Project Report

INET - Network Architecture Projects

Factor Analysis of Electric Vehicle Adoption

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1. Introduction

"Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Commission, 1987). With the significant increase of sustainability awareness in today's society, the United Nations has published 17 Sustainable Development Goals (SDGs). They are an universal call to action to protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. One of the 17 goals of SDG set by the United Nations is Climate action, which states that "Greenhouse gas emissions are more than 50 percent higher than in 1990. Global warming is causing long-lasting changes to our climate system, which threatens irreversible consequences if we do not act." (SUSTAINABLE DEVELOPMENT GOALS). One of the contributors to the greenhouse gases are vehicles, which according to (Fueleconomy) contribute to about 1.4 billion tons of greenhouse gases in the atmosphere each year. In the US, vehicles contribute about 29% of the total U.S greenhouse gas emissions, which makes it the largest contributor of U.S GHG emissions stated in (U.S. Environmental Protection Agency). Washington State has set ambitious goals for EV adoption, but there is still a lot of work to be done to meet these targets. With the help of a dataset (Data.WA.gov), in this paper we will discuss the key factors and trends that drive electric vehicles adoption, such as: government policies and consumer preferences.
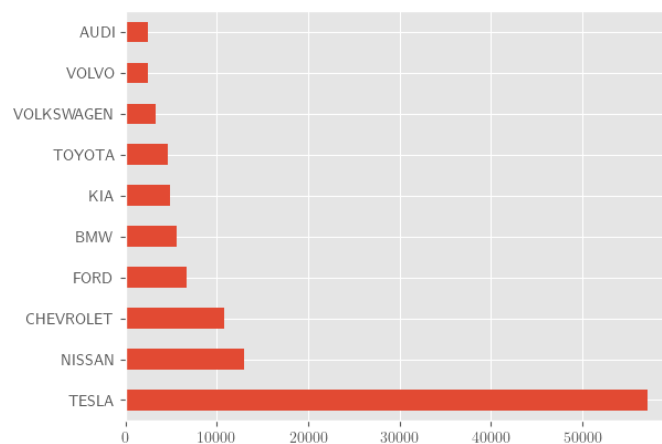
2. EV Market

Figure 1

The initial step into understanding the past and current EV Market, we have to distinguish the 10 EV manufacturers with the highest sales from the dataset. Figure 1 shows top ten manufacturers based on the amount of EVs sold by each of them over the years in Washington State. Although very widely-known vehicle brands such as: Audi, Volkswagen, Nissan, Kia, Chevrolet and Ford have a long success story in selling Internal combustion engine (ICE) vehicles, we see that their numbers are quite low in sales, mostly less than 10000 units. On the other hand, Tesla, which is known for selling only EVs, dominates the market with more than 50000 units sold over the years.
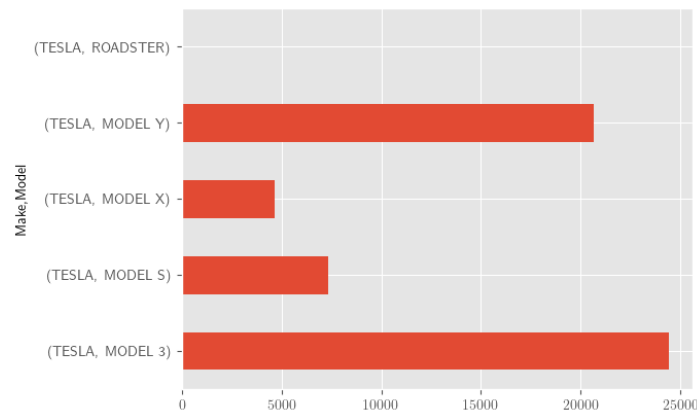
2.1 Tesla models sales

Figure 2

Considering that Tesla has rapidly risen to prominence, we need to delve deeper into the models that they sell and the features they offer. There are four vehicle models being sold, called: Model S, Model X, Model 3 and Model Y. Each of them are released in different years and have different starting prices. The first one, Model S was released in year 2012 and sold for $88,490. It was followed by Model X in 2015 for the highest price of $98,490. Model 3 was released in year 2017 with the starting price of $40,240. It was then followed up in 2020 by Model Y with the starting price of $50,490.

Based on figure 2, we can point out that Model Y and Model 3 are the models that have the highest amount of sales. This can be credited to their more affordable selling prices. Model 3 was designed to bring electric mobility to a bigger audience, and it has achieved becoming a best-seller.
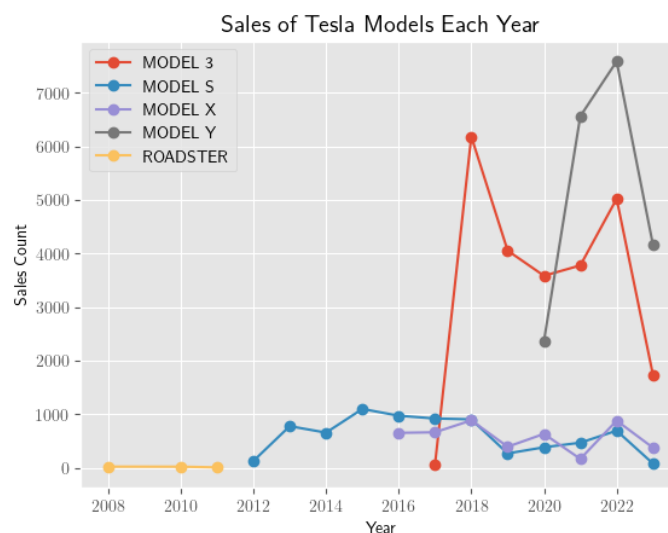

Figure 3

Based on figure 3, we can see that for both Model S and Model X sales have been constant over the years, while for Model 3 and Model Y sales have increased. We can see from the graph that for all models there has been a decrease in sales in 2018. One of the reasons can be

the consumers have anticipated and waited for the introduction of a new model, which is Model Y, an affordable SUV, for which sales have then surpassed those of Model 3. Secondly, this decrease can also be attributed to the pandemic of Covid-19, in the year that the whole automotive industry faced major shocks due to declines in production, factory and vehicle dealership shut downs (Coffin, Downing, Horowitz, & LaRocca, 2022).

2.2 Why users are choosing Tesla?

The innovative company has a significant first-mover advantage in the market, pioneering early in the EV market. One of the main factors consumers choose Tesla, is that they are not only a car manufacturing company, but also a tech one. The introduction of cutting-edge technologies have gotten a lot of attention over the years. Some of the key features are: Navigate on Autopilot, Autosteer, Smart Summon and Fully Self-Driving Capability (Tesla). These features include advanced safety and convenience, assisting drivers in route optimization and easier navigation in complex roads. Moreover, all new Tesla cars have the hardware needed for full self-driving and the system is designed to conduct trips without action from the driver. On top of these, Tesla vehicles are continuously upgraded through over-the-air software updates. This is a key factor for buyers, since the EV owners expect upgrades, meaning that each year their car will be able to have better and new features easily.

When it comes to design, Tesla was the first to use a touch screen in the dashboard which now is an industry standard for all luxurious vehicles. It also offers a really unique door opening. Model X SUV comes with Falcon wing rear doors for easier loading.

Another important factor is the performance offered by the Tesla cars. They are known for their fast acceleration with Model X Plaid being able to accelerate from 0 to 60mph in only 1.99 seconds and the slowest being Model 3 Rear-Wheel Drive, only capable to reach 0-60mph in 5.8 seconds which is nonetheless still considered quick. For model Y and 3 Performance variants accelerations are 3.1s and 2.5s (Compare Models). This makes Tesla capable to compete with some of the supercars that are in the range of millions of dollars.

Additionally, Tesla provides different types of charging speeds with the highest charging speed reached by using the proprietary supercharger, which can charge up to 200 miles in 15 minutes (Charging your Tesla). The company has invested greatly in Supercharger stations and extensively increasing the charging infrastructure, making long distance trips feasible with over 45,000 global Superchargers (Supercharger). These chargers can only charge Tesla vehicles, giving them an advantage in the market. Nonetheless, since November 2021 Tesla started to allow other brands to be able to charge at their stations (Non-Tesla Supercharger Pilot).

All of these factors combined together have gathered significant attention and recognition over the years. As a result, Tesla has established itself as a sought-after brand, in strong comparison to other manufacturers.

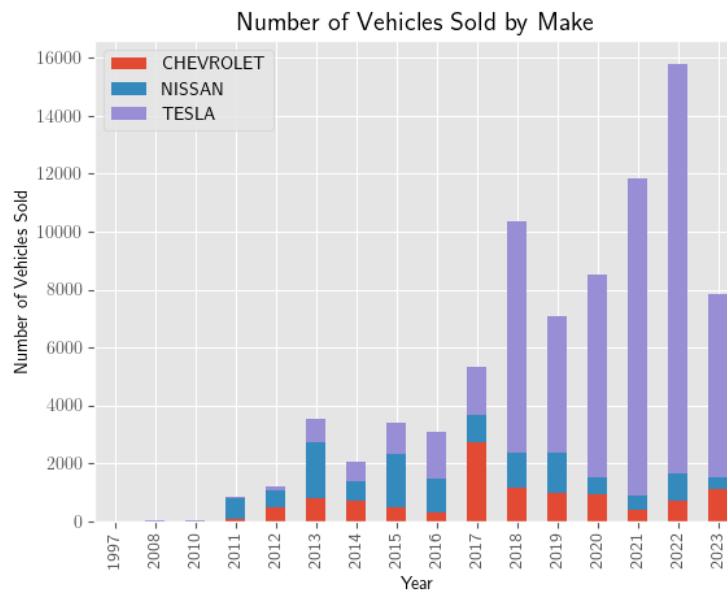## 2.3 Trend analysis of sales for top three manufacturers

Figure 4

In this graph we have taken into account three most significant manufacturers of EVs in terms of sales in Washington State depicted over the years, which are Tesla, Nissan and Chevrolet. Our objective is to illustrate the sales trend, capturing the peaks and drops of the sales and what factors have impacted them.

Apparently, the number of Tesla units sold remains steady with small increases, until 2018 where the number of units sold has a huge spike compared to previous years. One of the factors that has contributed in this was the ability of Tesla to solve their manufacturing issues (Forbes, 2018). This becomes more evident following the continuous increase over the next years. Another factor worth mentioning was the introduction of new affordable models, Tesla Model 3 in 2017 and Tesla model Y in 2020.

It should be pointed out that in years 2019 and 2020 the number of units sold is lower than in 2018. The explanation about this sales drop, as mentioned above, could be the pandemic of Covid-19. During this period unemployment in US skyrocketed to an all-time high of 13.0% (U.S. Bureau of Labor Statistics, 2022).

It is important to also look at how the competition is doing. With regard to sales, we can extract from Figure 1 that the biggest competitors to Tesla are Nissan and Chevrolet. In years 2013 and 2015 Nissan was outselling their competitors and the same thing could be said for Chevrolet in 2017. Since their sales numbers are not very high, it is interesting to understand what caused their peak times. In 2017, Chevrolet introduced their first electrical vehicle that was offering over 238 miles in a single charge and the possibility to fully charge the vehicle in 9 hours or 90 miles in 30 minutes using DC fast charging (Chervolet Bolt EV - 2017). Although this might sound good enough, it is quite slow compared to Tesla's Supercharger. Considering Tesla's faster charging speed, the extensive network of the Superchargers

offering the possibility for long trips, and keeping in mind that Tesla offers Sedan or SUV models compared to the small car that is Bolt EV, it is difficult for the Chevrolet model to compete with the affordable innovative models of Tesla. This is one of the reasons there are plans to discontinue this model (Green Car Reports, 2023).

For Nissan, their peak in 2013 could be attributed to the fact that they were one of the first brands to provide a fully electrical car and pioneering in the mass market starting their production on the first Nissan Leaf in 2010. According to a study done by (Tal & Nicholas, 2016), more than 49% of the sales of Nisan Leaf are attributed to the Federal tax credit, for which we will talk in more detail in the next chapter. Over the years their sales have shrunk, therefore Nissan Leaf is also meeting a fate similar to Chevrolet Bolt, meaning that it is planned to be discontinued in 2026 (Electrek, 2023`).

3. Federal and State Incentives

Recently, the global shift towards sustainable energy has prompted governments to act in support of the environment. They are taking measures and pushing various policies that incentivize the adoption of electric vehicles. One of the most crucial policies are the tax credits offered for EV owners.

In the United States, the promotion of EVs was supported by Federal Tax Credits, a policy published in July 2011 (Energy Efficiency & Renewable Energy, 2011), that offered up to $7500 tax credit for the purchase of advanced technology vehicles. In 2022, this policy was updated and included under Clean Vehicle Credit section in the "Inflation Reduction Act" (Clean Vehicle Tax Credit), which was a policy that aims to curb inflation by possibly reducing the federal government budget deficit and investing into domestic energy production while promoting clean energy. In this tax are included new vehicles bought before and after the Act, used vehicles and commercial vehicles. New vehicles can qualify for up to $7,500, used vehicles up to $4,000 and for commercial vehicles up to $40,000 based on the criteria they fulfill.

In Washington State, there are specific tax exemptions for owners of alternative fuel vehicles and plug-in hybrids. As stated in (Washington State Department of Licensing) the exemption applies to dealer and private sales of new, used, and leased vehicles sold on or after August 1, 2019. Particularly, new vehicle transactions must not exceed $45,000 in purchase price or lease payments. For used vehicles, transactions must not exceed $30,000 in fair market value or lease payment. Based on (Cars.com) both Chevrolet Bolt and Nissan Leaf buyers fulfill this price criteria and will benefit from this exemption, while the only Tesla model with a price tag under $45,000 will be Tesla Model 3 Rear-wheel drive.

According to findings from a study done by (Jenn, Springel, & Gopal, 2018) monetary incentives have a statistically significant effect averaging around 2.6% increase in sales of EVs per $1000 offered throughout the US. This paper also indicates that other incentives such as HOV lane access can be important. On top of this, increasing consumer awareness of incentives can be a very significant lever in which to increase the effectiveness of the monetary incentives themselves. In states where cumulative knowledge is high, there is a corresponding response seen in vehicle sales. Moreover, in order to make EVs more

affordable for consumers and promote their diffusion in the market, the conclusions of (Tseng, Wu, & Liu, 2013) indicate that with the provision of tax incentives, the lifetime total cost for EV types that are driven for 120,000 miles over 12 years was found to be generally affordable with no more than 5% higher cost than a conventional vehicle.

An empirical analysis from (Li, Tong, Xing, & Zhou, 2017) done on EV sales and charging station deployments demonstrate positive feedback loops that could alter the diffusion process of the EVs. It finds that the federal income tax credit of $7,500 contributed to about 40% of EV sales during 2011-2013, with feedback loops explaining 40% of that increase. As a result, subsidizing charging station deployment could increase significantly the impact of tax incentives.

Regarding state level incentives, (Jin, Searle, & Lutsey, 2014) state that they play a significant early role in reducing the cost of ownership and driving EVs. In Washington, one of the states with the largest EV incentives, has sales shares that are approximately 2-4 times the national average. Their statistical regression findings reveal that the total monetary benefit to consumers positively correlates with EV sales.

Although the impact of policies and incentives is significantly positive, there are many barriers and issues that need to be considered regarding them. This study (Liu, Dai , Guensler, & Rodgers, 2022) identified potential barriers for households with diverse income levels, family types and number of children. They found that families with one child with an annual income of $82,600 (2019 U.S. national median income for three-people family), is eligible for only 70% of $7,500 federal tax credit. Credits are even less available for families with lower income or more children. They state that further complicating any policy benefits assessments is that vehicles from lower-income households which are less eligible for credits, produce higher emissions.

Particularly, an analysis of the distribution of EVs in Washington done by (Boucher & Merida, 2022), shows that the median income, an Inflated Life Proxy (ILP), and education have the highest associations with EV concentrations. So, the highest EV adoption shares are found in the areas of the highly educated and affluent clean tech privilege, and has not progressed beyond early adoption despite years of incentives. In fact, the ones benefiting the most from the incentives are the high-income families, which as stated in this paper (Xing, Leard, & Li, 2021), 70% of the credits were obtained by families who would have still bought an EV even without the credit. Their results also suggest that vehicles that EVs replace are relatively fuel-efficient and that a subsidy designed to provide greater incentives to low-income households would have been more cost effective and less regressive.

It is worth mentioning that the way the incentives are designed and distributed can impact their effectiveness. According to a survey conducted in the U.S (Robertson & Helveston, 2022), participants of the survey overwhelmingly prefer immediate rebates, on average valuing them by $580, $1450, and $2630 more than sales tax exemptions, tax credits, or tax deductions, respectively. These effects are significantly larger for lower-income households, used vehicle buyers, and buyers with lower budgets. Therefore, decision makers should be urged towards more progressive economic policies: consumption, wealth, and income taxes, in order to direct civil society towards greater economic moderation and equality, generally.

In order to make EVs more affordable for consumers and promote their diffusion in the market, the conclusions of (Tseng, Wu, & Liu, 2013) indicate that with the provision of tax incentives, the lifetime total cost for EV types that are driven for 120,000 miles over 12 years was found to be generally affordable with no more than 5% higher cost than a conventional vehicle.

4. Conclusion

In summary, the electric vehicle market has expanded and continuously gained more acceptance, towards an environmentally conscious future. There are a lot of competitors in the market, but their sales are low compared to Tesla. Tesla dominates the market through a number of factors. They are able to offer affordable innovative vehicles with better features than competitors to a similar price range. Tesla captured the attention of the consumers with their high-end models and established themselves as the dominant design. With the introduction of their affordable models, they seized a significant share of the growing EV market. Its main competitors, Nissan and Chevrolet also had their opportunity to be popular in the market, but over the years they could not compete with Tesla and were not able to capitalize on their vehicles. They decided to discontinue them, re-thinking and designing new EVs.

As the market of EVs is still a niche and there is much potential for growth, government policies and tax incentives have played a key role in promoting their adaptation. Federal tax incentives have shown to have a positive impact, specifically a 2.6% increase in sales of EVs per $1000 tax credit offered. Important is to keep in mind that charging station deployment could increase significantly the impact of tax incentives. Washington State is one of the states with the largest EV incentives, and has sales shares that are approximately 2-4 times the national average. Although the policies and incentives have a positive effect in the market, there are several issues that need to be taken into account.

The consumers that benefit the most from incentives are families with high income, who would have still bought an EV even without the credit. Results also suggest that vehicles that EVs replace are relatively fuel-efficient and that a subsidy designed to provide greater incentives to low-income households would have been more cost effective and less regressive. Governments should consider different target groups, depending on their socio-economic levels, and promoting inclusive and extensive initiatives.

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