Exploratory Data Analysis of the Drivers of EV Performance, and Consumer Experience & Behavior

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EDA Assumptions for this Research

- Focusing on cars for this exploration – LDV1 (passenger cars and sports utility vehicles)
- Definition of an EV car (carandriver.com):
    - Battery electric vehicles (BEVs), which run entirely on electricity stored in batteries.
    - Hybrid electric vehicles (HEVs), which use a combination of gasoline and electricity to run.
    - Plug-in hybrid electric vehicles (PHEVs), which can be plugged in to charge the batteries and use electricity or gasoline to run.
    - Fuel cell electric vehicles (FCEVs), which use hydrogen to generate electricity to run.

EV Attributes and Technology

- Average electric vehicle real-world fuel economy/mpg is considerably lower for Honda, GM, Suzuki, Stellantis, and VW models when compared to Lucid or Hyundai.
- It is known that electric vehicles emit less CO2 emissions than gasoline or diesel-powered vehicles traveling the same distance.
- However, some electric car models are much less efficient than their competitors.
- CO2 emissions by electric vehicle model year are trending downward toward carbon negativity.

The US Environmental Protection Agency (EPA) has maintained the Automotive Trends Data (ATD) since 1975 (https://www.epa.gov/automotive-trends/about-automotive-trends-data). Starting in 2010, the ATD began including the attributes, real-world fuel economy/mpg, CO2 emissions, among other metrics of the manufacturers' electric vehicle models.

By excluding electric pickups and truck SUVs from our analyses, we were able to explore relationships between electric car attributes and quality data. To investigate the relationship between CO2 emissions of electric vehicle models and their real-world fuel economy/mpg, we initially conducted a Pearson's correlation analysis without any data transformation.

This analysis revealed a negative correlation coefficient of r = -0.74. Subsequently, we applied a logarithmic transformation to the real-world fuel economy/mpg data (designated as ln_y), considering an apparent exponential relationship between the variables. With a second correlation with the transformed data, we observed a more pronounced negative correlation with a correlation coefficient of r = -0.79. We feel caution should be taken during interpretation of these analyses given the small sample size (n=37). It is known that electric vehicles emit less CO2 emissions than gasoline or diesel-powered vehicles traveling the same distance.

However, there appear to be some electric cars models that are much less efficient than their competitors. With the next set of analyses, we compare manufacturers by real-world fuel economy to identify who may be producing these less efficient electric vehicle models.

EV Performance

- EV cost assumes an average person in the US drives 15,000 miles per year.
- A new 2023 vehicle is in the price range of 26-113k.
- The largest cost in the 1st year is the depreciation cost.
- There is a definite correlation between the cost to buy the car and the depreciation.

Five Year Cost of Ownership

According to the US census, 91.9% of households have at least one vehicle. One of the most expensive items that an average person spends in their lifetime is a vehicle. There are currently three major types of cars based on fuel types on the market today. They are the internal combustion engine vehicles, internal combustion engines with supplemental battery vehicles or hybrids, and fully electric vehicles (EVs).

Arguments have been made to encourage the purchase of EVs over traditional internal combustion engine cars that bury fuel and increase carbon dioxide emissions. The environmental protection agency reported that of the 5,586M metric tons of carbon dioxide emissions in the United States, 29% of the Greenhouse gas emission is produced by transportation. To combat the increase in Greenhouse gasses, on December 8, 2021, President Biden signed an executive order aiming to end purchases of vehicles that produce emission by the federal government by 2027 for light-duty vehicles (10,000lbs) and by 2035 for other vehicles in a push to create a clean energy economy. This was done in hopes of encouraging the increase in the number of all electric vehicles.

It was found in a 2022 survey, fuel efficiency, safety and low price were the most important considerations when purchasing a new vehicle and not the environmental concerns. Why many do not account for is the hidden cost of buying a vehicle is the cost of ownership. There exist several websites that calculate a 5-year estimate for the cost of ownership with non-existent APIs or restricted access to them based on commercial usage.

For this project, data was extracted from the Edmunds database. Tables from the html pages were extracted from a subset of 2023 vehicle data using a python script. The data was converted and saved as a .cvs file. The file contains the analysis of the yearly cost of ownership for five years for a new 2023 internal combustion engine car/traditional car, hybrid and electric cars which reads the Edmunds.csv and the data files. The data extracted was confined to only examine cars, specifically sedans and SUVs, from the model year 2023 due to the limiting number of models and data available of fully electric cars in prior years. The actual cost of ownership will vary from person to person depending on what assumptions the databases assume. The seven main factors examined for the cost of ownership included in the analysis are taxes and fees, fuel, maintenance, repairs, financing costs or interest, insurance premiums and depreciation.

Edmunds assumes an average deprecation of 23.5% of the manufacturer's suggested retail price for the first year of ownership and a 60% depreciation in five years. They also assume that a typical person

drives 15,000 miles/year, 55% of the time in the city and 45% of the time on the highways. A 60-month finance term with 10% of the cost of the vehicle down is used in their estimations. The actual price of fuel or electricity and the amount of taxes paid depends on the location. For the purpose of this analysis, mid-Michigan was used.

Charging Performance

- Data was collected from ChargePoint, the second largest charging network, only behind Tesla.
- Average overall charge is 2.82 hours, using 5.81kW.
- Charge times are greatest on Wednesdays with an average of 2.94 hours needed to charge and electric vehicle.
- Typical EV takes about 8 hours to charge. Most drivers do a top-off charge, rather than a full charge.
- Sunday is the lowest at 2.1 hours. It is not until the weekend days that we see a substantial drop in the hours needed to charge an electric vehicle.
- There is only a gradual decline over the days of the work week.
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- In 2011, there were just over 5,000 charging ports and in 2022, there were over 153,000 charging ports.

Consumer Experience and Behavior

Demographic of EV Buyers:

- Males are more likely than females.
- Younger adults are more likely than older adults.
- Americans with a higher education are more likely than those with a lower education.
- Americans with a higher household income are more likely than those with a lower household income.
- Americans who live in urban areas are more likely than those living in suburban or rural settings.

Additional Topic Areas for Future Projects

- US vs Global Markets – alignment of the markets
- Environmental Impact – blood batteries, lithium mines, etc.
- What Is the True Cost – economics of use, e.g., end of life/battery disposal
- Infrastructure Support – can the current power grid support the number of EVs projected
- Hidden Costs – what are the costs after initial purchase