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The Effects of Electric Vehicle Manufacturing on the Automotive Supply Chain: A Case Study of Tesla and Ford

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“The Effects of Electric Vehicle Manufacturing on the Automotive Supply Chain: A Case Study of Tesla and Ford”

by

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I hereby recognize and pledge to fulfill my responsibilities as defined in the Honor Code and to maintain the integrity of both myself and the College as a whole.

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Abstract

The growing demand for electric vehicles (EVs) has contributed to rising concerns over how the automotive supply chain -- from procuring raw materials to delivering the final product to the consumer -- will adapt. The dominant explanation for this trend in demand is a shift in consumer preferences (and government regulation?). Previous research has primarily relied on observational data and thus has had to wait for trends to develop over time, especially in an emerging market. I use a case study from a peer-reviewed academic journal titled Energy to find what consumers and automotive companies are looking for in an EV and how they can develop a profitable business model. Contrary to what has been assumed, the rise in demand for EVs is an increase in consumer interest and government policies. However, the suppliers and manufacturers of traditional gasoline and diesel-powered internal combustion engine (ICE) vehicles need to decide whether it is profitable for them to invest in scaling their EV production.

CHAPTER 1: Introduction

The automotive industry has seen tremendous transformation in recent years as a result of the spike in the production of electric vehicles (EVs) and the rising demand for environmentally friendly automobiles. A critical approach to lower greenhouse gas emissions and lessen the effects of climate change is the move towards EVs. The automotive supply chain, which has historically been focused on the manufacture of internal combustion engine (ICE) vehicles, faces substantial issues because of this shift. Major adjustments to supply chain management, supplier roles, and production procedures are anticipated because of the emergence of EVs. The aim of this paper is to explore the implications of EV manufacturing on the automotive supply chain. This paper will analyze the challenges and opportunities that arise from this shift, as well as examine the strategies that automotive companies can use to adapt to this new paradigm.

Automotive Industry Market Size and the Emergence of EVs

With a projected $3.0 trillion worldwide market in 2023, the automotive industry is one of the biggest and most complicated in the world (IBISWorld). The automotive supply chain is made up of a diverse group of suppliers, from raw materials and component suppliers to logistics and distribution companies. The manufacturing of ICE vehicles, which can run on either gasoline or diesel fuel, has been at the heart of the conventional automotive supply chain. Nonetheless, the rise of EVs is revolutionizing the automotive industry as electric motors take the place of conventional ICE vehicles. EV production is expected to grow significantly in the coming years, with projections indicating that EV sales will account for approximately 50% of all new car sales by 2035 (Goldman Sachs). The growth of EV production presents significant opportunities for automotive companies to reduce their carbon footprint and contribute to global efforts to mitigate the impact of climate change. However, this transformation also presents significant challenges to the automotive supply chain.

Supply Chain Obstacles

The automotive supply chain is faced with several obstacles because of the shift towards EV production. The necessity to retool production lines to produce EVs is one of the most significant obstacles. EV production requires new equipment and processes, such as battery assembly lines and electric motor production lines, in contrast to ICE vehicles, which have a rather standardized process. This requires significant investment and can take years to implement, resulting in production delays and potential supply chain disruptions. Additionally, the need to manage the supply chain for EV components. Batteries, electric motors, and power electronics are just a few of the specialized parts that are required for EVs but are uncommon in ICE vehicles. This requires automotive companies to identify and work with new suppliers, many of whom may be new to the automotive industry. This can result in increased costs and supply chain complexity, as well as potential quality and reliability issues.

Notwithstanding these challenges, the transition towards EV production offers the automotive industry several opportunities. One of the most significant opportunities is the potential for cost savings through the adoption of new production processes and technologies. EV production lines are often more automated than ICE production lines, which can result in lower labor costs and improved production efficiency. In addition, EVs require fewer components than ICE vehicles, which can result in reduced material and component costs. Furthermore, the potential for automotive companies to differentiate themselves from their competitors through the production of EVs. EVs are seen as a key solution to reduce greenhouse gas emissions and mitigate the impact of climate change, as such, they are becoming increasingly popular with consumers. Automotive companies that can produce high-quality, reliable EVs may be able to gain a competitive advantage in the market.

With the potential to drastically cut greenhouse gas emissions and support international efforts to mitigate climate change. The emergence of EVs is revolutionizing the automotive industry. The automotive supply chain, however, is also faced with significant challenges because of this shift. The transition to EV manufacturing requires considerable investment in new machinery and procedures, as well as the necessity to identify and collaborate with new suppliers.

Chapter 2: History and Industry Overview

In the last decade, electric vehicles (EVs) have become increasingly popular, although they were originally introduced more than a century ago. Consumers are looking for ways to save money as fuel prices continue to soar, which will lead to an increase in demand for EVs, whether they are hybrid, plug-in hybrid, or all-electric. The development of the first EVs was facilitated by a series of advances in battery and electric motor technology during the 1800s, not by a single country or inventor (United States Department of Energy). Although the main sources of transportation at the time were horses and buggies, innovators in Europe and North America started to develop the first small-scale EVs.

During the early 17th century innovators in Hungary, the Netherlands, and the United States started experimenting with the concept of battery-powered vehicles and created some of the first small-scale EVs. Robert Anderson, an English inventor, developed the first crude electric carriage at the time. Anderson produced energy in the form of an electric current using crude oil (United States Department of Energy). William Morrison, a Scottish scientist who lived in Des Moines, Iowa, is credited with developing the first practical EV in the United States in 1890. Morrison’s six-passenger electrified wagon, capable of reaching a maximum speed of only 14 miles per hour, generated interest in EVs (United States Department of Energy). The United States saw the emergence of EVs from several automakers in the years that followed. There were more than 60 electric taxis in New York City. EVs reached their pinnacle in 1900, accounting for almost one-third of all vehicles on the road (United States Department of Energy). They persisted throughout the next decade, and sales were strong.

It is crucial to consider the development of the personal vehicle industry and the various forms of transportation available at the time to understand the appeal of EVs throughout the

1900s. Horses and buggies were still the main forms of transportation at the turn of the 20th century. Due to advancements made to the internal combustion engine (ICE) throughout the 1800s, gasoline-powered vehicles also became accessible around the same time as EVs (United States Department of Energy). Notwithstanding their benefits, ICE vehicles have certain drawbacks. Compared to other types of personal transportation like riding horses or driving carriages. Additionally, they were quite noisy and emitted unpleasant exhaust. EVs were attractive to consumers because they were quiet, simple to operate, and did not release pollutants like ICE vehicles. Individuals and families living in cities, in particular, swiftly adopted EVs as they were the best option for brief excursions within cities (United States Department of Energy). Just a small number of vehicles were capable of making long trips due to the poor road infrastructure systems outside of cities.

Several inventors explored ways to enhance the technology because of the increased demand for EVs. Thomas Edison, one of history's most notable inventors, was one of these trailblazers who thought EVs were the best technology and strived to develop a better battery (United States Department of Energy). Even Henry Ford, the founder of the Ford Motor Company, worked with Edison to consider the possibilities for affordable EVs. Nevertheless, the production of the Model T by Ford in 1901 delivered a significant blow to the EV industry. The Model T introduced ICE automobiles to the general population since it was affordable and therefore easily accessible. By 1912, ICE vehicles cost just $650 (equivalent to around $20,000 in 2023). On the other hand, EVs were selling for $1,750 (equivalent to just under $54,000 in 2023). Moreover, Charles Kettering created the electric starter in 1912, which did away with the necessity of manually turning the engine to start the vehicle and significantly increased sales of gasoline-powered ICE vehicles. (United States Department of Energy).

The downfall of EVs was also impacted by several other advancements. American road infrastructure, including paved roads, highways, road signs, markers, and bridges had considerably improved by the 1920s (Department of Transportation). These changes made it easier for Americans to travel outside cities. When crude oil was discovered in Texas in 1901, there was an excess of gasoline available, making it inexpensive and convenient for Americans living in rural areas. As a result, gas stations began to spring up across the nation (United States Department of Energy). In contrast, very few individuals had access to electricity during that time outside of urban areas. As a result, EVs slowly disappeared from the market and had become outdated by 1935 (United States Department of Energy).

Fast forward to the 1990s, EVs went through a period of stagnation over the following three decades with minimal technological advancements. The market for alternative fuel vehicles declined due to the availability of cheap, plentiful gasoline and advancements in ICE technology. Gas shortages and oil prices, however, sharply increased in the late 1960s and early 1970s, peaking in 1973 during the Arab Oil Embargo (United States Department of Energy). This reignited interest in finding domestic energy sources and lowering the nation's reliance on foreign oil. The Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976 was passed by Congress in response, giving the Energy Department the power to support research and development for electric and hybrid cars (United States Department of Energy).

After the 1960s and 1970s oil crises, around twenty years have passed, and interest in EVs has waned. New state and federal restrictions, however, caused a shift in the situation. Interest in EVs was rekindled in the United States by the Clean Air Act Amendment of 1990, the Energy Policy Act of 1992, and new transportation emissions standards published by the California Air Resources Board (United States Department of Energy). At this time, automakers began converting several of their well-known models to run on electricity. Thus, EVs had a driving range of up to 60 miles and could perform at speeds and levels comparable to those of ICE cars.

According to some experts, the introduction of the Toyota Prius marked a key turning point in the development of EVs. The Prius, the first mass-produced hybrid EV, debuted in Japan in 1997 before going on sale internationally in 2000. (United States Department of Energy). Celebrity endorsements from the likes of Tom Hanks, Julia Roberts, Leonardo DiCaprio, Jessica Alba, and Natalie Portman helped the Prius acquire popularity right away and raise its visibility (English). The Prius has since become the most popular hybrid vehicle as gasoline costs have increased and worries about carbon emissions have increased. The Prius has become the best-selling hybrid car worldwide (United States Department of Energy). The announcement made by Tesla Motors in 2006 that they will produce a high-end electric sports vehicle with a range of more than 200 miles on a single charge was another turning point that had a significant impact on the EV industry (United States Department of Energy). The Tesla Roadster, which was originally made available in 2008, had a driving range of 245 miles and required 40 hours at 110V or four hours at 220V to fully charge (Tesla Motors). Tesla received a $465 million loan from the Department of Energy's Loan Programs Office in 2010 to establish a manufacturing facility in California (United States Department of Energy). Since then, Tesla has grown to be the largest employer in California's automotive industry due to the enormous popularity of its vehicles.

Other well-known automakers including Ford, Chevrolet, Hyundai, and others, accelerated the development of EVs in response to Tesla's announcement and subsequent success. The Chevy Volt and Nissan LEAF were launched in the United States market at the end of 2010. The Volt, the first commercially produced plug-in hybrid vehicle, includes an ICE that steps in to provide backup power if the battery runs out, allowing users to primarily travel on electricity while extending the vehicle's drive range (United States Department of Energy). As fuel prices continue to increase the popularity of EVs is growing.

Chapter 3: Literature Review

Climate change is no longer a problem in the distant future. The effects of climate change are being seen and felt today. Understanding the damages due to climate change at both national and local scales is important for assessing the benefits that will accrue from any policy that limits climate change, as well as for informing policies to adapt. As the global mean temperature rises, various sectors will be adversely impacted, such as agriculture, crime, coastal storms, energy, human mortality, and labor. Taken together, these effects could cost roughly 0.7 percent of gross domestic product (GDP) for every 1-degree Fahrenheit increase in temperature on average (Plumer & Popovich). The U.S. economy would stand to lose between about one and four percent of GDP annually by the end of the century through effects on mortality, labor and the energy sector alone under a high emissions scenario.

EVs have been increasingly popular since the first fully EVs were released in Japan and the United States in 2011 by Nissan. However, with the ramifications of climate change playing out across the globe, policies with the intention of mitigating climate change have been signed into law in many of the major regional trading blocs such as the United States-Mexico-Canada Agreement (USMCA) and the European Union (EU). One-way countries are taking responsibility for cooling the Earth’s temperature is by setting goals to meet certain quotas for electric vehicles being sold. They are doing this by subsidizing companies like Tesla, and consumers themselves, or eventually banning gas-powered cars within the next decade or so. The problem that suppliers and manufacturers may come across with these goals and quotas being set is the amount of time it takes to build an electric vehicle due to the lithium necessary to produce the battery. This issue will affect the automotive supply chain because manufacturers will have to alter their production to meet them while meeting consumer demand. The following review of the literature confirms that electric vehicle manufacturing presents a problem with the weak investment in the necessary technologies, the limited access to natural resources required to build the battery of the vehicle, and the overall profitability of producing and selling electric vehicles and possible solutions to address these problems. It concludes that producer and consumer subsidies are needed for mass production and adoption.

The adoption of electric vehicles, their profitability, and their effect on the automotive supply chain are fairly consistent across the literature. Lithium remains one of if not the most important materials required to build an electric vehicle. Issues related to mining and the refinery of lithium plague electric vehicle suppliers and manufacturers due to long lead times. Egbue & Long (2012) presented a model consisting of an integrative literature review and a State-of-the-art market analysis (SAM) to determine the importance of lithium to the future of EVs. Instability and uncertainties in the present supply place global energy and environmental sustainability goals at risk. They used the ABI/Inform and Academic Search Complete databases to search through the vast amount of academic and peer-reviewed articles for ones that met the criteria. Forty-eight articles were identified and further screened. Overall, 24 peer-reviewed articles, nine reports, four conference proceedings, and seven non-journal articles were included in their review. The authors' research focuses on the lithium supply chain compartmentalized under six major components including, lithium resource/reserve, supply, demand, geopolitical environment/trade partnering, cost, and recycling.

This research sets up a framework for highlighting risks in the lithium supply chain, and literature that has been published to help come to conclusions and identify gaps in the new literature. The authors found an interdependence among the different challenges faced by EVs with regard to the supply of lithium and highlighted risk areas. Some of the literature discussed trade partnering and policy relationships with major lithium producers from a United States perspective. The implication was that the United States has fairly stable relationships with major lithium-producing countries such as Chile and Argentina. Partnerships are also key to securing lithium supplies because lithium is concentrated in a few locations.

Coffin et al., (2018) offer a brief overview of the lithium supply chain in regard to battery production for EVs. The authors do this by discussing the different stages of the EV supply chain and describing the inputs necessary at each stage. Additionally, they examine the major battery manufacturers supplying the American market and the available international trade data and describe the trends. Lastly, the authors provide estimates of value added to the United States from every EV battery sold. The authors' data shows the major EV models as of 2017 and to no surprise the EV supply chain is mostly similar to the ICE supply chain. However, instead of competing based on the engine and transmission, EVs compete based on their batteries. The importance of batteries and the price that comes with them make up most of an EV's price. The battery manufacturing supply chain has three main parts: cell manufacturing, module manufacturing, and pack assembly. Additionally, international trade data in lithium batteries for imports and exports respectively from 2013-17 in millions of dollars. The authors also highlight that China and the United States are the largest suppliers of lithium-ion batteries worldwide. The Democratic Republic of the Congo (DRC) produced more than one-half of worldwide cobalt in 2016. However, the scarcity of mined lithium makes the prices expensive. Chile and Argentina are the two top global exporters of lithium carbonate. Lithium is already used for other things but with an increasing demand for EVs, there will be less lithium to go around. The data estimates of value added by the country for EV batteries are dominated by the United States, Japan, South Korea, and Hungary.

The call to action was heeded by researchers who began to study how electric vehicle production would affect the traditional ICE automotive supply chain. For example, Klug (2013) devised an explanatory research design consisting of a multi-method approach to understanding the automotive supply chain implications of EV manufacturing. Klug tested to see if the new technology used by EVs would dramatically change existing automotive supply chains. Klug used data found from a literature review of 15 cases. These cases were picked based the on availability of information and the logistical focus on how and why various supply chain forms differ from each other. Klug compared the EV supply chain with the ICE supply chain. The analysis concentrated on the inbound supply chain, in-house challenges of growing output levels, and the outbound perspective of the car manufacturer. Automotive manufacturers and suppliers which have traditional core components in engines, clutches, and gearboxes have to realign their strategy and identify new aftermarket business opportunities. Spare and easily replaceable parts like exhaust systems and mufflers are obsolete in EVs. Furthermore, traditional starters, alternators, and fuel pumps are not needed in EVs. ICE manufacturers will face radical changes in sales and distribution. Klug’s findings were replicated two years later by Rezvani et al., (2015) who also conducted a literature review of research studies published in peer-reviewed journals focusing on consumer adoption of EVs in an attempt to introduce an exhaustive outline of the agents for and barriers against consumer adoption of EVs.

Rezvani et al., (2015) secondary objective is to pinpoint gaps and limitations in existing research and suggest an agenda for future research. Furthermore, the high manufacturer’s suggested retail price (MSRP) on EVs can be a barrier for low-income households to adopt EVs or even buy a vehicle, to begin with. In order to facilitate EV adoption, it is important to understand how consumers perceive EVs and what the possible drivers for and barriers against consumer EV adoption are. Databases that were used include Emerald, Jstor, Sage, Science Direct, Springer, Wiley, and search engines. The first selection criterion for the studies was whether the goal of the study was to identify agents for and barriers against consumer EV adoption behavior. The second selection criterion was to review findings from different empirical studies which comprise predictors of consumer intention to adopt, or actual EV adoption behavior. These papers are important because the authors were interested in how research can inform automotive companies about actual consumer intentions and behaviors. Studies that did not include behavioral variables such as fuel prices or financial incentives were excluded. The authors' results of their literature review are that consumer EV adoption behvaior has been explained as a mix of planned, emotional and symbolic behavior. These findings comprise predictors of consumer intention to adopt or actual EV adoption. Additionally, consumer emotions are an overlooked aspect of consumer EV adoption research. A limitation of the paper is concerned with consumers' financial literacy and absorptive capacity to calculate and compare the financial benefits of ICEs and EVs. Consumer responses to the environment and environmental policy can affect their behavior.

Zarazua et al. put the findings from the above literature reviews into qualitative and quantitative data in 2020 by conducting 227 semi-structured interviews with 257 participants from over 200 institutions across the five Nordic countries (Sweden, Norway, Finland, Iceland, and Denmark) as a place of study considering these countries are traditionally recognised for having relatively progressive policy agendas and as leading nations in EV uptake. The participants were members of national and local government ministries, Universities and research institutions, electrical supply companies, and private sector manufacturers. The authors ask the participants questions about the business context of electric vehicles (EVs) and vehicle-to-grid technology. The approach is inherently qualitative rather than quantitative because consumers buy what they want versus what they need. Overall, the interviews conducted by the authors indicated that EVs currently face an unfavorable business model as a result of unprofitable product lines for the industry and unaffordable vehicles for consumers. The results highlight the lack of a favorable business model that is a result of unfitting business models and a supply chain that is not incentivised to optimize the production and delivery of EVs to consumers.

A variety of specific methods have been suggested to address the profitability of electric vehicles for manufacturers and distributors thus impacting every link in the automotive supply chain. Kahlen et al., (2014) simulated a wholesale market scenario to study the effect of the business strategy for balancing services. The wholesale market begins with generators, which connect to the grid and generate electricity. The electricity produced by generators is bought by an entity that will often resell that power to meet demand. Large fleet owners increase supply leading to a larger clearing quantity and a price decrease. On the other hand, the demand increases leading to an increase in both the clearing quantity and price (Chen). Investing in EV technology as a majority internal combustion engine (ICE) manufacturer is very expensive due to the fact you already have billions of dollars invested in ICEs. In the model, the authors are able to control the electric vehicle market penetration and model customers with realistic driving profiles. They compare the model of the wholesale market with and without virtual power plants (VPPs) which are centrally controlled systems of interconnected energy sources consisting of electric vehicles (EVs) and evaluate it against the social, environmental, and financial indicators. The authors' results of the model show that profitability increases with the more EVs you have in a fleet because you'd make more money per unit and will reach economies of scale.

There are increasing benefits for consumers of electricity the more fleet owners participate in VPP trading. The average wholesale price is significantly lower when VPPs are available. As fleet owners and vehicle manufacturers are gradually focusing more on EVs they have to keep in mind any government policies that may arise as EVs become more popular. It is important to be an early producer to take full advantage of the initial profits and gain market share. This approach may not be suitable for all organizations, but the information provided by the article can be used to help develop alternative strategies. Wolbertus & Gerzon offer a solution regarding the efficiency of charging infrastructure. In 2018 these authors issued a survey using the Dutch Association for Electric Drivers members and asked them whether they would rather have a private charging station at their permanent residence or rely on a public charging station to test if implementing a pricing strategy will increase the efficiency of electric vehicle charging stations.

The authors state that oftentimes drivers will idle their cars in the charging spots causing the availability of charging stations to be lowered for a given amount of time. In total 559 people were contacted with 128 replies. An additional 168 replies were gathered from a Twitter poll through the Dutch Charging Station Organization. The authors' results show that a fee can be very effective in increasing the efficiency of a charging station because consumers were less likely to install an at-home charging station if the charging infrastructure was available nearby and simply did not want to pay extra if their vehicle was not charging or was fully charged. Reliable and accessible charging infrastructure is an issue consumers raise when thinking about buying an EV. However, manufacturers and distributors (dealerships) need to have adequate supply to meet the demand of their consumers.

Data were collected by Liao et al., in 2019 from surveys developed and performed by the Urban Planning Group at the Eindhoven University of Technology in the Netherlands to test if applying prevailing business models for ICEs such as purchasing the vehicle outright or taking out a loan to cover the costs is unlikely to achieve similar market success with EVs. The authors seek to assess and quantify consumer preferences for business models in the context of EV adoption. The criteria to be included in this survey were you had to have a driver's license, own a car or expect to buy a car in the following three years, and the car couldn't be used, pre-owned, or a company car. The final dataset consisted of 1003 respondents. The authors' results show that EV leasing is the most popular option while battery leasing is less preferred than full-price purchase. For ICE and PHEV full price purchases are preferred. Implementation of incentives in the leasing business model can increase further market shares than when only applied to buying. EV leasing is significantly more preferred to buying which implies that vehicle leasing has added value for EV adopters. Car manufacturers can work on familiarizing potential EV business models with leasing and providing easy access to leasing which reduces transaction costs.

Regardless of the specific methods used to increase the profitability of EVs consumers have to be willing to purchase or lease them or they have to be incentivized to switch from traditional ICEs to EVs. Gu et al., (2019) used the Stackelberg game theory based on conditions of imperfect information to understand how government subsidies should be allocated in order to maximize the total profit of the automotive supply chain. The authors' model includes ICE and EV manufacturers and retailers. There's one scenario where the EV retailer is franchised by the EV manufacturer and another where the ICE retailer, sells ICEs. Consumers can pick either option. It should be every individual's responsibility to care for the environment but if there are no personal incentives to do so many people won't go out of their way to do their part. When EV and ICE manufacturers sell a vehicle to the franchisee the franchisee doesn't know the accurate manufacturing cost but they have an estimate. The authors acknowledge that retailers make decisions on how to price the vehicle based on its cost assumptions. Consumers are rational and buy what they can. Furthermore, in order to maximize the total profits throughout the EV supply chain, the subsidy allocation ratio should consider EV customers first. In the early stage, the higher the subsidy budget, the more funds should be allocated to EV manufacturers. In the later development stage, it is recommended that all the subsidies should be given to EV customers because at that point manufacturers will have enough money invested in their operations. The authors found that in the early stage, higher fuel prices, lower electricity prices and less EV charging times should lead to more subsidies being allocated to EV customers, and in the later stage, with the development and maturity of EV technology, all subsidies should be allocated directly to EV buyers. Governments should pay more attention to subsidy budgets for the EV supply chain because they are the ones pushing for change. The authors emphasize that after a period of time, subsidies won't be important because by that time user experience will have improved and more consumers will be accepting of EVs. In order to pinpoint trends in the EVs consumers were buying and how to make them more profitable Breetz & Salon (2018) investigated vehicles that according to United States sales were the most popular for their category (ICE, EV and PHEV) the Toyota Corolla, Nissan Leaf, and Toyota Prius to test if the Nissan Leaf EV will have a higher total cost of ownership than the Toyota Corolla ICE. 2011 was the first year a fully electric car was available on the mass market. Fourteen cities were selected because they had monthly reports of gasoline and electricity price points. EV competitiveness will depend on subsidies because if they don't no one will buy them so if there is a rapid increase in people driving EVs then that will cause others to want to do the same. The authors' results show that despite the $7500 tax rebate, the Leaf had higher net capital costs than the Corolla mainly because the Leaf lost most of its value over time and was more costly. The Corolla and Prius retained 45% and 40% respectively of their value after five years compared to 16% for the Leaf. Incentives become costly as the scale of EV adoption rises. The cost is borne by the taxpayer and only the wealthy can enjoy the benefits.

Improvements to the links in the automotive supply chain to meet government quotas and consumer demand will only be strengthened by investing in the necessary technologies, increasing the access to natural resources required to build the battery of the vehicle, increasing the overall profitability of producing and selling electric vehicles, and subsidizing producers and consumers to mass produce and eventually switch from ICEs to EVs. However, further research is needed to more clearly categorize the logistics surrounding the policies of lithium mining and refinement to address these challenges so climate change goals can be met.

Chapter 4: Theoretical Analysis

Electric vehicle manufacturing is a multi-step process that includes designing, engineering, prototyping, production, and assembly. A number of crucial elements, including battery technology, powertrain design, manufacturing procedures, supply chain management, and environmental impact, may be separated out in the theoretical study of the production of EVs.

Battery technology

EV battery technology is essential since it affects the vehicle's performance, cost, and range. Electric cars employ a variety of battery chemistries, but the most common one used is lithium-ion (Li-ion) batteries (United States Department of Energy). Due to their high energy density, low self-discharge rate, and a long-life cycle of 15-20 years, lithium-ion batteries have emerged as the most popular battery technology in electric cars (United States Department of Energy). The cathode, anode, and electrolyte are the three main parts of a Li-ion battery. However, solid-state batteries are a promising new technology that is currently in development. These batteries use a solid electrolyte instead of a liquid electrolyte, which provides several advantages, including improved safety, faster charging times, and higher energy density (Braga). Solid-state batteries also have the potential to reduce the cost of electric vehicles using less expensive materials than traditional Li-ion batteries.

Manufacturing Process

The manufacturing processes of battery technology of EVs are similar to those of traditional gasoline-powered ICE vehicles, but with some key differences due to the unique components of an EV. Battery manufacturing is one of the most significant differences between an EV and an ICE vehicle. There are several battery chemistries available, including lithium-ion (li-ion), which is commonly used in EVs (Coffin & Horowitz). Another distinctive element of EVs is the electric motor, which is made by assembling the rotor, stator, and housing parts. The motor is designed to generate high torque at low speeds making it suitable for EVs. The chassis serves as the framework for the body, battery, and electric motor of an EV. EVs have distinctive features that must be included in the interior layout, such as regenerative braking controls and battery charge indicators. The final testing of the fully finished EV is ensuring it operates properly. The performance, safety, and dependability of the EV are examined, as well as the battery's capacity and charging speed.

Supply Chain Management

The Supply Chain Management of EVs is a complex process that involves managing the flow of materials, parts, and components from suppliers to the final assembly plant. The battery supply is the first link in the supply chain for EVs (Coffin & Horowitz). The battery pack is a crucial part of EVs, and the supply chain for it must be carefully monitored. Managing the quality and dependability of the supply chain is crucial to ensuring the performance and safety of EVs, as battery cells and modules are frequently acquired from various suppliers (Coffin & Horowitz). As the popularity of EVs grows, so does the demand for charging infrastructure. Managing the supply chain for charging stations requires coordination with suppliers of charging equipment, installation services, and electrical infrastructure (Zarazua et al). The materials used in the production of EVs, such as aluminum, copper, and rare earth metals, must be sourced from responsible suppliers to ensure sustainability and ethical practices (Coffin & Horowitz). The supply chain must be managed to ensure the availability and quality of these materials. The transportation of components and finished vehicles is a critical aspect of supply chain management for EVs. EV components and finished vehicles may require specialized transportation to minimize damage and ensure timely delivery (Coffin & Horowitz). Managing quality control throughout the supply chain is essential to ensure the reliability and safety of EVs. Quality control processes must be in place for components and finished vehicles to ensure that they meet the required standards.

In comparison to traditional ICE vehicles, EVs have the potential to drastically reduce the environmental impact of transportation. Yet, there are still some environmental impacts from EV manufacturing and use (United States Environmental Protection Agency). Since they do not burn fossil fuels, EVs release fewer greenhouse gases while operating than ICE vehicles. However, energy is needed to create EVs and their battery packs, and this energy can come from places that produce greenhouse emissions, such as coal-fired power plants. As a result, some of the advantages of EV operation may be outweighed by the greenhouse gas emissions linked to their creation. Electricity, which can come from renewable or non-renewable sources, is required by EVs to charge their battery packs. It is possible to lessen the environmental impact of EVs by charging them using renewable energy sources like solar or wind power. Lithium and cobalt must be extracted in order to make EVs which might have an adverse effect on the environment. Land is also required for the manufacture of EVs in order to harvest metals and minerals and to build new manufacturing facilities. Habitat degradation and land degradation are a few of the environmental impacts that may arise from EV production. Also, improper management of the disposal of used batteries at the end of their useful lives may have negative effects on the environment (United States Environmental Protection Agency).

Compared to gasoline and diesel-powered ICE vehicles, EVs emit fewer nitrogen oxides and particulate matter, which are air pollutants. The environmental impacts of EVs rely on a number of elements such as the energy source used to generate electricity, the materials, and manufacturing processes used to make batteries, and how batteries are handled at the end of their useful lives (Plumer & Popovich). EVs have the potential to greatly decrease transportation's negative environmental impacts, but their whole environmental impact must be taken into account during their entire life cycle.

Hypothesis

Since the primary paper I use to formulate this theory is Zarazua et al. (2020), I must consider the expectations of these authors when hypothesizing the possible outcomes of the impact EVs have on the automotive supply chain. After exploring the literature, I believe if traditional ICE car manufacturers within the United States invest in developing a brand-new business model for the sale of EVs there would be a streamlined path for manufacturers to better meet the increasing demand for EVs.

Chapter 5: Case Evaluation

"The market case for electric mobility: Investigating electric vehicle business models for mass adoption" by Zarazua et al. (2020) is a comprehensive case study that explores the market potential for EVs and investigates the business models that can facilitate their mass adoption. The authors offer a thorough examination of the many aspects of EV demand, such as price, drive range anxiety, charging infrastructure, and the regulatory landscape. The authors then explore the various business models, including direct sales, leasing, and shared mobility, that are being used to encourage EV adoption. Although direct sales are the most popular business model, the authors point out that leasing and shared mobility are also gaining popularity and can be useful in encouraging EV adoption in certain markets. The authors point out that although EVs may cost more upfront than ICE vehicles, overall ownership costs may be cheaper as a result of fuel and maintenance cost reductions. Drive range can also be a major deterrent to adoption, however advances in battery technology and the expansion of charging infrastructure help tp overcome this problem. The regulatory landscape, including government incentives and regulations, as well as the function of stakeholders like utilities and charging infrastructure providers are also included in the case study. The authors note that although regulatory support has been crucial in promoting EV adoption, continued innovation in business models and technology is still required to enable widespread adoption. The case study also offers insightful information on the market potential for EVs and the business strategies that might speed up wide-scale adoption. The thorough examination of the policy and regulatory landscape by the authors, as well as the variables influencing consumer adoptions of EVs, offers crucial direction for all stakeholders involved including manufacturers, policymakers, and investors. The case study also emphasizes the necessity of continuing innovation and stakeholder cooperation to advance the sustainability and feasibility of EVs. This includes the development of new business models, improvements in charging infrastructure, and supportive policy and regulatory frameworks.

Most Similar Designs Case Study

The United States automotive industry declined in 2022, but the EV sector stood out as a bright point. To catch Tesla and secure their futures, automakers more than increased their spending on EV production. About 800,000 fully electric EVs were made in the United States in 2018, more than tripling the previous year's figures to take up over 6 percent of the market (Johnson). Government incentives made available by the Inflation Reduction Act, which was implemented in August 2022, may have contributed to this increase in sales (Johnson). This act gave buyers up to $7,500 for new EVs and up to $4,000 for used EVs. Furthermore, Tesla continued to lead the market with 65 percent of all EV sales. Other automakers, including Ford, Hyundai, and GM, are starting to assert their ownership. Ford claimed the title of second-largest United States EV producer in 2022 after selling 61,757 EVs (Johnson).

The most popular EV in the United States is the Tesla Model Y. Since it first appeared on the market in 2020, demand has been high. The base model starts at a price of $65,990, which features an all-wheel drive (AWD) dual motor, 76 cubic feet of storage, and a 330-mile drive range. At 220V, charging time can take anywhere between 11 and 12 hours (Johnson). With a wall connector commonly used in consumers, homes can charge up to 44 miles per hour of charging. A mobile connector can charge up to three miles an hour. Superchargers found at highway rest areas and gas stations can charge about 124 miles in 15 minutes. With a destination charger that can be found in municipal parking lots can charge up to 44 miles in one hour of charging (Tesla Motors).

The battery supply chain for the Tesla Model Y and the Ford Mustang Mach-E differs in several keyways, including the source of the battery cells, the chemistry of the batteries, and the supply chain management strategies used by the two companies. The battery cells Tesla uses are sourced from Panasonic, LG Chem, and Contemporary Amperex Technology Co. Limited (CATL) (Barrera). Ford, similarly, gets its battery cells for the Mustang Mach-E from LG Chem (Coffin & Horowitz). For its EVs, Tesla predominantly uses a nickel-cobalt-aluminium (NCA) battery chemistry that offers high energy density and long-range capabilities (Barrera). Ford, in contrast, uses a nickel-manganese-cobalt (NMC) battery chemistry, which strikes a balance between durability and energy density (Coffin & Horowitz). As Tesla controls the production of battery cells and battery modules, Tesla has vertically integrated its battery supply chain. Tesla's batteries are managed by a unique technology that enhances their effectiveness and longevity (Johnson). Ford, on the other hand, has outsourced the manufacturing of its batteries and is dependent on LG Chem for the supply of battery cells as well as the production of battery packs. Currently, the Gigafactory in Nevada, which is jointly run by Tesla and Panasonic, produces the batteries for the Model Y. In contrast, LG Chem produces the batteries for the Ford Mustang Mach-E in South Korea (Johnson).

For all three Tesla vehicles, the battery cells are manufactured by Panasonic, and the battery modules and packs are manufactured by Tesla. The battery cells for the Model 3 are manufactured in the United States, while the battery cells for the other two models are produced in Japan. Tesla outsources some of their models, such as the Model S and X, to suppliers for certain components and parts because it allows them to focus on its core competencies and optimize its production processes (Coffin & Horowitz). By outsourcing certain components, Tesla can reduce costs and increase efficiency in their production process. The trend seems to be if a certain model is most popular in the United States Tesla focuses on production in the US and the other models' batteries get outsourced.

Ford has long been the most popular vehicle brand in the United States and has always been that way. Ford introduced its first full EV the Mustang Mach-E in 2019 and has grown significantly in popularity. The basic five-seater sports utility vehicle (SUV) costs $46,895. In 2022, about 39,458 Mustang Mach-Es were sold (Johnson). The driving range for AWD is 224 miles, while RWD is 247 miles. The Mach-E may use a wider network of public chargers from different companies; however, their charging times vary. The Mach-E's maximum power input is 150V, which means that its fastest rate is slower than Tesla's Model Y. Ford claims that using an Electrify America fast-charging station can add 50 miles in only 10 minutes (Ford Motor Company). Ford also announced that it will build a battery factory in Michigan using Technology from CATL, the leading producer of EV batteries in the world. Additionally, Ford announced that it will own 100% of the facility and use CATL's equipment and services to manufacture batteries (Bradsher).

How Tesla Sells its Vehicles

The demand for fully EVs is rising. There are several causes for this, including increased safety and car pollution regulations, technological advancements, and changing consumer preferences. Yet, Tesla Motors and its distinct business strategy may be credited for a large portion of the mainstream acceptance and enthusiasm for EVs.

Unlike other car manufacturers who sell through franchised dealerships, Tesla sells directly to consumers. It has established an international network of galleries and showrooms controlled by the corporation, mostly in metropolitan areas. Tesla believes that by controlling the sales channel, it can accelerate the development of its products (Zucchi). Most significantly, it improves the shopping experience for customers. Tesla showrooms do not have any possible conflicts of interest, in contrast to other traditional auto dealerships. Only Tesla employees who work in sales and service interact with customers. Consumers can customize and purchase a Tesla online. With its own network of more than 30,000 Global Superchargers, Tesla made it possible for consumers to charge their vehicles quickly for a fraction of the cost of regular fuel. Of course, the goal is to speed up the adoption of EVs by making maintenance less expensive and complicated (Zucchi).

Many financial analysts and investors consider Tesla to be more of a tech company than an automobile manufacturer. This is best explained by the increase in the stock price of the company beginning in 2013 when it soared by more than 300% in only one year (Zucchi). Tesla and the technology industry are similar in a number of ways. Tesla has adopted the tech industry's mantra of altering the status quo. Tesla is determined to alter current business structures inside the automotive industry by selling directly to customers, much like other tech companies.

Although Tesla did not invent the electric car or even the luxury electric car, Tesla did invent an effective business strategy for introducing enticing EVs to the market. Building a network of charging stations was one of the tactics used to overcome one of the biggest challenges to the adoption of EVs, charging on long drives (Zucchi). One of the reasons Tesla's stock has skyrocketed since its initial public offering (IPO) is due to its distinctive business plan, which involves maintaining control over sales and service. Ford is attempting to compete with Tesla by selling directly to consumers by not having EVs in stock at their dealerships (Zucchi).

How Ford Sells its EVs

Ford has truly embraced EVs in recent years and currently sits at number two in US sales behind Tesla. To sell EVs, Ford dealers may have to spend over $1 million. Ford divided its passenger car company into three distinctive companies this past March in 2022: Ford Pro which is responsible for commercial and fleet vehicles, Model e which includes EVs and plug-in hybrids, and Ford Blue which consists of ICE vehicles Lambert et al). After learning about the Ford Pro plan during Ford's annual dealer meeting last year, several of their dealerships have been selling and maintaining vehicles from all three divisions. This sounds excellent; however, dealerships must invest their own funds to sell EVs, or else they continue to sell ICE vehicles and try to sell EVs in the future.

With these new dealer commitments, Ford is building the basis for a promising future in EV sales with these new dealer agreements, both in retail and online. Ford dealers may now sell EVs under five new pillars. Ford CEO Jim Farley and other leaders from the three divisions outlined the future of EV dealerships (Lambert et al). The first pillar and arguably the most important is training. Ford is investing in educating their dealers on how to sell EVs and then relaying that information to the consumers. The second pillar is charging. In order to ensure that customers always have a place to charge their EVs, even if they do not have a home to charge their vehicle. Fast chargers are being installed at Ford dealerships. Public fast chargers are also available on the Blue Oval Network. About 96% of Americans live within 20 miles of a Ford dealer and 85% live within 10 miles. The third pillar is eCommerce. Having transparency with non-negotiable pricing due to the fact that dealers control the pricing of their vehicles. Ford, however, wants its pricing to be fair to its consumers and to be constant, so it will be monitoring the process from the entrance to exit to make sure that the customer signs the bill of sale for the same price that was stated at the beginning of their vehicle search. This enhances the opportunity for the greatest customer satisfaction. Ford announced that in a single year, internet orders increased from 6% to 50%. The fourth pillar is Physical experiences. All EV clients have access to remote delivery, pickup, and delivery provided along with dealership loaner vehicles for all EV customers. The fifth and final pillar is Digital experiences. Opportunities for software and subscription benefits (Lambert et al).

Ford has effectively given its dealers an ultimatum: either sell EVs in accordance with these new requirements or don't; either way, Ford will continue to back them. Dealers must be accredited under two categories in order to continue selling EVs under the Ford brand, which will come at a significant dealer investment in any case.

Ford demands an estimated investment of $500,000 to become model e certified. According to Ford, this figure is a reasonable estimate of what will it cost to build the required infrastructure to meet all the demands of developing the EV industry (lambert et al). Around 90% of the projected cost is for charging infrastructure, whose costs are heavily influenced by location, grid capacity, labor, construction, etc. Another prerequisite for this certification is that Ford dealerships must install at least one fast charger that is accessible to the public and that generates 120V of electricity (Lambert et al). Consequently, the substantial investment.

Ford sees that in order to compete with Tesla, fast charging is necessary. The CEO of Ford Jim Farley has stated that he is paying careful attention to Norway in particular and that he monitors reports every month to track changes abroad, particularly in light of what Tesla is doing. Tesla has roughly 1,200 staff in Norway spread across 21 physical sites, with a country with a population of 5.4 million (Lambert et al).

Chapter 6: Discussion

Tesla and Ford have different approaches to selling their EVs, and there are several notable differences between the two companies in terms of their marketing, distribution, and branding strategies. Tesla is a luxury brand that focuses on innovation, technology, and performance, while Ford is a mainstream brand that has a more traditional image. Tesla’s brand is associated with innovation and high-end features, while Ford’s brand is associated with reliability and affordability. One of the most significant differences between the two companies is their current sales model. Tesla sells its cars directly to consumers through its online store, while Ford primarily sells its cars through traditional dealerships. Tesla’s direct-to-consumer sales model allows the company to maintain control over the customer experience and offer a more personalized and streamlined buying experience. Ford’s dealership model offers the opportunity for consumers to have a more hands-on experience with the car before purchasing, and dealerships can provide additional services like financing and maintenance. Tesla is known for its innovative and unorthodox marketing strategies, often relying on social media and word-of-mouth to generate buzz for its products. Ford, on the other hand, tends to rely on more traditional marketing tactics, such as television and print advertisements, to promote its products. Tesla offers a limited range of models, with a focus on luxury and performance, while Ford offers a wide range of models, including both affordable and luxury options. This difference in model range reflects the two companies’ differing approaches to the EV market, with Tesla focusing on a niche market of luxury EVs and Ford aiming to offer electric options for a wider range of consumers. Tesla has invested heavily in its own network of Superchargers, which are fast-charging stations exclusively for Tesla vehicles. Ford had partnered with various charging networks to offer its customers access to charging stations but does not have its own proprietary charging network.

Tesla and Ford have different approaches to selling their electric vehicles, with Tesla focusing on a direct-to-consumer model and luxury branding, while Ford relies on traditional dealerships and a wider range of affordable and luxury models. Despite these differences, both companies are contributing to the growing popularity of EVs and are working towards a more sustainable future for personal transportation.

Chapter 7: Conclusion

Tesla has successfully disrupted the automotive industry through vertical integration of their supply chain and direct sales models for EVs. Tesla controls the production of its software for all their vehicles and batteries for the most popular selling model produced. When you think of buying a car you typically think of physically being in a brick-and-mortar dealership with a plethora of vehicles to look at and test out. With Tesla, you do not get that same hands-on experience however Tesla is saving money by not having huge dealerships with their cars sitting in a parking lot. Ford now is attempting to invest in EV production with their Mustang Mach-E but is also investing in a training program for EV-specific sales teams. In order for EVs to be produced on a mass scale automakers have to be willing to invest in educating their dealers on EV-specific sales methods that are completely different from ICE vehicles. Additionally, having separate divisions that handle the sale of ICE vehicles and EVs allows the consumer to have a more specialized approach. Ford has the second-highest EV sales in the United States because they have started to mimic Tesla and create an entirely different way of selling EVs. By doing this Ford is starting to see just how profitable EVs can be.

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