**Analysis and Prediction of Electric Vehicle Ownership in Washington State**

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**ABSTRACT**

Over the last decade, electrical vehicles (EV) have rapidly gained popularity and demand in the United States as EV slowly become more efficient. This study explores the rising population of EVs on the roads to investigate trends and causes for this drastic shift in demand. Based on this analysis, a prediction of the future EV population will be made. The datasets utilized are limited to the availability of the data openly provided by the government. For this purpose, data exploration will be focused on the Washington (WA) state EV population datasets made publicly available by the WA State Department of Licensing (DOL) [1][2].

This study will incorporate geographical and time series analysis of the EV population from 2017 to 2023. Based on the trend observed in the time series analysis, an appropriate regression model is trained to predict the amount of EVs that are likely to be registered in 2024, 2025, and 2026. The fitted forecast model will be evaluated for its accuracy using its mean absolute percentage error (MAPE) [3][4]. Using the expected trend of EVs in WA, inferences will be made on the outlook of EVs in the coming years.

**INTRODUCTION**

For decades, developing fully electrical vehicles has been a daunting, yet highly desired goal by automakers. Beginning with its conceptions and initial renditions of steam powered EVs in the early 1900s, these vehicles were the center of attention until their decline after oil became a more efficient fuel source. The desire for EVs effectively perished until around the 1970s when the rise in gas prices urged automakers to seek alternatively fueled vehicles. In tandem with the success of the fully electric lunar-vehicle, the appeal for EVs was once again on the rise [5].

Despite slow, but steady research and development of more efficient, fully electric vehicles, it wasn’t until the 2000s when efficient hybrid vehicles first hit the market. Immediately following this milestone, the first plug-in hybrid vehicles (PHEVs) and eventually complete EVs became commercially available. Despite this, PHEVs and EVs were still undesired compared to gas cars due to their relatively inefficient batteries and high prices. This is due to the cost of batteries alone, which likely also discouraged automakers from developing more efficient batteries. However, this quickly changed around 2014 when battery costs dropped, making EVs more affordable and desirable to the public [5].

Fast-forward to 2023, EVs are now the center of attention, especially in the U.S. With the provision of Artificial Intelligence and federal rebate incentives, it is no wonder they are becoming more popular to this day [6]. Consequently, batteries have become drastically more efficient with a maximum of 80 miles in 2011 to 265 miles in 2015 and 520 miles in 2022 [7].

This study seeks to explore how the popularity of EVs has changed since 2017. With constant improvements in efficiency and declining prices, demand for EVs is likely to continue rising in the upcoming years. Analyzing this trend allows us to predict how many EVs we are likely to see hitting the road in the next few years. Simultaneously, geographical observations can help us pinpoint where we are likely to see the bulk of EV purchases.

For this study, hybrids, PHEVs, and EVs will all be referred to as EVs.

**THE DATASETS**

For the last few years, WA’s DOL has been actively collecting data on the vehicles that have been registered with the state. These datasets have been made publicly available on Data.gov [1][2] and contain information on all electrical vehicles currently registered with the state. Both datasets are assumed to be the population data for WA and are constantly updated each week.

The first dataset, denoted “vehicle\_history”, contains monthly vehicle registration counts the DOL has collected at the end of each month from January 2017 to November 2023. Each month contains basic information on newly registered EV, such as the type of EV, the battery and if it is a passenger vehicle. However, for this study, only the date and vehicle registration counts are relevant. There are a total of 19700 rows. Each row was either separated for its month or for its vehicle county-state information [1].

The second dataset, denoted “vehicle\_data”, contains all 163005 EV vehicle information currently registered as of 2023 by the DOL. The dataset contains each vehicle’s 1-10 VIN, county, vehicle brand, and geographical coordinate. This dataset will only be used for geographical data and only the county, coordinates, and brand will be used [2].

**DATA PREPERATION**

**Pre-Processing**

Both datasets must be cleaned before performing any analysis. Rows of both datasets containing any missing values will be removed. For vehicle\_history, missing data entails either the date, county or EV count was missing. Unfortunately, we do not have any features that could confidently fill the NaN values. Similarly, vehicle\_data would entail missing geographical or automaker information. Although the make, model, and model year columns can be used to predict each other, observation of the data reveals that these features are either completely present or completely missing, making estimative filling improbable.

The dates for vehicle\_history were converted into pd.datetime objects for easier extraction of the parts of the date. Doing this allows us to quickly transform the original categorical type date values to numerical date values that will assist with our predictive model.

The coordinates of vehicle\_data were originally stored as Point objects, originally being used via shapely module. These values were transformed to list formatted tuples of [x, y] for mapping usage by the folium package.

**Geographical Preparation**

Two supplementary GeoJSON datafiles [8] were included to provide the coordinates that will be used to map out WA and its counties. The states coordinates are separated from county coordinates. Each of the datafiles contain 500K coordinates of each state in the U.S. and the counties for each of the states separately. The county coordinates must be extracted for our geographical analysis; however, the datafile categorizes them using the state ID. Extracting the state ID from the states datafile provides us with id=53, which is used to extract the dictionary of coordinates for each county in WA. With all state and county information, the coordinate outlines for WA and its counties were extracted from the JSON file.

**ANALYSIS**

**Understanding Vehicle History**

The vehicle history data contains a count of the total number of EVs and the total number of vehicles registered each month as described in the data information provided on Data.gov [1].

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Figure 1: Cumulative # of EVs Registered with WA Up to 2023

A graph showing the growth of a company

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Figure 2: # of EVs Actively Registered as of Each Month Between 2017 to 2023

Assuming this is true, we can compute the total count of new EVs for a given year. Calculating the cumulative sum of each year produces the trend in Figure 1. This trend matches the expected observed rise in EV popularity throughout the last few years. However, this implies that about 275 thousand of the approximately 7 million residents of WA (3.9% of population) own an EV in 2021.

As exciting as this sounds, 275 thousand is about 16.2% of the total EVs in operation in the U.S. in 2021, with California, Texas, and Florida taking the lead [9]. However, California alone holds 76.5% of all the EVs in the U.S. If Texas and Florida are above WA, our computed sum becomes illogical.

This insight implies that the provided description was incorrect. Knowing this, we can adopt another description that instead vehicle\_history counts the total number of EVs that were *actively* registered with the DOL at a given month, i.e. each month contains the *net cumulative sum* of all EVs registered in the WA.

**Vehicle History Analysis**

Figure 2 provides the cumulative sum of EVs registered with the DOL as of a given month. The trend confirms our initial understanding of the rise of EVs. We can also observe an exponential increase in EV ownership with each progressing month. In 2021, WA owns is approximately 86 thousand EVs, or about 1.2% of its total population and 5.1% of U.S.’s total EVs in operation. It is immediately more consistent with the data of active EVs in the U.S. mentioned earlier. Unfortunately, it is also unveiled that December 2023 currently has no data (as of December 18, 2023).

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Figure 3: # of EVs Registered Each Month (Separated)

Figure 3 provides a side-by-side view of each month throughout the years from which we can observe a steady trend for each month from 2017 to 2022. The slope between each point on a given line provides the net change in EVs that were actively registered between each month. With each year plotted side by side, a consistent rate of change can also be observed between two months across each year. By computing the mean change of each year, we can obtain an approximate estimation of the number of EVs for December 2023.

The missing information can also be obtained by utilizing a regression model; however, a decision was made to not use this method. Each month may have different factors, such as holidays, annual refreshes, and others, contributing to their change. Assuming a common trend for the entire year is likely to produce an imprecise estimate. It is more probable to observe the same effects of a month across the years, allowing the consequent change to be a more precise feature to estimate with.

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Figure 4: t

The normal distribution of the change rate of EVs each month can be observed in Figure 4. Computing the sample mean for December with

provides us with an average rate of increase of 2.1%. This provides a net increase 3383 EVs from November 2023 to approximate a total of 163222 total actively registered EVs in December 2023.

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Figure 5: # of EVs Actively Registered as of Each Month Between 2017 to 2023 (Fixed)

The new cumulative number of actively registered EVs is shown in Figure 4 containing the estimated count.

**PREDICTION**

**CONCLUSION**

**REFERENCES**

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