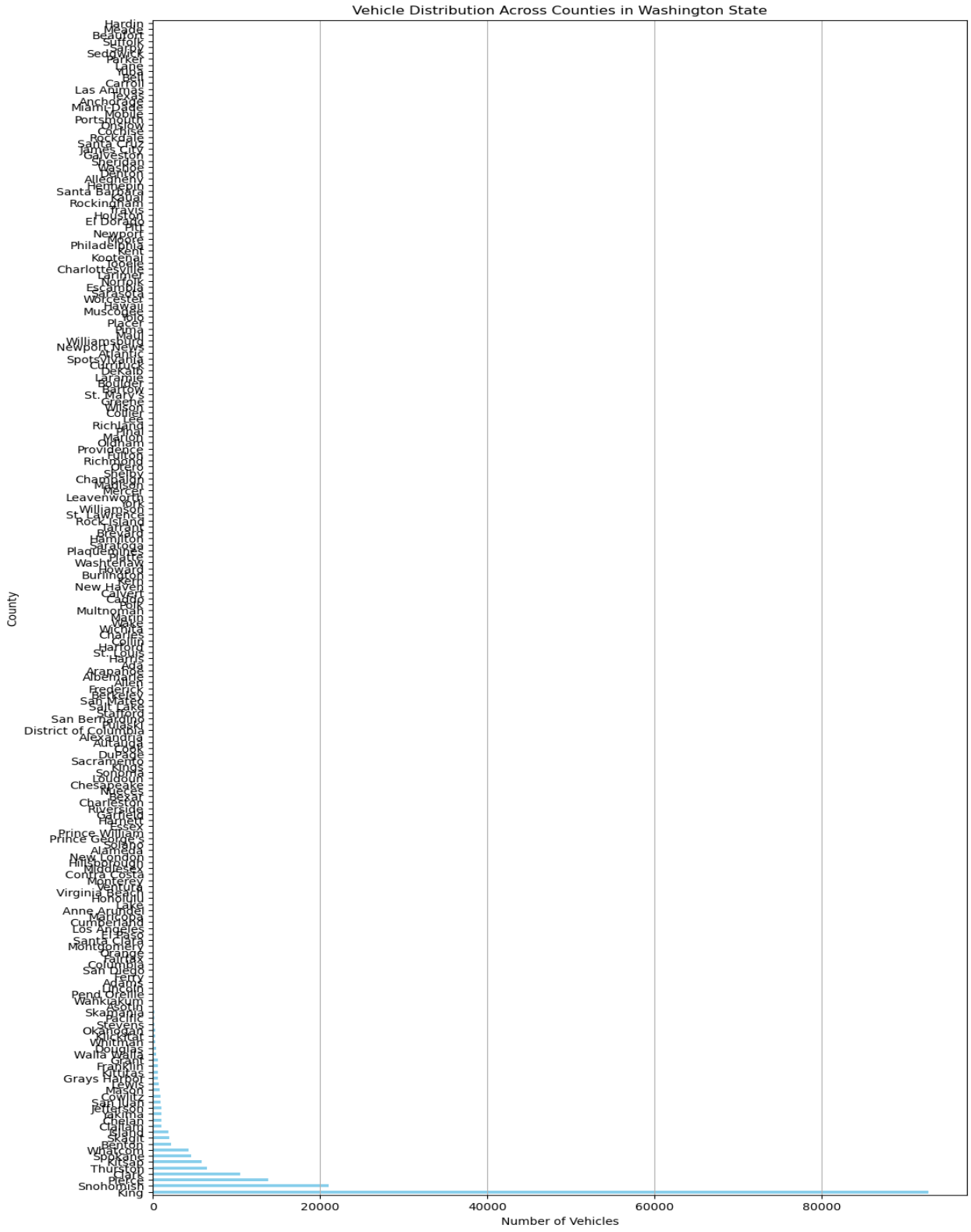
- Summary Table for vehicles of different Make and Electric Range:

	Make	Electric Range
0	ALFA ROMEO	33.000000
1	AUDI	46.454745
2	AZURE DYNAMICS	56.000000
3	BENTLEY	19.666667
4	BMW	34.711427
5	CADILLAC	8.798429
6	CHEVROLET	76.570332
7	CHRYSLER	32.212162
8	DODGE	32.000000
9	FIAT	85.645408
10	FISKER	8.755102
11	FORD	10.812914
12	GENESIS	0.000000
13	GMC	0.000000
14	HONDA	46.600240
15	HYUNDAI	15.858715
16	JAGUAR	163.254310
17	JEEP	22.365402
18	KIA	38.850175
19	LAND ROVER	25.000000
20	LEXUS	18.800000
21	LINCOLN	23.543071
22	LUCID	0.000000
23	MAZDA	25.781513
24	MERCEDES-BENZ	9.346130
25	MINI	18.016704
26	MITSUBISHI	30.646138
27	NISSAN	79.839501

28	POLESTAR	30.399660
29	PORSCHE	42.693152
30	RIVIAN	0.000000
31	ROLLS ROYCE	0.000000
32	SMART	62.325926
33	SUBARU	1.350181
34	TESLA	60.214775
35	TH!NK	100.000000
36	TOYOTA	28.095102
37	VOLKSWAGEN	22.927058
38	VOLVO	16.135737
39	WHEEGO ELECTRIC CARS	100.000000

6. County Distribution:

• How are vehicles distributed across different counties in Washington state? Represent the distribution using a barh chart.



Observation

- King has the greatest number of vehicles in the Washington state around 53%

7. Price Analysis:

• Compare the average base MSRP of vehicles eligible for the Clean Alternative Fuel Vehicle (CAFV) program versus those that are not

Observation

- Average Base MSRP for CAFV Eligible: $0.00, Not Eligible: $0.00

8. Geographical Analysis:

• How does the base MSRP vary across different cities in Washington state?

Observation

	City	Base MSRP
0	Aberdeen	0.0
1	Aberdeen Proving Ground	0.0
2	Acme	0.0
3	Adairsville	0.0
4	Addy	0.0
5	Adna	0.0
6	Airway Heights	0.0
7	Alameda	0.0
8	Alderdale	0.0
9	Alderwood Manor	0.0

9. Legislative Districts:

• Which legislative districts have the highest number of registered electric vehicles? Provide a ranked list

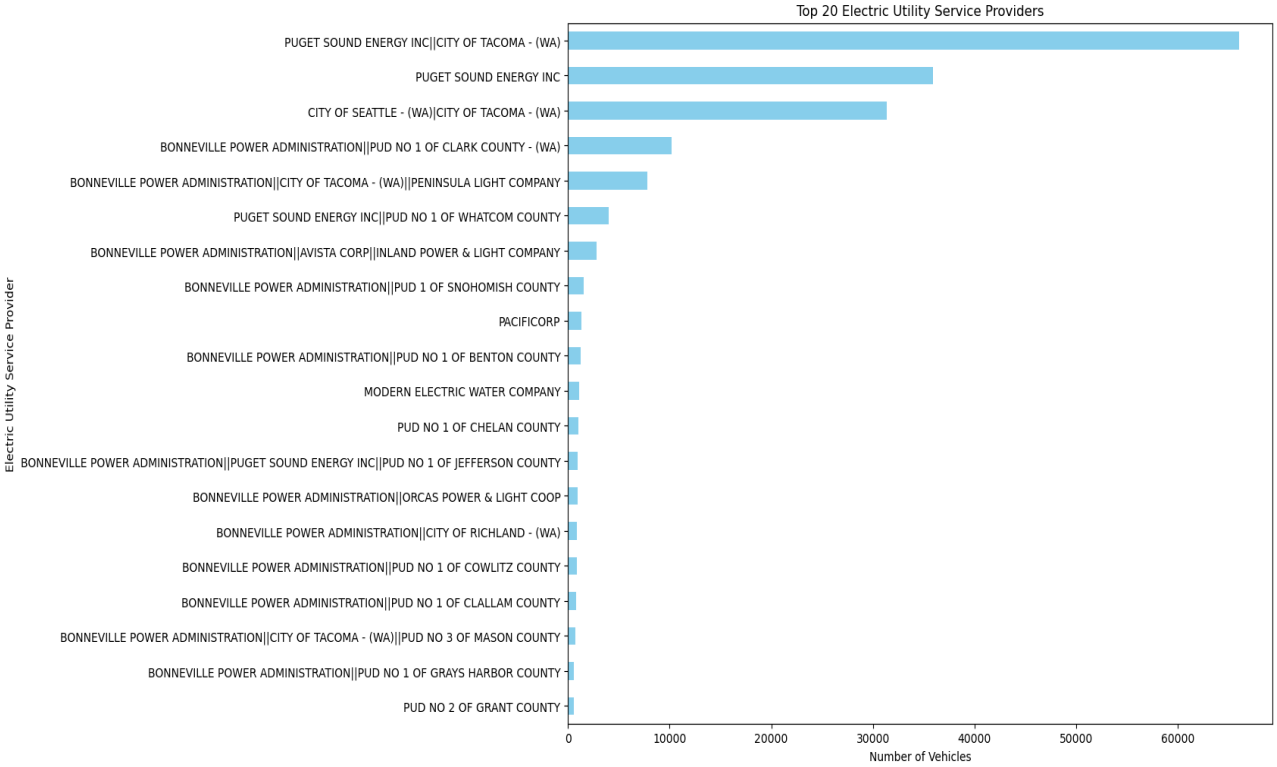
Observation

- 41 legislative districts have the highest number of registered electric vehicles
- Ranked List:
- Legislative District
  41.0 8831
  45.0 7425
  5.0 6810
  48.0 6631
  1.0 6265
  Name: count, dtype: int64
  Legislative District
  9 5
  16 4
  3 2

```
40    2
6     1
Name: count, dtype: int64
```

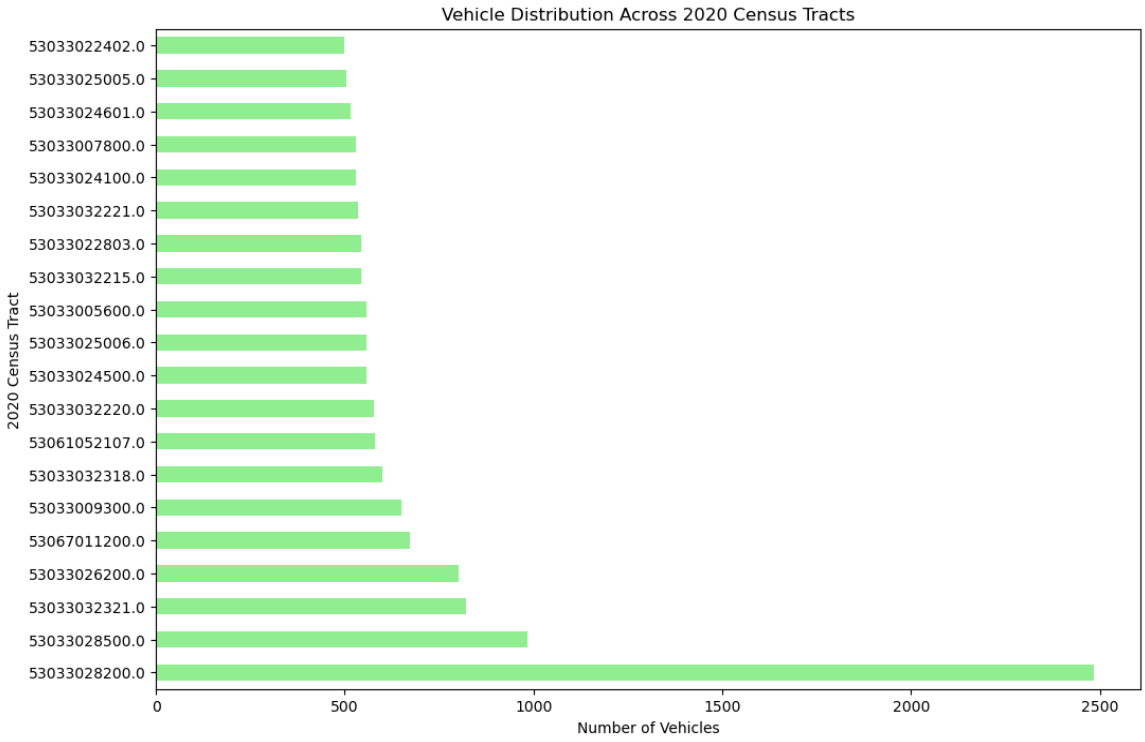
10. Electric Utility Providers:

• What is the distribution of electric utility service providers for the vehicles in the dataset?



11. Census Tract Analysis:

• How are vehicles distributed across different 2020 Census Tracts? Provide insights based on vehicle counts per tract.



12. Electric Range Correlation:

• Is there a correlation between the electric range and the base MSRP of the vehicles? Provide the correlation coefficient and interpret the result.

Observation

- Correlation Coefficient between Electric Range and Base MSRP: nan
- Correlation Coefficient (r):
  1: Perfect positive correlation.
  0.7 to 0.9: Strong positive correlation.
  0.4 to 0.6: Moderate positive correlation.
  0.1 to 0.3: Weak positive correlation.
  0: No correlation.
  -0.1 to -0.3: Weak negative correlation.
  -0.4 to -0.6: Moderate negative correlation.
  -0.7 to -0.9: Strong negative correlation.
  -1: Perfect negative correlation
- There cannot be a Correlation between Electric Range and Base MSRP

13. VIN Analysis:

• Identify any patterns or commonalities in the VIN (1-10) for the vehicles. Are there any frequent prefixes or suffixes

- Most common VIN prefixes (first 10 characters):

```
VIN (1-10)
7SAYGDEE6P    1239
7SAYGDEE7P    1235
7SAYGDEE8P    1197
7SAYGDEEXP    1191
7SAYGDEE5P    1177
Name: count, dtype: int64
```

- Most common VIN suffixes (last 10 characters):

```
VIN (1-10)
7SAYGDEE6P    1239
7SAYGDEE7P    1235
7SAYGDEE8P    1197
7SAYGDEEXP    1191
7SAYGDEE5P    1177
Name: count, dtype: int64
```

14. Eligibility Status:

• What percentage of vehicles are eligible for the Clean Alternative Fuel Vehicle (CAFV) program

Observation

- Percentage of vehicles eligible for CAFV: 37.29%

15. Model Popularity:

• Which vehicle models are the most popular in the dataset? Provide a frequency table of the top 10 models

Observation

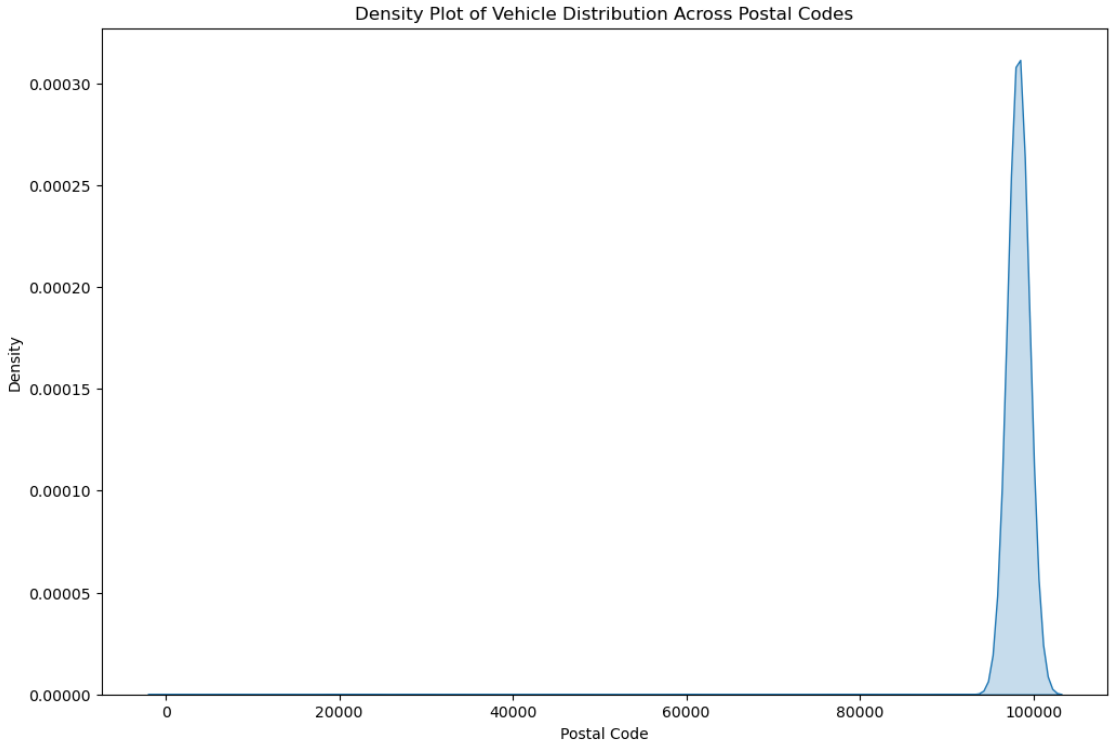
- Frequency Table of top 10 Models:

```
Model
MODEL Y           35993
MODEL 3           30091
LEAF              13365
MODEL S            7734
BOLT EV            6821
MODEL X            5796
VOLT               4796
ID.4               3937
WRANGLER           3392
MUSTANG MACH-E     3322
Name: count, dtype: int64
```

- MODEL Y is most popular in the dataset

16. Postal Code Distribution:

• How are vehicles distributed across different postal codes? Provide a heatmap or density plot

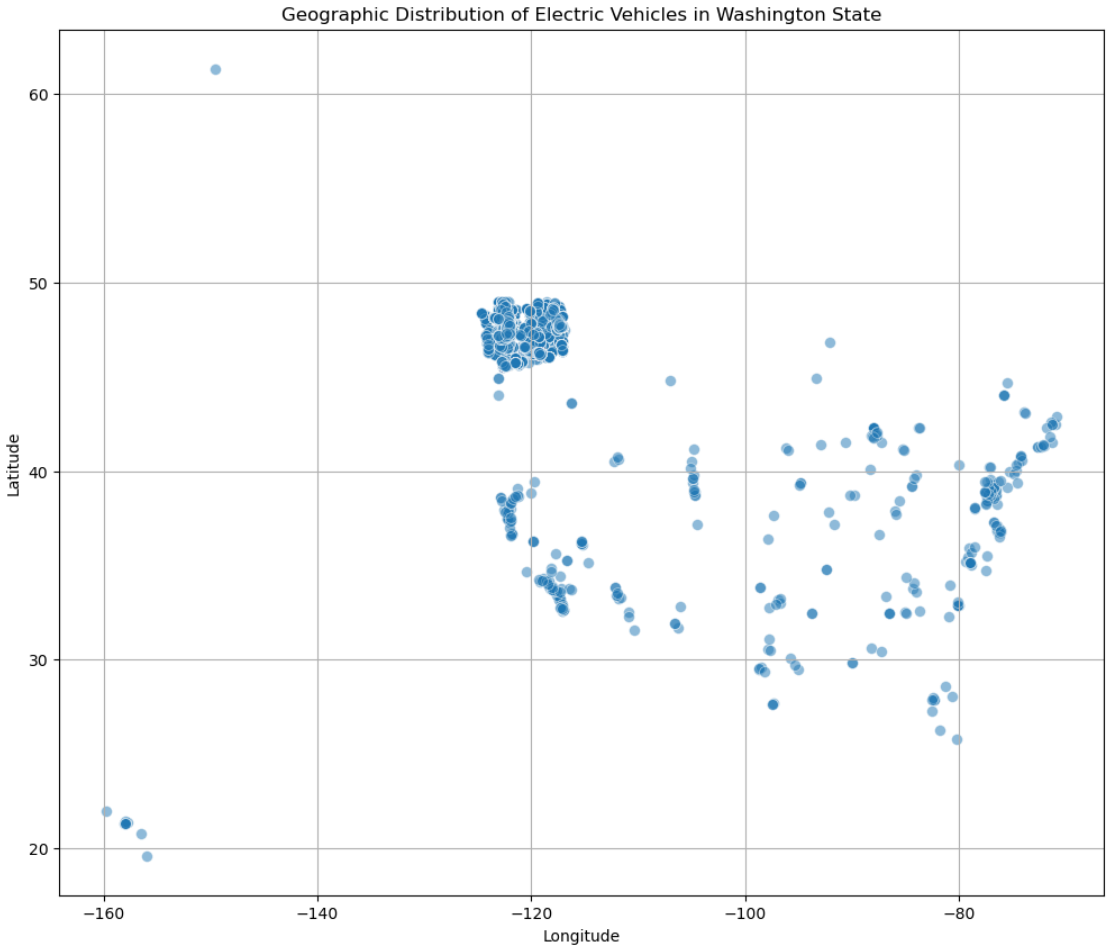


Observation

- Density Plot of Vehicle Distribution Across Postal Codes shows postal code at 100000 is maximum

17. Vehicle Location Analysis:

• Analyze the geographic coordinates to determine any clusters of electric vehicles in certain areas of Washington state.

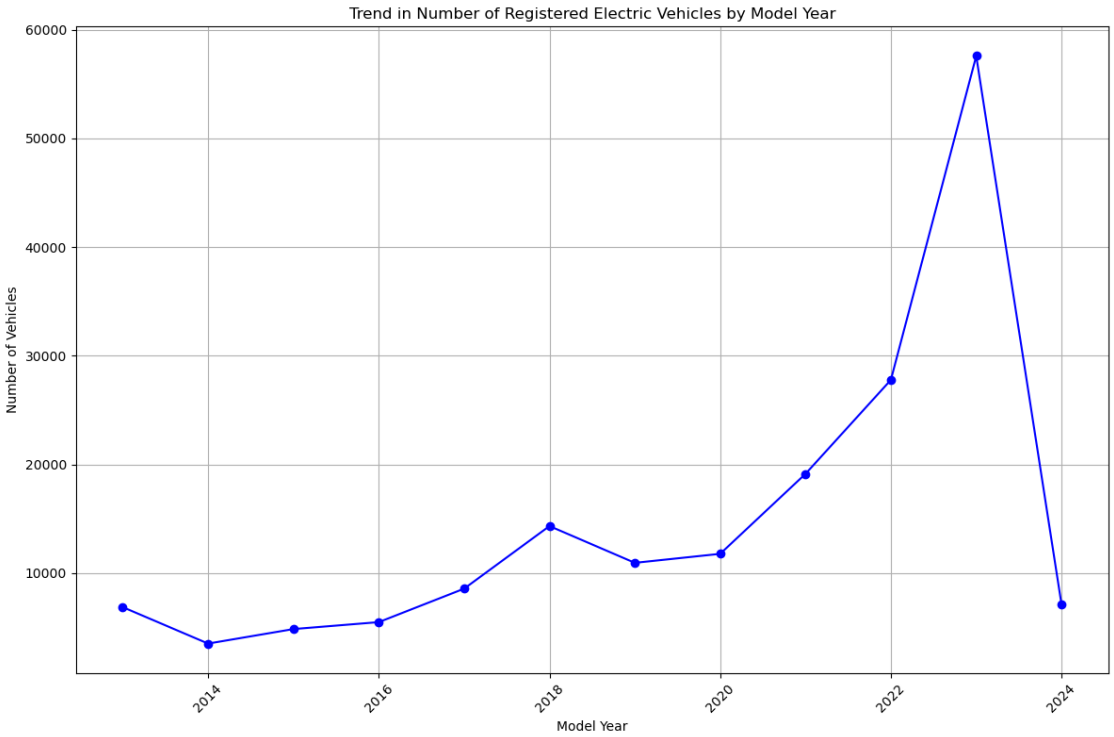


Observation

- `At longitude 49 and Longitude -120 the distribution is maximum`

18. Model Year Trend:

• Analyze the trend in the number of registered electric vehicles by model year. Provide a line chart to show any increase or decrease over the years.

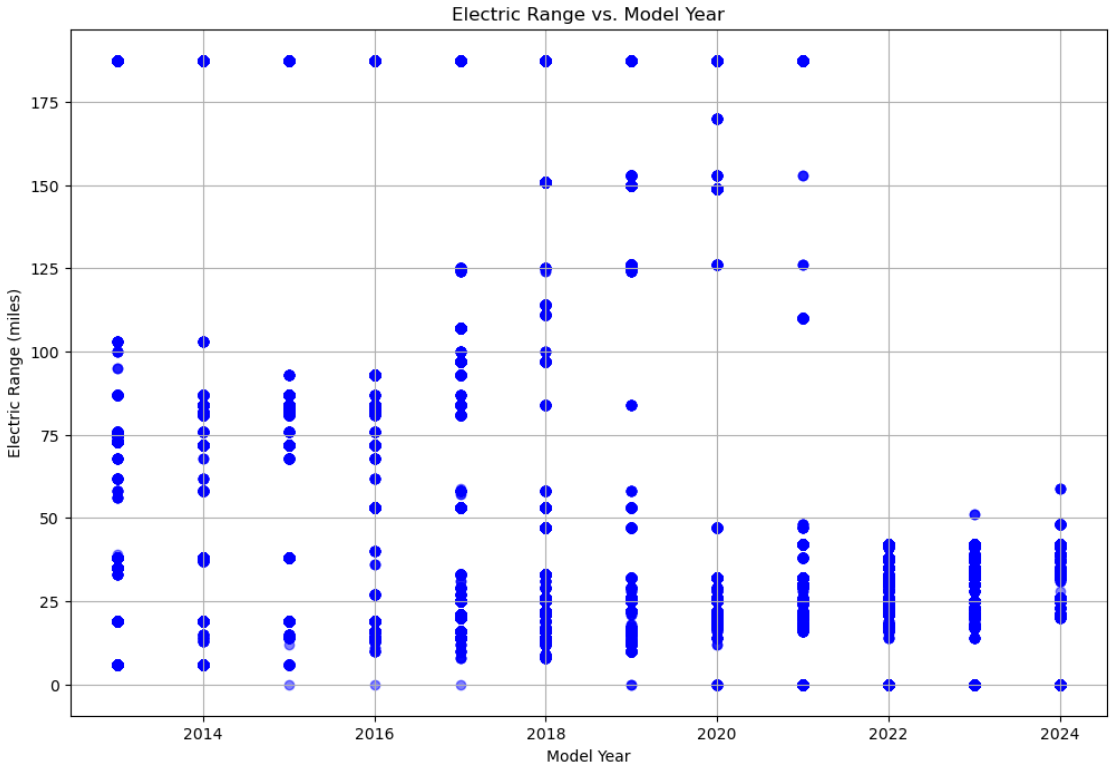


Observation

- The was a steady growth in between year 2014 and 2020
- 2020 to 2023 saw a skyroketting growth in the number of vehicle registered
- After mid of 2023 there was a drastic fall in number of registrations in 2024

19. Range vs. Year:

• Is there a trend between the model year and the electric range of the vehicles? Provide a scatter plot and analyze the trend.



Observation

- The correlation coefficient is -0.55
- This negative correlation indicates that newer model years generally have lower electric ranges compared to older model years.

20. Legislative District and MSRP:

• How does the average base MSRP vary across different legislative districts

Observation

- Legislative District
  1.0 0.0
  24 0.0
  23 0.0
  22 0.0
  21 0.0
  Name: Base MSRP, dtype: float64
- The Base MSRP remains the same for every Legislative District
- There seems to be no connection between Legislative District and Base MSRP