Examining the Rise of Electric Vehicles:
A Technological Fad or the Future of Transportation

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction:

Since the industrial revolution, energy needs have exponentially skyrocketed as modern industries have evolved to rely on various forms of energy. One of these modern industries reliant on large amounts of energy is the transportation industry. In the US, transportation accounts for approximately 28% of all energy used throughout the whole country (EIA, 2019). Of that 28%, 96% is in the form of petroleum, with natural gas, biomass and electricity accounting for the rest (EIA, 2019).

With growing concerns for a potential energy crisis on the horizon, the transportation industry has been looking to wean itself off of non-renewable energy, like petroleum, and begin using cleaner, renewable energies, such as electricity. This has led to a revolution in the automobile industry, as more and more manufacturers are making fully electric vehicles (EVs) and hybrid electric vehicles available to the general population. With these companies investing their futures into electrically powered vehicles, they are aiming to create a modern transportation industry completely run off renewable energy.

This paper discusses the growing use of electric power in the transportation industry, specifically exploring its rapid growth in the automobile industry. By examining the current electric and hybrid car market and the factors involved with its growth, such as the advantages and disadvantages over conventional petroleum powered vehicles, its widespread adoption in performance vehicles and motorsport, and overall acceptance by the general population, this thesis hopes to provide some insight as to how the automotive industry will look moving forward into the future.

The Stakeholders of the Automotive Market:

Despite many of the first automobiles created being powered by electricity, the automobile's commercial success came with the creation of the internal combustion engine (ICE). Henry Ford's mass-produced Model T, powered by a 4-cylinder gasoline engine, revolutionized transportation in the early 20th century (Zurschmeide, 2018). With more of the population able to own cars, people moved farther away from city centers, effectively creating the modern suburban landscape. The automobile ushered in more freedom and opportunity for the average person, creating a much larger and stable middle class. The Model T's game changing integration into the transportation industry left a major mark on all aspects of society, but it also set the standard for gasoline powered automobile engines.

The Social Construction of Technology theory (SCOT) states that new technologies have to be accepted by a variety of relevant social groups in order to succeed. SCOT essentially contrasts the idea of the 'best technology always wins', as it holds society's acceptance of the technology equally as important as the technology itself (Social construction of technology, 2019). The Model T is the perfect example of SCOT in action. There was a need for personal transportation devices in the early 20th century and the Model T's ability to cheaply mass-produced filled that need. The public accepted the notion of having a personal, gas-powered automobile and the infrastructure, such as paved roads, highway systems, and gas stations followed. Electric cars were around during this time, but the technology was not comparable to the gasoline engine, as their ability to be mass-produced, consistent reliability and performance were far better than the electric options of the day. This led to the transportation industry shaping itself to suit gasoline engines.

Since SCOT fits perfectly over the rise of gasoline cars, it makes logical sense to examine the rise of electric cars through the same framework. Over 2 million electric cars were sold in

2018, up from just a few thousand in 2010. Current studies predict that by 2040, a majority of the cars sold will be electric (Berryman, Doherty, McKerracher, & Soulopoulos, 2019). These statistics show a growing number of people are placing their trust into electric car technology. However, SCOT theory suggests that the technology and its societal acceptance have to grow at similar rates in order for electric cars to stabilize and become the new standard in transportation. A variety of societal factors have to be considered in parallel with the statistical data in order to make substantial conclusions.

The most important stakeholder to consider is the consumer. Consumers are the group that has to decide if electric vehicles are practical and economical, and the industry is completely reliant on how many consumers purchase EVs and hybrids. Both the advantages and disadvantages of owning an electric car have to be examined to put the thesis into context. Commercial businesses requiring travel also fall into the consumer stakeholder category, as EVs could prove to be more economical for shipping goods, potentially saving businesses substantial amounts of money. A small but powerful subset of consumers are car enthusiasts, who largely influence automotive trends due to their extensive knowledge on cars and their ability to communicate that knowledge to the average consumer. Consumers will be the ones weighing topics such as the cost of owning and maintaining an EV, the environmental advantage, range and daily practicality, which will ultimately decide the future of transportation.

Car companies are another large stakeholder when considering the current state of the electric vehicle industry. If there is a demand for EVs, then car companies will have to meet that demand in order to remain profitable. Car manufacturers such as BMW, Chevrolet, and Toyota are already selling electric and hybrid electric vehicles to the public. This shows that top car companies already see the EV industry as potentially profitable.

A smaller, but highly influential group is the motorsport and performance automobile community. Automotive racing leagues and their governing federations, such as Formula 1, Formula E, the Fédération Internationale de l'Automobile (FIA), serve as a platform to test new technologies and push automotive innovation to the absolute limit. Many car manufacturers use motorsport as a way to test out new ideas and eventually make their way into their street cars, so the regulating bodies of motorsport have an interest in EV and hybrid vehicles. Influencing in a similar way to motorsport, general performance vehicles, such as supercars and hypercars, also experiment with electric and hybrid technologies and introduce innovation into the general car market. Both these groups have continuously set trends in the car market and are important stakeholders in the larger transportation industry.

The government is another primary stakeholder that needs to be considered when examining the rise of electric cars. As stated before, the current infrastructure of the transportation industry is suited for gasoline powered cars, with an abundance of gas stations available for use throughout the whole country. With the demand for electric cars rising, the demand for communal car chargers will rise as well. It would be up to governments at all levels to meet this demand and provide the proper infrastructure to suit the electric vehicle market.

The current EV market and its growth:

Globally, approximately 85 million passenger vehicles were sold in 2018 (Berryman, Doherty, McKerracher, & Soulopoulos, 2019). Of that 85 million, just over 2 million were BEVs (Battery Electric Vehicles) or PHEVs (Plugin Hybrid Electric Vehicles), which is up from a few thousand in 2010 (Berryman, Doherty, McKerracher, & Soulopoulos, 2019). Overall, the global market for EVs has grown at about 60% each year (Hertzke, Müller, Schaufuss, Schenk, & Wu, 2019). By region, China leads overall sales and penetration rate, with an EV market that

is 3 times larger than that of the US or Europe (Hertzke, Müller, Schaufuss, Schenk, & Wu, 2019). Despite various regions in the world growing at different rates, in all of these automotive markets, EV and hybrid vehicle sales are on the rise.

In the United States, there were approximately 1.1 million EVs on the road of the 111 million passenger cars registered in 2019. However, the total EV market share in recent years has been continually growing, going up 1.6% in 2018 to 1.8% in 2019 (Schefter & Michelle, 2019). Although more and more car manufacturers are beginning to make EVs and hybrids, the market is still dominated by few automakers. In the US, Tesla, GM, and Nissan account for 62% of all electric vehicles sold in 2018, with Tesla being the standout industry leader with around 32% of the total market (Schefter & Michelle, 2019). There isn't much variation in EV car models as well, with the top 5 EV car models making up 60% of total sales in 2018 (Schefter & Michelle, 2019).

Processing all of the numbers and statistics above, it is clear to see that currently EVs make up a small but growing part of the total automotive market. Although there are a growing number of electric options, internal combustion engines still reign supreme in the personal vehicle industry, but how long before EVs start chipping away and becoming a much more dominant player in the market? Bloomberg predicts in their "Electric Vehicle Outlook 2019" that they expect 57% of all passenger vehicle sales will be electric by 2040 (Berryman, Doherty, McKerracher, & Soulopoulos, 2019). They credit this rapid uptick to factors such as the price of batteries becoming substantially cheaper and emissions regulations getting tighter, forcing automakers to respond with a surge of new EV models and innovations. This bold prediction lays out that the EV market has the potential to dominate in the coming decades, but as SCOT states, the ability to rise doesn't necessarily mean that it will, as public acceptance is an equally

important factor. To determine if the demand will meet the growing number of EV produced, one must analyze the question: Why buy an EV over a standard internal combustion engine?

Societal factors involved in EV ownership:

According to SCOT, EVs and Hybrids have to be accepted by a variety of relevant social groups in order for them to become a dominant player in the automotive market. The technology aspect is important, but the narrative around owning an EV is equally as important. To convince the general public that purchasing an EV is the way of the future, the EV industry doesn't just have present itself as an alternative to conventional gasoline powered cars, but that the advantages far outweigh the disadvantages. Analyzing each sociotechnical aspect pertaining to purchasing and maintaining an EV while overlaying the SCOT framework provides a clearer picture of how this technology could stabilize and become the standard.

One of the most important sociotechnical factors to explore is the practicality of owning an EV. Practicality encompasses both the economic feasibility for the average consumer, as well as the day to day sensibility for the driver. The economic aspect will ultimately be the largest driver of consumers to change the power source of their car. EVs, when compared with similarly sized and made gasoline powered cars, are more expensive to purchase. The base price of a Chevrolet Volt, the 2nd most popular EV model in 2018, was $33,520. When compared to another Chevrolet sedan, the Malibu, with a base price of $22,095, it is hard to tell that there is an around an $11,000 difference between the two models. (U.S. News and World Report, 2018). This price difference is due to the cost of the lithium batteries used in the electric car. However, the price of batteries has been decreasing each year, and price parity is expected between the EVs and ICEs by the mid-2020s (Berryman, Doherty, McKerracher, & Soulopoulos, 2019). To offset the current price disparity and encourage citizens to become early adopters to EVs, the US

federal government offered up to $7,500 in tax credit for purchasing an electric vehicle, capped at 200,000 vehicles per automaker. Tesla and GM, the two largest EV producers in the US, hit that cap in 2019 and consumers will not be receiving the tax credit moving forward (Schefter & Michelle, 2019).

Cost doesn't stop at simply purchasing a car. Fuel and maintenance is also a large part of the economic burden of owning a personal vehicle. Regular gasoline costs on average $2.25 per gallon, whereas the average electric eGallon costs around $1.15. (Energy.gov). This saves the consumer nearly half of what they would spend typically on fuel for a gasoline powered car. Home-charging equipment, however, costs anywhere between $700 and $1200 to purchase and install (Sestric, 2017). Also, due to electric motors having much fewer moving parts than an ICE, they require fewer regular repairs and maintenance. Routine maintenance, such as oil changes and air filter replacement, are unneeded in EVs, which only require less frequent fixes like tire rotation and brake replacement. Considering all the costs associated with owning and maintaining both types of vehicles, it is hard to definitively say that one is more economical than the other at this time, but at the current rate that EVs prices are dropping, the economic scale is tipping in favor of going electric.

Switching to electric is not just an economic change, but requires a driver to change certain ways they go about caring for their car. The biggest day to day change would be the idea of charging your car instead of refueling at a gas station. The typical time it takes to charge an EV from empty to full is about 8 hours, however most drivers tend to top up charge instead of using their batteries until empty (Pod-Point, 2019). A rapid charger, such as the Tesla Supercharger, can provide up to 200 miles in range in around 30 mins, but only higher end electric cars, like Teslas, are compatible with these types of chargers (Pod-Point, 2019).

Charging port accessibility is also a large factor when deciding to purchase an electric car. Most drivers of gasoline cars don't think twice about where the closest gas station is, as the modern societal infrastructure was built having a surplus of gas stations available in all regions and locations. In an electric car, finding a public charging port can be a challenge, especially when time is a factor. This introduces the notion of range anxiety: a commonly used term for EV owners worrying about running out of charge.

Range anxiety is probably the biggest hoop a consumer has to jump through in order for them to switch to electric. With long charging times, having to stop and charge a vehicle now takes up potentially hours of the day instead of a quick 5-minute gas fill up. The current charging infrastructure is growing and the number of available chargers increases each year, but it remains a challenging problem to work out. A patchwork of solutions such as super-fast charging, battery swapping and wireless charging are emerging, but none of these innovations make EVs fully competitive with ICEs unless paired with a home or workplace charger (Berryman, Doherty, McKerracher, & Soulopoulos, 2019). On top of all of this, similar to a cell phone or laptop, the older the batteries get in an EV, the less charge they hold, decreasing their range. With all these variables, range anxiety seems to be the most complex hill to climb for the EV industry. Matching the consumer need with increasing technology is at the root of the issue, and solving it requires automakers, government and private business to work together to build the proper infrastructure to meet the demand.

Another important sociotechnical factor to consider is the social benefit of owning an EV. Electric power is a sustainable source and doesn't directly emit an exhaust byproduct into the environment. This is seen as a cleaner and more environmentally friendly energy source, so purchasing an EV or hybrid is thought of as "doing one's part in the world." Oil and gasoline is

deeply entangled in politics and the global economy, so personally divesting from relying on fossil fuels can feel freeing in some way. With global governments tightening their emission regulations, both automakers and consumers want to stay ahead of the game by switching to EVs now.

The growing EV industry presents itself in a way that they are the future of transportation. Automakers, consumers and governments all see the potential of this technology and are investing in it, hoping the benefits and growing numbers will outweigh and fix its shortcomings. Cutting down on battery cost and charging time are technical improvements that are needed in order for stabilization to occur. Infrastructurally, charging ports will have to become as accessible as gas stations, if not more accessible to encourage consumers to make the switch. As soon as these current issues with EVs are resolved, it is then automakers jobs to communicate to consumers and governments that EVs are the superior automotive choice, showing a rhetorical closure to the EV vs. ICE debate and demonstrating a technological stabilization.

Trickle-down effect from racing and performance:

Motorsport Racing and the performance automobile industry have always been at the forefront of automotive technology. Although a small, specialized subset of the automotive consumers and manufacturers, it is important to explore their influence on the automotive industry through the lens of SCOT as both sides always seem to mirror each other throughout history. The innovations in the EV and hybrid automotive industry are due in a large part to the technology being used in and integrated into performance vehicles. Many of the modern advancements in automobile performance and efficiency have come from performance vehicles, such as racecars and hypercars, as they push automotive technology to the absolute limit. This is

often referred to as the trickle-down effect, where technology originally designed for motorsport finds their way into road cars, changing the shape of the industry.

Numerous examples of the trickle-down effect can be seen on almost all cars currently on the road. Innovations such as four-wheel drive, disk and anti-lock brakes, and the use of lighter composite materials all trace their origins to motorsport (Edelstein, 2019). They were designed with the simple intention of getting a car to go fast around a track or course rather than factoring in all the societal needs. However, the intent of these technologies happen to overlap with the needs of the public and were integrated into road cars, making them better and more efficient. A more modern example of the trickle-down effect is turbocharging an engine. Turbocharging revolutionized racing as they were able to make faster, more powerful engines while subsequently decreasing the weight of the car and its gasoline consumption. Turbochargers eventually made their way into road cars, as their power to fuel economy ratio makes them extremely appealing to everyday consumers.

With the precedent set for race technologies making their way into road cars, now it is time to explore what electric and hybrid technologies are being used in the performance industry and how they can find their way into influencing the rise of the EV industry. The FIA, the governing body of the world's top racing leagues, has been at the forefront of using electric and hybrid electric power in their cars. In 2014, FIA changed their regulations on Formula 1, the world's premier racing league, stating that all engines must be hybrid. That same year, Formula E, the FIA's first fully electric racing league, had its inaugural season. In 2019, the FIA announced plans to become carbon neutral by 2030, a fascinating announcement considering the basis of their whole sport stems from burning substantial amounts of gasoline for the sake of entertainment (Formula 1, 2019). Even NASCAR, a sport that prides themselves on racing big,

muscular V8s, plan to debut hybrid engines as early as 2022 (Bright, 2019). With the world's racing leagues ditching fully gasoline engines and even introducing fully electric racing, one can deduce that this type of power is more efficient and will soon find its way in every road car.

Automakers use the performance and racing world as a marketing tool while also getting to test and develop new technologies. Mercedes, BMW and Jaguar are all constructors in Formula E. All three companies are also on the forefront of the EV industry and by competing in Formula E, they are showing the public their investment in electric power while also being able collect important data for their EV research and development. Amidst their emissions scandal, Volkswagen decided to pull out of all motorsport events thinking it would send the wrong message to consumers. Instead, they decided to have their racing team create a fully electric racecar for the sole purpose of just creating one. The result was the Volkswagen I.D. R, which currently is thought to be the fastest car around a track ever created. While Volkswagen created this car to show their dedication to sustainable energy amidst a scandal, it still shocked the motorsport world at how well a fully electric car could perform and set a new performance standard.

It is important to state that although there is much overlap between the racing world and automotive industry, this section of the paper should serve to complement the SCOT analysis rather than be a key factor in the discussion. The two worlds mirror each other, but the societal factors pertaining to one don't completely translate to the other. However, both of these parallel industries are striving to create the best technology for the future, so it is crucial to talk about them both when predicting the automotive industry and where EV and hybrid technology fits in. Since race technology has always trickled down to the automobile industry and motorsport integrating electric power into all their engines, it is quite possible that the innovation that pushes

EVs ahead of ICEs in society gets it start in a performance vehicle, and motorsport will serve as the catalyst for the stabilization of electric transportation.

Conclusion:

After examining the rapid rise of the EV industry through the lens of SCOT, it can be deduced that the EVs will be around for at least the near future with potential to rival ICEs, but have some significant societal and technical hurdles to overcome to remain on the trajectory they are on. Right now, production and sales are consistently rising year to year. New and exciting innovations continue to improve the EV experience and sustainable electric power falls in line with global government interests. Motorsport is adopting electric and hybrid electric power, improving the technology and its perception by the public. All of this is a recipe for EVs to become a dominant player in the market, which numerous projections predict. However, any one of the variables involved, such as the uncertainty about EV infrastructure and range anxiety, can cause these rising numbers to stall. There is still work to be done on both the technical and societal aspects, but as long as they are overcoming their respective obstacles at similar rates, they are abiding by the SCOT framework and stabilization is in sight. As this paper laid out, there is a good understanding about where the EV industry is currently and what it can become in the near future and in order for it to hit those goals, the sociotechnical factors presented have to continue to rise together.

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