**Data Analytics Research Project:**

**Electric Vehicle Population Dataset**

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**Introduction**

The first mass-produced, modern, hybrid vehicle was the Toyota Prius which was released worldwide in 2000 (*Timeline*, n.d.). Soon after Tesla Motors introduced the first fully electric vehicle (EV) to the market in 2008 and the U.S. Department of Energy began investing in nationwide charging infrastructure for EVs (Q.ai, 2022; see also (*Timeline*, n.d.)). EVs are the future of transportation as owning one reduces operating costs, increases fuel savings, and has many environmental benefits (Electric Vehicle Research and Development, n.d.). Due to the increased prevalence of EVs in the past two decades, as well as the environmental benefits owning an EV has, research should be conducted on this emerging area in the automotive industry.

The Electric Vehicle Population dataset contains information (location, vehicle type, vehicle make and model, etc.) on battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) registered through the Washington State Department of Licensing. BEVs run using one or more batteries that power a motor with electrical energy. PHEVs use both a battery-powered electric motor and a gasoline-powered combustion engine to fuel the vehicle. Electric range refers to the distance, in miles, the vehicle can travel on a full charge. Both types of vehicles need to be charged at charging stations to operate (Research and Analysis Office, Washington State Department of Licensing, 2023).

Analysis of the existing Literature and Elective Vehicle Population dataset can lead to answers to the following questions:

1. What has been the U.S. adoption trend for EVs over the last ten years, and how does it differ by location and vehicle type?
2. How do the environmental and financial effects of the use of EVs compared to those of conventional vehicles?
3. How do the driving habits of people who own EVs compare to those who own conventional vehicles?

By doing this research we hope to gain insight on the distribution of electric vehicles in the United States and how it impacts global warming.

**Related Works**

**Literature Review 1**

According to a review of the literature on the adoption trend of EVs in the U.S. over the past ten years, as well as how adoption trends vary by region and vehicle type, the market for EVs has seen significant growth in recent years. This growth has been spurred on by government incentives and policies, technological advancements, and a shift in consumer attitudes and preferences.

According to a 2019 study by Penmetsa et al., sales of EVs in the U.S. have increased significantly over the past ten years, going from 17,813 units in 2011 to 208,000 units in 2017. The authors point out the growth rate has varied widely by geographic area, with California leading the pack in terms of EV adoption and representing over half of all EV sales in the U.S. in 2017. While several regions in the Southeast and Midwest have fallen behind, other states with strong rates of EV adoption include Washington, Oregon, and New York (Penmetsa et al., 2019).

Parallel to this, a 2021 study by Chen et al., reveals the rate of EV adoption in the U.S. varies depending on the kind of vehicle, with BEVs being more popular than PHEVs. BEVs account for roughly 80% of EV sales in 2017. The authors also point out that hybrid vehicles have increased their market share recently, especially in the luxury vehicle sector (Chen et al., 2021).

The adoption of EVs in the U.S. is influenced by several factors. According to Penmetsa et al., for instance, government programs and incentives, such as tax breaks and rebates, have been crucial in promoting the use of EVs (2019). According to a study by Lin & Wu, consumer attitudes and inclinations toward environmental sustainability and technological innovations, such as advances in battery technology and charging infrastructure, have also fueled the rise of the EV market (2018). The primary obstacles to EV adoption have been cited as high upfront costs, a short driving range, and a lack of charging infrastructure. The development of wireless charging systems and developments in battery technology, for example, could assist to overcome these obstacles and spur future growth in the EV market (Penmetsa et al., 2019).

Overall, the examination of the literature indicates that the U.S. EV industry has grown significantly over the past ten years, but adoption rates have varied across various geographic areas and vehicle classes. The key factors influencing the growth of the EV industry are government incentives and legislation, technology advancements, and shifting customer attitudes and preferences. To encourage the widespread use of EVs in the U.S., issues like high upfront prices, a short driving range, and a lack of charging infrastructure must still be resolved.

**Literature Review 2**

Hannappel (2017) investigated the effect of global warming on the automotive industry. Global warming, the increase in temperature of the Earth’s atmosphere and oceans, is largely impacted by the emission of man-made carbon dioxide. The transportation industry contributes to 14% percent of the world’s carbon dioxide emissions. Specifically, the road industry makes up for half of this percentage, meaning 7% of global carbon dioxide emissions are due to vehicles driving on the ground (Hannappel, 2017).

In his paper, Hannappel (2017) focuses on passenger vehicles of six major countries (Europe, the USA, China, Japan, Russia, India, Philippines) in which 70% of registered vehicles reside. To reduce global carbon dioxide emissions, governments have placed strict rules on their respective transportation industries. For example, the European Environment Agency has been monitoring carbon dioxide emissions yearly and is placing heavy fines on manufacturers that surpass the target of an annual fleet average of 95 grams of carbon dioxide per kilometer emission (fleet average calculated from mass and sales volume of producer) (Hannappel, 2017).

To meet target fleet average goals, vehicle manufacturers need to produce EVs. Now the question is which kind of vehicle (hybrid or fully electric) will be sufficient to meet these goals? Hannappel states the variations of powertrain electrification are as follows: Hybrid electric vehicles, plug-in hybrids and range extender vehicles, battery electric vehicles, and fuel cell electric vehicles (2017). Compared to a typical combustion engine which releases a magnitude of 70-200 grams of carbon dioxide tailpipe emissions, hybrid vehicles and plug-in hybrid vehicles and range extender vehicles release 30-100 grams of carbon dioxide tailpipe emissions. Battery electric vehicles and fuel cell electric vehicles release zero grams of carbon dioxide emissions, therefore fully electric vehicles are the only ones that can enable car manufacturers to meet the fleet average goals (Hannappel, 2017).

Hanneppel concludes that by 2050 most pure combustion engine vehicles will be replaced by purely electric vehicles (2017). For this to occur, the design of electric vehicles must continuously develop to a point where the range of electric vehicles matches that of combustion engine vehicles. There also needs to be as many charging stations as there are gas stations, the cost of battery and fuel cells must come down, and the production of hydrogen fuel cells must become more environmentally friendly (Hannappel, 2017).

**Literature Review 3**

Lately, there has been developing interest in figuring out how the driving propensities for EV proprietors contrast with the people who drive ordinary vehicles. A recent study by Catherine Wolfram et al. examines the driving patterns of EV owners and compares them to the driving patterns of conventional vehicle owners (2021). The authors found EV owners in California drove an average of 5,300 miles less per year than gasoline vehicle owners, which is a larger difference than what previous studies have reported. They attribute this to "limited range anxiety" and the higher cost of EVs compared to conventional vehicles (Catherine Wolfram et al., 2021). The study also found the driving patterns of EV owners are more affected by the availability of charging infrastructure and the size of their household than by the type of EV they own. The authors suggest policymakers should focus on expanding charging infrastructure and providing financial incentives to make EVs more accessible to low-income households (Catherine Wolfram et al., 2021).

Similarly, other investigations have discovered the driving propensities for EV proprietors might be impacted by various variables, including charging framework accessibility, battery reach, and driving examples. According to a study by Firnkorn and Müller (2012), the availability of charging infrastructure significantly influenced the driving habits of EV owners; those with access to a public charging station drove more electric vehicles per day than those without access. According to additional 2022 research from the National Renewable Energy Laboratory (NREL), electric vehicle owners who live in colder regions drive less during the winter months. This is probably due to the lower cold temperature (Wilson et al., 2018).

As far as factors that influence driving propensities, investigations have discovered that EV proprietorship and use are impacted by different variables, including socioeconomics, vehicle type, and driving examples. ZEV Alliance's 2019 study found that wealthy, highly educated urban dwellers are more likely to own an electric vehicle. The study also found that people who frequently drive long distances or travel by car are more likely to own an electric car (Slowik, 2019).

In general, studies show that electric vehicle owners typically drive fewer miles per year than conventional vehicles. The driving habits of electric car owners can also be influenced by factors such as the availability of charging infrastructure, battery range, and driving habits. Further research is needed to understand the complex factors driving the use and adoption of electric vehicles and to identify strategies to promote their widespread adoption.

**Analysis**

**Tools & Methods**

We used R and Python for our data analysis and visualization. The Python libraries we used in our analysis include pandas and numpy. The tidyverse, sf, ggplot2, ggmap, viridis, mapdata, maps, RColorBrewer, and plotly are the packages we use for data analysis and visualization in R. To perform the Exploratory Data Analysis, we used Python for data manipulation and Seaborn with Matplotlib for data visualization.

**Data Cleaning & Transformation**

Data cleaning and transformations are crucial steps in the data analysis process that involve preparing raw data for analysis by removing errors, inconsistencies, and missing values and transforming it into a format suitable for analysis. Here are the data cleaning and transformation techniques we used in our analysis.

***Removing Duplicates***

This involves identifying and removing duplicate rows or observations in a dataset to avoid double-counting.

A screenshot of a computer

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Figure 1. Python code for dropping duplicate record entries in the EV Population Dataset.

***Handling Null Data***

We used the following code to see which columns in our dataset had null values. We performed data cleaning on those columns and removed the null values. A screenshot of a computer

Description automatically generated with medium confidence

Figure 2. Python code for counting the number of NULL values in each select columns of the EV Population dataset. After counting the null values, they were removed from the dataset.

***Filtering Data***

This involves selecting specific subsets of data that meet certain criteria or conditions. We filtered the data to only include records from Washington state.

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Figure 3. Python code for creating a subset of the EV Population Dataset for only Washington state.

**Statistical Analysis**

Our geographical visualization shows the longitude, latitude, make, model, and count of the electric vehicle in different sub-regions of Washington state. To begin, the data was grouped by County and Make to find the most prevalent make for each county. The state and county boundaries for Washington were obtained using map\_data() function and joined to the data frame using left\_join() function. We then set colors for each EV company to show them distinctively.

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Figure 4. Map of Washington state in which the most prevalent EV is indicated for each county. Tesla EVs are marked in green, Nissan EVs in blue, and Ford EVs in red. Tesla is the most prevalent EV in Washington state.

From this visualization, it can be interpreted that Tesla is the most used EV in almost every county in WA except in Columbia, Garfield, and in some parts of Walla Walla. Similarly, it can be said that Ford is purchased or used in only non-Tesla sub-regions of WA, and Nissan EVs are most prevalent in a few island counties off the coast of WA.

**Exploratory Data Analysis (EDA)**

To begin our analysis, we investigated which state in our dataset has the greatest number of EVs. We found that Washington state has the most vehicles i.e., 118665.

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Figure 5. Python code and output for counting the number of EVs registered per state. Washington state contains the greatest number of records.

We filtered our dataset to include only data from Washington and no null values. To perform the EDA on our dataset, we first did the data pre-processing and data cleaning as explained in the data cleaning & transformation section.

**Visualizations**

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Figure 6. Bar plot of the number of EVs grouped by car manufacturer in Washington state.

The above visualization shows the top ten car manufacturers of EVs in Washington state and their count. We can see that Tesla is the most-owned type of EV in the state, while Nissan and Chevrolet are the second and third most-owned EVs respectively. Volvo is the least-owned EV among all the other company vehicles.

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Figure 7. Bar plot of the number of EVs grouped by car model in Washington state.

Similarly, we plotted a graph for the top ten most used EV models in the state. We found that Tesla’s Model 3 is the most used model and Mustang’s Mach-E is the least used among the top ten most used models.

Our next analysis was to see which vehicle type people prefer between BEV and PHEV. We plotted a pie chart of the percent distribution of BEVs and PHEVs. We found that BEVs are more owned when compared to PHEVs.

A blue and orange pie chart

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Figure 8. Pie chart of the percent distribution of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) in the EV Population dataset. BEVs (blue) account for 76.9% of the records and PHEV (orange) account for 23.1% records.

**Correlations**

We plotted a bar graph of the mean electric range of vehicles in WA by model year for the years 2011 - 2020.  It can be observed that with the increase of the model year there is also significant growth in the electric range. When looking at the count of vehicles registered per model year, we can see as the model year increases the number of BEVs registered in WA state also increases. Therefore, it can be stated as the electric range of BEVs increases over time, more people are purchasing and owning BEVs.

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Figure 9. Bar plot of the mean electric range of BEVs grouped by model year in Washington state. Only records from model year 2011-2020 are included. Notice the increase in the mean electric range of BEVs as the years go on.

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Figure 10. Count of vehicles registered in Washington state grouped by the model year. As the model year increases, the number of registered vehicles also increases.

Our next analysis compares the distribution of electric range of BEVs and PHEVs. We plotted a box plot, to clearly depict the difference between their adoptions. We found that the minimum electric range of BEVs in WA is greater than the maximum range of PHEVs in WA.

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Figure 11. Box plot comparison of the distribution of electric range for BEVs (blue) and PHEVs (orange) in the EV Population Dataset. All distribution values (minimum, 1st quartile, median, 3rd quartile, and maximum) of BEV are all greater than those of PHEV.

Then we compared the distribution of electric range for various car manufacturers and car models. It is observed that Chevrolet models are the most variant in electric range. In addition, Tesla provides the highest electric range in. It is observed that Nissan’s Leaf has the most widely distributed range. Tesla’s Model 3 offers the most electric range and Chevrolet’s Volt has the least. From these box plots Tesla Model 3 is best option for individuals who want to drive long distances and the Nissan Leaf or Chevrolet Volt models are best for those who only need to travel locally.

(a)A picture containing diagram, screenshot, rectangle, plan

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Figure 12. (a) Box plot of the distribution of electric range of various EV manufactures. (b) Box plot of the distribution of electric range of various EV models.

**Results**

Our data analysis indicates among EV brands, Tesla is the most owned in Washington. Furthermore, the Model 3 is the most popular Tesla model. Additionally, it appears drivers in Washington prefer electric vehicles with greater range capabilities. This may be due to the need to travel longer distances or the desire for added convenience and flexibility.

We also found when it comes to the type of EV, BEVs are more frequently purchased than PHEVs. This could be because BEVs offer a greater electric range than PHEVs. BEVs rely solely on electricity for power and have larger batteries, providing a longer range on a single charge. PHEVs, on the other hand, have smaller batteries and a gasoline engine backup, which limits their electric range and fuel efficiency compared to BEVs. Another factor to consider is gasoline is more expensive than electricity, so fueling and charging a PHEV will most likely be more expensive than charging a BEV.

Finally, the analysis shows there is a positive correlation between the popularity of electric vehicle models and their electric range. Overall, these findings shed light on the current state of electric vehicle adoption in the United States and provide insight into the preferences of electric vehicle drivers.

**Conclusion**

The adoption of electric vehicles (EVs) in the U.S. has been increasing over the past few years, but the rate of growth has been slower than in other countries such as Norway and China. One reason for this slower growth rate is that the popularity of EVs varies depending on the type of vehicle and location. For example, in some areas, PHEVs are more popular than BEVs. In addition, EVs are more well-known in metropolitan areas than in rural areas.

Further research is needed to understand the impact of factors such as government incentives, charging infrastructure, and consumer attitudes on EV adoption. Irrespective of these hardships, EVs have the potential to significantly reduce greenhouse gas emissions, particularly when powered by renewable energy sources such as wind and solar. They may also be cheaper to operate over the long term due to lower fuel and maintenance costs. However, the higher initial cost of purchasing an EV may deter some consumers from adopting this technology.

Although there is still much to learn about EV usage patterns, ownership of EVs appears to be a viable option for many drivers and is contributing to reducing global warming. However, additional data on EVs in all states in the U.S. needs to be collected and analyzed to gain insights of the impact the U.S. has on global warming. Despite these challenges, the trend towards greater adoption of EVs is positive, and the transportation industry in the U.S. is moving in the right direction.

**Team Member Contribution**

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| --- | --- |
| **Section** | **Team Member** |
| Introduction | Tanmaya |
| Related Works | Niku (1), Tanmaya (2), Nivedita (3) |
| Analysis | Niku |
| Visualizations | Niku, Nivedita, Tanmaya |
| Results | Nivedita |
| Conclusion | Nivedita |
| Editing & Formatting | Tanmaya |

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