Applying the theory of disruptive innovation to recent developments in the electric vehicle market

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ABSTRACT

Electric Vehicles (EVs) have the potential to disrupt conventional Internal Combustion Engine (ICE) automobiles, which could bring major changes to the economy, the environment, and everyday life for millions of people. Christensen's (1997) model of Disruptive Innovation (DI) has become a popular way to anticipate future technological change. In Disruptive Innovation, a new product with initially lower performance is released; however, over time, this product improves and adds value in ways that allow it to overcome existing incumbent products. The main goal of this paper is to analyze recent developments in EV market development to see if the principles introduced through DI theory have held true for this potentially disruptive technology. Approaches from industry incumbents such as Nissan, GM, and BMW are contrasted against the strategy of industry newcomer Tesla Motors in order in analyze the applicability and predictive ability of Christensen's theories. In this analysis, I have found that the theory has held up well in areas such as incumbent use of sustaining technologies; however, in other areas such as disruptive product performance trajectory and the so-called "Jobs To Be Done" paradigm, I have found important differences between what should happen according to the theory and with what actually occurred. Based on this finding and the work of other scholars, it may be necessary to add a new categorization of high-end innovation to DI theory.

JEL Classification: M10, O32, O33, M31, L62
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INTRODUCTION

The automobile is on the cusp on a revolution. Advanced computing will allow for self-driving automobiles. Automatic anti-collision brakes are already widely available in the marketplace. Internet capability will connect cars like never before. Perhaps most critically, innovations have allowed alternatives to the traditional Internal Combustion Engine (ICE) to emerge. Gasoline-Electric hybrids such as the Toyota Prius have already proven to be a sales success and Electric Vehicles (EVs) or Plug-In Hybrid Electric Vehicles (PHEVs) are being mass-produced and sold on the market today.

All of this is taking place against a backdrop of increased concern over global warming. A 2014 report from the United Nations Intergovernmental Panel on Climate Change (IPCC) has concluded that flooding, drought, rising sea levels, famine, and animal extinctions are all likely consequences of a warming climate caused by man-made carbon emissions (Gillis, 2014). Furthermore, the transport sector accounted for up to 27% of final energy use and its CO2 emissions are expected to approximately double by the year 2050 ("Climate Change", 2014). A shift in this sector away from petroleum-based energy could have a huge impact on carbon dioxide emissions.

The advent of the EV may have the greatest ability to affect both the automobile industry and environmental concerns. EVs do not produce tailpipe carbon emissions and can be powered by a large variety of sources, including carbon-free renewable energy such as wind and solar energy. Electric motors are about three times as efficient as ICEs (Tilleman, 2013) and they offer advantages over ICE technology in areas such as torque, noise, acceleration, and required maintenance (Hensley, Newman, & Rogers, 2012).

One way to examine this new technology is to analyze it using existing technological theories that have proven effective in other industries. The results should be of use in predicting the trajectory of EV technology development. Therefore, I would like to look at the most latest developments in the field of EVs through the concepts of Disruptive Innovation (DI), first popularized by Harvard professor Clayton Christensen in books such as *The Innovator's Dilemma* (1997). As EVs do not have many of the elements of the dominant ICE technology, I feel that this is an excellent example to look at the automobile industry through the perspective of DI theory.

Christensen and his co-authors have stated that in order to make DI a more robust theory, it needs to be tested in a wide area of fields and technologies. Exceptions to this theory, if any, will help to strengthen the theory overall (Christensen, 2006). Therefore, testing the predictive capability of DI theory, and finding anomalies, if any, should improve the quality of the theory itself.

In order to test these theories, first I will review the basics of DI theory. Next, I will write a literature review featuring related research, criticism, and feedback from other writers. Third, I will write about EV technology at the time of the publishing of Christensen's first major work, *The Innovator's Dilemma*, in 1997. Following that, I will write about developments in the field of EVs from that time of that book's publishing up to present day. Finally, I will analyze how these market developments and how they fit into DI theory.

INTRODUCTION TO DISRUPTIVE INNOVATION THEORY

According to Christensen (1997), there are two main types of technological innovations: Sustaining and Disruptive. Sustaining Innovations are introduced to maintain a previously established performance curve favored by mainstream customers, while Disruptive Innovations "result is worse product performance, at least in the near term… (But) bring to market a very different value proposition that what had been available previously" (Christensen, 1997, pg. xviii). Additionally, sustaining innovations almost always favor incumbent firms, while disruptive innovations almost always favor new market entrants (Christensen, 1997). Also, disruptive innovations almost always use existing materials and technologies packaged in a new or simpler way, while sustaining innovations are more likely to contain exotic or expensive components (Christensen, 1997).

The impetus for DI theory was Christensen's study of the optical disk drive industry, where industry incumbents "did everything right" but repeatedly fell to industry newcomers when new disk drive sizes appeared. According to Christensen, he wanted to explore this "Innovator's Dilemma" and find out how well-established, well-run companies could fall to industry entrants time and time again. The theory has been used by Christensen in a wide variety of industries and has been even used to describe a county's national innovation progress (Christensen, Craig, & Hart, 2001) and as a way to possibly lift millions out of poverty (Hart & Christensen 2002).

Within the category of Disruptive Innovations, Christensen & Raynor (2003) further classified them into two different types: Low-End Disruption and New-Market Disruption. Low-End Disruptions are the type described in the original *Innovator's Dilemma* (1997) analysis: these are innovations which often have lower performance than mainstream products along a certain performance trajectory, yet contain other advantages or benefits that appeal to different groups of consumers. New-Market Disruptions, on the other hand, appeal to new value networks and new customers "who previously lacked the money or skills to buy the product, or different situations in which the product can be used" (Christensen & Raynor, 2003, pg. 44). Ultimately these New-Market disruptions target "nonconsumers" who are now able to use these new innovations, as they are more affordable and easier to use than previous products. Both of these types of disruptions gradually improve until they have enough performance to appeal to mainstream consumers.

Another key part of DI theory is the Resources, Processes, and Values (RPV) framework. "Resources" explain what a company has at its disposal, such as capital, labor, and intellectual property; "Processes" explain how a company has learned to do business; and "Values" explain what a company thinks is important and where the company will utilize its resources. Essentially, this framework is used to explain a company's "abilities and disabilities" (Christensen, 1997). Through this framework, it is possible to see why industry incumbents tend to fail at disruption, while industry newcomers are typically much more successful. Incumbents often have significant advantages in areas such as resources, but their internal processes and values do not accommodate changing from sustaining to disruptive innovations. In other words, "an organization's *capabilities* become its *disabilities* when disruption is afoot" (Christensen & Raynor, 2003, pg. 177).

One more concept that is often used in Christensen's DI analysis is the "Jobs To Be Done" model. This is a different way of thinking about market segmentation; instead of breaking down the market by traditional elements such as age, gender, and income, the "Jobs to be Done" model asks a different question entirely: What kind of "job" are customers trying to accomplish when they use a certain product? This approach is more circumstance-based and takes a closer look at the reasons why customers really want to use a certain product. According to this theory, customers "hire" a product to do a certain "job", which may not be exactly what the original product designer had anticipated.

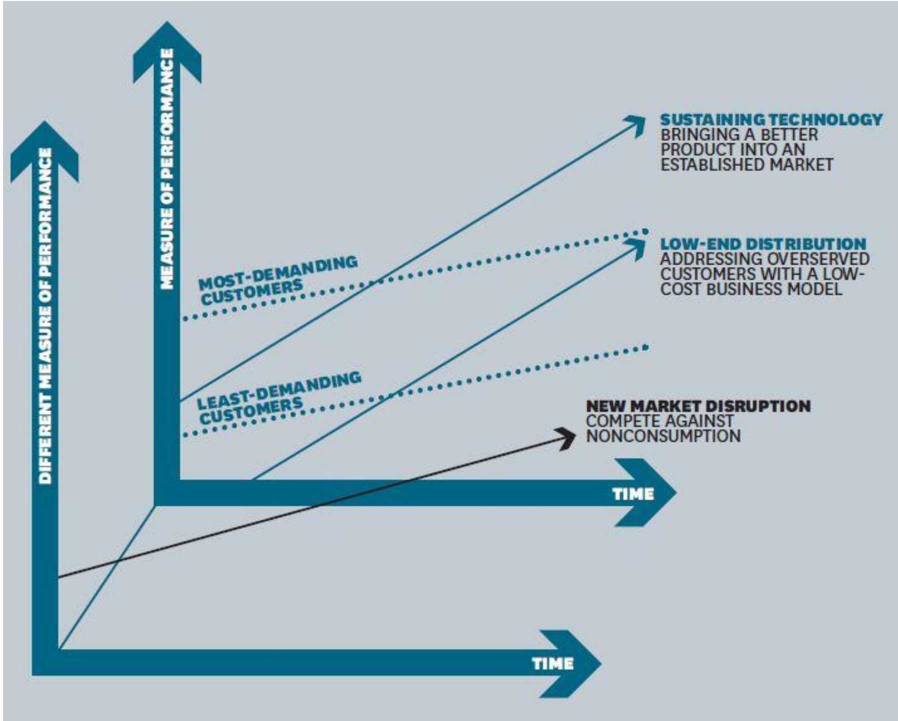

Figure 1. Graphical Representation of Disruptive Innovation Theory
Source: Ovans (2011)

LITERATURE REVIEW

Disruptive Innovation theory has attracted a large amount of attention since its introduction. *The Innovator's Dilemma* was rated by *The Economist* as one of the six most important business books ever (Lambert, 2014), and the concept for DI was included in Harvard Business Review's list of "Charts that Changed the World" (Ovans, 2011). It has been called "seminal and groundbreaking" (Schmidt & Druehl, 2008) and has "received extensive coverage in business publications" and been "cited extensively by scholars working in diverse disciplines and topic areas" (Danneels, 2004).

For all of its influence, the theory has found detractors as well. Many writers have found various issues with the theory, ranging from vague definitions to its suitability as a predictive theory. For example, Sood and Tellis (2011) have identified at least four weaknesses with the theory: tautological or shifting meanings, ambiguous application, scarcity of empirical evidence, and a lack of predictive capability. Another response was from Danneels (2004), who determined that the theory was in need of much more clarification and research. He posits several themes and questions for future potential research in this area, including improved definitions, suitability for predictive use, the abilities of some incumbents to survive disruptions, and the relative merits of being customer-oriented or establishing spin-off organizations to pursue disruptive innovations. Danneels encourages using "the foundation provided by Christensen for theory testing purposes" in the hope that it would be more useful as a predictive model, as opposed to its current "after the fact" ex post analysis.

Other writers have recommended adjustments or additions to the Disruptive Innovation framework. Hardman, Steinberger-Wilckens & van der Horst (2013) recommended a three-point test for potential disruptions: whether or not the technology is disruptive to market leaders, disruptive to end users, or disruptive to infrastructure. Meanwhile, Markides (2006) suggested that the Disruptive Innovation model be split into two different types: business model innovations and radical product innovations. Business model innovations included such examples as Dell and Southwest Airlines, while radical product innovations are "new-to-the-world" products such as personal computers and mobile phones that "disturb prevailing consumer habits and behaviors in a major way".

Utterback and Acee (2005) discuss the need to consider other discontinuous forms of technological change, as opposed to Christensen's focus on "attacks from below". They find several situations where innovations start at the higher end tiers of the market and then move gradually downwards until they reach the mass market- in exact opposite fashion to the mechanisms proposed in Christensen's Disruptive Innovation theory. Examples of this phenomenon include compact discs displacing audio tapes and vinyl records, electronic fuel injectors displacing carburetors, and electric calculators displacing slide rules.

Schmidt and Druehl (2008) also proposed further distinctions in Disruptive Innovation theory by dividing up disruptive encroachment into four different categories, one of high end encroachment and three of low end encroachment. The purpose of this distinction was to further clarify the different mechanisms by which a new, disruptive product can affect market leaders. They also emphasize the need to constantly project changes not only performance but also in cost, and the importance for both incumbents and newcomers to consider all four types of encroachment in their framework. Positioning new products and technologies is critical to the success or failures of new innovations, and directly interacts with many of the main concepts of Disruptive Innovation theory. Schmidt and Van Der Rhee (2014) also recommend considering a higher-end approach for new disruptive technologies, instead of simply focusing on the bottom of the market and moving up.

Christensen responded to many of these criticisms in a 2006 article that discussed the development of Disruptive Innovation theory over time and also introduced an overall framework for theory building in general. To Christensen, theory building is an "iterative" process that "builds cumulatively" over time. Accordingly, finding anomalies in a theory is actually an opportunity to improve and re-assess the theory in question, and therefore they should be sought out whenever possible. He responds to many common criticisms, saying that Disruptive Innovation theory is not "post-hoc" and much of the confusion regarding the theory involves the many different meanings and connotations of the word "disruption" in the English language.

As for the ability of Disruptive Innovation theory to be predictive, Christensen (2006) references several cases, including Intel, which successfully developed its low-end Celeron processor in response to the threat of disruptive threats from below. As for the prospects of a high-end disruption, Christensen seems open to the idea that it might make a useful addition to DI theory. However, he insisted that it used a different choice of words to make its meaning more unambiguous and to separate the concept from low-end or new-market disruptions.

The automobile industry itself has several distinctive factors that should be incorporated in any analysis of the field. For decades, the industry has been "locked in" by the ICE engine and its interlinking network of car dealerships, gas stations, and auto mechanics (Cowan & Hulten, 1996). The industry has been dominated by a handful of oligopolistic firms for decades, supported by path dependencies and complimentary support networks (Pilkington & Dyerson, 2004). Wells and Nieuwenhuis (2012) found that the automobile mobility system in particular is resistant to change at the regime level, and that the major carmakers themselves play a major part in maintaining this stability. The industry is also protected from change by large barriers to both entry and exit, which discourages the formation of competing alternatives.

Existing literature also reveals a wide variety of significant barriers to widespread EV adoption. The cars themselves often suffer from "costly batteries, small ranges, slow speeds, and difficult and time-consuming recharging conditions" (Hoyer, 2008). Beyond the cars themselves, though, a wide variety of issues were identified by Browne, O'Mahoney, & Caulfield (2012) including mid-term barriers such as public perception of limited driving range and lack of charging points, and long-term barriers include infrastructural challenges and overcoming ICE lock-in and path dependence.

RESEARCH OBJECTIVES

In his 1997 book, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*, Christensen identified electric vehicles (EVs) as a disruptive innovation and a "potential future threat" to automobile industry. In fact, an entire chapter of the book was devoted to a case study of EVs as a future potential disruption. While Christensen (1997) has said that the findings in that case study should not represent the "right" way to sell EVs nor an explicit prediction as to the future of EVs (pg. 235), it is nevertheless a useful exercise to see how the person credited with creating DI theory would apply the theory in this situation.

In the case study, Christensen (1997) recommended several courses of action for a theoretical company that was developing and selling an EV in the late 1990's. These included: charting the trajectory of market demands (pg. 237), finding non-mainstream markets where the product's weaknesses can becomes its strengths (242), making the product simple, reliable, and convenient (245), introducing the car at a low price point (246), finding new distribution channels for the product (248), and spinning off or creating a new organization that would be content to sell products at low volumes (250).

Since the publication of *The Innovator's Dilemma*, the development of Lithium-ion (Li-ion) batteries has enabled increased battery capacity and decreased weight compared to earlier materials (Vayrynen & Salminen, 2012; "Fact #607", 2010). As a result, EVs of today have increased performance compared to those of 1997 and the market prospects for EVs have changed dramatically.

In this research, I will analyze the predictive capability of Disruptive Innovation (DI) theory by comparing post-1997 developments in the EV market against what was stated in Christensen's theories. To date I have been unable to find updates to the applicability of disruptive innovation theory to EV technology. My goal is to fill in this gap through my analysis and therefore contribute to the development of DI theory as a whole.

In particular, I intend to focus on areas of Sustaining vs. Disruptive technological development in established firms, the application of corporate-level Resources, Processes, and Values (RPVs) in the development of disruptive technology, the importance of distribution methods for disruptive products, and the application of the "Jobs to be Done" model to marketing disruptive products. Additionally, I will analyze the case of Tesla Motors, which as a newcomer with a disruptive innovation in an established industry should provide the best platform for analyzing DI theory and predictions.

RESEARCH DISCUSSION

History of EVs to 1997. Despite the recent advances in EV technology, the concept of using electricity to propel an automobile has been around for a long time. In fact, the first EVs predate the first Benz ICE model (Hoyer, 2008). There are records of EVs as far back as 1834 and they accounted for around one-third of all automobile production at the turn of the 20th Century (Kley, Lerch, & Dallinger, 2011). This early, turbulent period in the automobile industry saw competition between a large number of companies selling gasoline, electric, and steam powered cars, as is often seen in a "fermenting" technology before the emergence of a dominant design (Sierzchula, Bakker, Maat & van Wee, 2012). However, the introduction of the electric starter by Charles Kettering in 1912 greatly improved the performance and utility of ICE vehicles and contributed to a downturn in EV sales (Midler & Beaume, 2010).

In the following decades of the mid-20th century, the ICE cemented itself as the dominant design of personal automobiles through the adoption of mass production techniques, and led to a case of technology "lock-in" which discouraged the use of competing technologies (Cowan & Hulten, 1996). These kinds of dominant designs become embedded in "product architecture, technology, usage specifications through regulations as well as design rules, customer's preferences or performance criteria" (Midler & Beaume, 2010). As a result, the business concept of the mass-produced vehicle powered by an ICE has "literally been built into the fabric of contemporary life" (Wells & Nieuwenhuis, 2012). When a dominant design emerges, it usually leads to a small number of firms controlling the market, which gradually took place over the post-war era (Sierzchula et. al 2012) Pollution concerns and the 1970s Oil Shocks led to some EV prototyping, but none of them were able to reach the mass market (Hoyer, 2008). Essentially, the trajectory of battery technology was stopped from around 1915 to the 1990's (Cowan & Hulten, 1996).

However, the introduction of a Zero Emission Vehicle (ZEV) mandate by the California Air Resources Board (CARB) in the 1990's once again led to increased interest in EVs from major manufacturers (Schierzula et al., 2012). Major carmakers, such as GM with the EV1, developed EVs in order to meet the

CARB mandate so that they could continue to sell conventional vehicles in the massive California market (Fletcher, 2011). However, during the entire time of EV1's production, GM management was lobbying against the CARB mandate, leading to a conflict of interest for the company (Paine, 2006). While the EV1 was leased to a limited number of consumers in selected markets in order to meet this mandate, its heavy, underpowered lead acid batteries in early models greatly limited its utility and range (Fletcher, 2011). Similar battery problems hurt this 1990's electric-car renaissance, and as a result it was "oversold", primarily due to battery size, cost, and charging concerns (Hoyer, 2008).

This is the period in which Christensen wrote *The Innovator's Dilemma* and the setting for his case study on the disruptive potential of electric vehicles. By the mid-1990's, batteries were still waiting for a "breakthrough" that would increase the car's range at high speeds (Cowan & Hulten, 1996). Given the limited technology available at the time, it was not unreasonable to suspect that EVs would be suited to only low-end applications for the foreseeable future.

History of EVs post-1997. The advent of the Lithium-ion (Li-ion) battery brought about the potential for great change in EV development. At first used in consumer electronics, the Li-ion battery was then scaled-up to fit the larger needs of moving a heavy vehicle (Fletcher, 2011). This fits with Christensen's (1997) theory that disruptive innovations usually use existing technology in a new way. In the 2000s, battery technology gradually shifted from nickel-based batteries to lithium-ion based batteries, as EV manufacturers determined that lithium-based batteries were the best current solution for competing with ICE vehicles. This new, promising energy storage solution led to rapid growth and investment in EVs. Starting especially in 2008, a large number of EV producers began appearing in the industry, which is once again a sign of a "fermenting" technology that is undergoing rapid growth (Sierzchula et. al, 2012).

With the advances in Li-ion battery power, mass market EV production from mainstream incumbent carmakers once again became a possibility. This led to a variety of products and strategies from major carmakers, such as the Nissan Leaf, the BMW i3, and "compliance cars", which are a limited group of EVs that exist primarily to fulfill zero-emission vehicles mandates.

Nissan Leaf The Nissan Leaf is a battery-only EV that in many ways is similar to any mainstream automobile produced by an incumbent carmaker. It has a hatchback design that can sit up to five people and has sufficient performance for everyday urban and highway driving. It has been the highest selling EV in history, with over 119,000 sales worldwide as of June 2014, enough to outpace the original Toyota Prius over a similar timeframe (Griemel, 2014).

At Nissan's Oppama factory in Japan, the Leaf uses the same assembly line as other conventional automobile models such as the Juke and Cube. At each point in the assembly line where ICE components are attached to the automobile, the manufacturing process simply substitutes the equivalent electric part for each ICE part. For example, at the point in the assembly line where the gas tank is attached to an ICE model, the battery pack is attached to the bottom of the Leaf. Likewise, where the ICE engine is attached to a Juke or Cube, the manufacturing process simply substitutes the electric motor and inverter for the Leaf. In this way, the Leaf is completely integrated into the same assembly line as conventional ICE automobiles. The doors, interior, accessories, and wheels are all processed at the same time on the same line, regardless of whether or not the car is an EV or an ICE.

BMW i3 BMW has developed a new “i” division to develop eco-friendly automobiles that make use of battery-powered drivetrains (Squatriglia, 2011). The first two models are the i3, an all-electric city car, and the i8, a plug-in hybrid supercar that combines an electric motor and a gasoline engine for high performance. The main contribution of the i3 to EV discussion is the car’s extensive use of new, lightweight carbon fiber technologies in the car’s frame (Lavrinc, 2013). As the batteries of EVs are quite heavy, the car’s weight and efficiency becomes much more critical and carmakers need to find ways to reduce the weight of the car in other areas (Pilkington & Dyerson, 2004). As a result of BMW’s carbon fiber chassis, the car’s weight is greatly reduced, thereby increasing the car’s range and drivability despite the extra weight from the its batteries.

Compliance Cars There is a category of EVs known as “compliance cars”; these have been produced mainly in order to meet government mandates such as emission regulations. As a result, these are typically produced in very low numbers for a certain area or region, and are leased rather than sold to customers. Often, as these cars are loss-making for the manufacturer, the number of compliance cars produced is the bare minimum necessary to fulfill the mandate.

The most famous example might be GM’s EV1, which was produced in the 1990’s to meet CARB’s ZEV mandate. Several compliance cars still exist today, especially in California, such as the Fiat 500e, the Chevrolet Spark EV, and the Honda Fit EV, among others. Typically these are existing ICE models that have been modified to use electric drivetrains. In DI theory, such usage of disruptive innovations inside a sustaining framework has been referred to as “cramming” and usually leads to unsatisfactory results for both companies and consumers (Christensen, Anthony, & Roth, 2004).

Tesla Motors Background. Entering the mainstream automotive market is not an easy task. Barriers to entry are extremely high and include factors such as “manufacturing scale, brand equity, channel relationships, customer management, and capital” (Hensley, et al 2012). In addition to these barriers, the industry itself has shown significant regime stability over the years which protects the interests of incumbents and discourages the success of industry newcomers (Wells & Nieuwenhuis, 2012). Nevertheless, the advancement of Li-ion battery technology has opened the door to new companies like Tesla that are looking to make an impact on the market (Sierzchula, et al 2012).

Headquartered in Palo Alto, California, Tesla Motors was founded in 2003 with the goal of producing electric cars powered by lithium-ion batteries. CEO Elon Musk has stated that the goal for Tesla was to spread the use of green energy and energy independence through the adoption of electric cars (Musk, 2006). He has said that a major goal of starting the company was not necessarily to be profitable, but to push the technology and stature of EVs in the mass market (DeMatio & Zenlea, 2012).

The company’s first product, the Tesla Roadster, was released in 2008 with a list price of $121,000 (“The electric-fuel-trade”, 2009). The car combined a Lotus Elise-based frame with a lithium-ion battery-powered electric powertrain for high-end sports car performance. This model was targeted at early adopters who were willing to pay a premium for new technology, and served as a way to refine manufacturing techniques with the goal of gradually moving towards more affordable mass-market automobiles in the future.

The Tesla Roadster was a textbook case of a "new market disruption" as explained by Van der Rhee et al. (2014). It had high performance metrics in core attributes favored by mainstream consumers (handling and acceleration), but it also introduced high performance in a secondary attribute as well (efficiency and low carbon emissions). This new kind of combination attracted consumers from a wide area: according to Gallon (2009), "just as many Prius as Porsche 911 buyers purchased the Tesla Roadster". Additionally, per Gallon (2009), this high-end approach was reflected in the incomes of these consumers as over 80 percent of Roadster buyers had incomes over $100,000.

Tesla began selling their next car, the Model S, in 2012. As opposed to the sporty Roadster, the Model S is a luxury four-door sedan, designed to compete with offerings from makers such as BMW and Audi. The Model S, like the Roadster, also continues to use Tesla's lithium-ion based drivetrain. Unlike the Lotus-based Roadster, however, all of the main components of the Model S are unique. Much of the car's manufacturing, from battery production to extensive aluminum frame stamping, is handled on-site at the former GM/Toyota NUMMI factory in Fremont, California (Markus, 2012).

The Model S received a significant endorsement in November 2012, as it was named the winner of *Motor Trend* magazine's annual Car of the Year competition. The magazine's editors praised the car's performance, acceleration, luxury, style, handling, and roomy cabin in addition to its highly efficient powertrain (MacKenzie, 2012). Additional mainstream praise came from the American publication *Consumer Reports*, which gave the car a score of 99 out of 100, tying it for the "highest-ever test rating" (White, 2013).

The next planned model for Tesla, the Model X, is slated to be a crossover SUV with seating for seven riders and all-wheel drive. Along with its electric drivetrain, the Model X will have unique styling designs such as "falcon wing" rear doors. Its positioning as a crossover all-wheel drive SUV will make electric vehicles more accessible while broadening to company's potential market.

As part of CEO Elon Musk's plan to continue developing increasingly accessible and mass-market electric cars, the company's third generation automobile is expected to be a lower-priced sedan that is competitive with entry-level luxury vehicles such as the BMW 3 series (DeMatio & Zenlea, 2012). The car, now known as the Model 3, is still in its development stages as of this writing, but its development remains a major focus of the company moving forward.

A key part of the company's future development will be its "Gigafactory" to produce Li-ion batteries at extremely high volumes. The plans are for the factory to be located near Reno, Nevada and to produce enough batteries for over 500,000 cars- more than the entire global production of 2013. The goal is that by increasing economies of scale, Tesla can bring down the price of batteries, especially for its planned Model 3 (Trop & Caldwell, 2014).

Tesla Motors: Product Philosophy. From the beginning, Tesla Motors wanted to be seen as a company that made more that "just" electric automobiles. Tesla hoped to go head-to-head with the world's leading manufacturers not just in green technology, but also in areas such as performance. As explained by CEO Elon Musk:

> "The goal of the Model S is to create the best car in the world, and to show that an electric car can be the best car in the world… Previously, people thought of the electric car as being quite compromised. They'd buy the car because it was electric instead of because it was the best car. That's the problem for widespread adoption of electric vehicles." (Markus, 2012; video 4:10)

In other words, Tesla's goal was that they did not feel that consumers had to sacrifice in order to drive electric cars. According to Musk, EVs could be just as stylish, useful, sporty, and fun as other automobiles. This strategy could be seen in the Model S, which combined conventional luxury car styling with rapid acceleration from its electric drivetrain.

Tesla did not want the pre-existing image of "electric cars" define its products. *Motor Trend* endorsed this view, saying that the car "delivers everything you'd expect from a premium sedan" and that it's "not some eco-mobile with tiny wheels and dorky proportions" (MacKenzie, 2012). Similarly, Model S's styling is more compatible with the common image of a luxury sedan. This is supported by another auto design critic, who said that the Model S is a "good-looking, reassuring design, clearly different from the Kamm-based aerodynamic shape of the Prius", although its design approach is meant to "hide the technical radicalism in a cloak of invisibility" (Cumberford, 2012).

Tesla's focus on high-end battery technology has allowed them to produce cars with driving ranges well in excess of other EVs. The 85 kWh Model S has an estimated range of 265 miles, compared to an EPA-rated 84 miles for the Nissan Leaf and 81 miles for the BMW i3 ("Compare", 2014). Extended driving range is crucial to the acceptance of EVs; one survey stated that 53% of consumers wanted EV range equal to a full tank of gas ("Plug-In", 2011). Tesla has also developed a network of fast charging stations called "Superchargers" that allow Model S owners to quickly recharge their battery while on long road trips (Ohnsman, 2013).

Tesla Motors: Disruptive Car Design. Designing cars around an electric motor also opens up new possibilities for car design. Lead designer Franz von Holzhausen explained this approach by stating "We turned a lot of preconceived notions on their head and said, 'Why does it have to be that way? (Zenlea, 2012)" With Tesla's low mounted battery and compact, rear-mounted engine, designers have much more freedom than with conventional automobiles. The lack of any sort of driveshaft opens up the interior of the vehicle, and additional luggage space can be found in both the front and the back of the car.

Another advantage of electric motors is that they have on-demand torque and do not need to be revved for maximum performance like conventional engines. What this means for drivers is instantaneous, powerful, and smooth acceleration. The Model S (P85 version) uses its electric motor to go from 0-60 MPH in 3.9 seconds, which is comparable to many of the world's best sports cars (Reynolds, 2012). Additionally, the weight from the low-mounted, heavy battery provides an extremely low center of gravity compared to most gasoline engine cars, improving the car's handling characteristics.

Much of Tesla's company culture (in other words, its Resources, Processes, and Values) is reflected in its Silicon Valley origins. Preproduction cars are known as "alpha" and "beta" cars, even critics referred to the company's products in software terms, calling Tesla's cars "vaporware" (Kong, 2011). Venture Capital funding was a key part in getting the company started, with several funding rounds providing tens of millions of dollars for the company. This Silicon Valley mindset also makes their development much more nimble and open to change than established car companies. In fact, Toyota head Akio Toyoda has referenced the company's "entrepreneurial culture" as of the reasons he chose to work with Tesla (Davis, 2010), although Toyota later broke off from their relationship with Tesla in order to focus on hybrids and hydrogen fuel-cell technology (Griemel, 2014).

Retail Strategy Tesla developed a retail strategy that is unique from traditional carmakers. Instead of a traditional independent dealership model, the company sells cars directly to consumers, either online or in special retail showrooms. Comparable to Apple Stores, these are located in high-end metropolitan shopping districts, and customers can custom-design their new automobile in the showroom.

Tesla, as a new entrant, was able to develop their own, completely new RPV structure and sidestep the entire traditional dealership system. Non-commissioned salespeople work in each showroom to answer potential customer's questions and arrange for test drives. Interactive touch-screen displays line the showroom's walls and allow customers to learn about the Model S at their convenience. Cars are ordered via the internet and delivered directly to customers. There is no need for the traditional dealership cost structure.

ANALYSIS OF AUTOMOTIVE MARKET DEVELOPMENTS THROUGH DI THEORY

Sustaining Innovations in the ICE Automotive Industry

DI Theory in regards to Sustaining Innovations fits very well with incumbent ICE carmaker's strategies. Mainstream car makers have worked hard and spent significant sums of money and resources towards gradual, sustaining innovation in automobiles and ICE technology. In fact, the improvements in primary performance attributes such as horsepower and acceleration have improved quite consistently for decades ("Fact #800", 2013). Additionally, since gas prices spiked in the mid-2000s, gas mileage has also improved on a consistent trajectory ("Eco-Driving Index", 2014). Still, despite these changes, "the structure of the (automotive) regime has adjusted in certain specific ways while the fundamentals have remained intact" (Wells & Nieuwenhuis, 2012). As stated succinctly by Ford executive chairman Bill Ford, "… for 100 years pretty much all we had was the internal-combustion engine. Of course, it changed and was refined, but you didn't have revolutions; you had evolutions" (Bonini & Kaas, 2010).

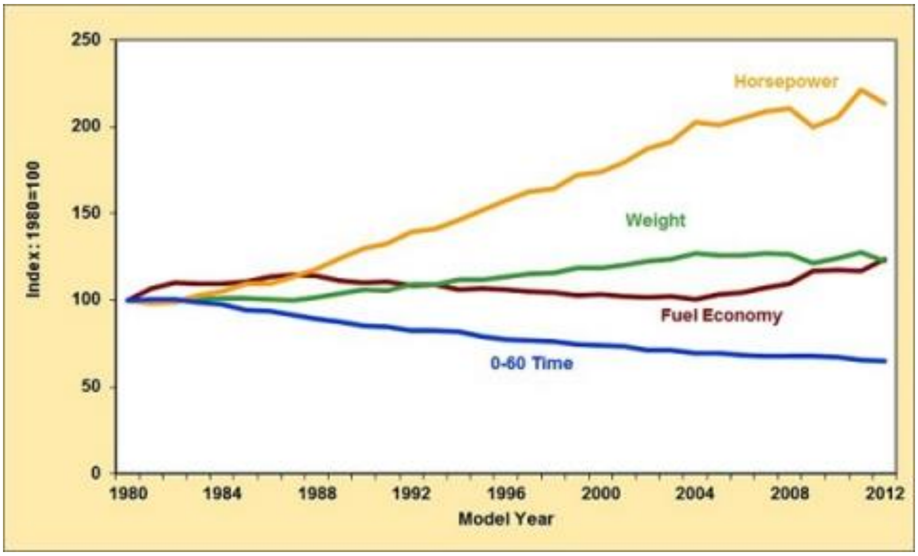

Figure 2: "Fact #800 Characteristics of New Light Vehicles Sold, 1980-2012"
Source: "Fact #800" (2013)

How did carmakers achieve these consistent, sustaining innovations in speed, horsepower, and (recently) fuel efficiency? One way is through employing technologies such as electronic direct fuel injection, turbochargers, Continuously Variable Transmissions (CVTs), higher compression ratios, hybrid drivetrains, cylinder deactivation, and variable valve timing (Figure 2). These technologies are all examples of Sustaining Innovations. They are being produced by incumbent firms, work in established value chains, and improve performance along the primary attributes that are most valued by mainstream consumers, such as horsepower and fuel efficiency.

As these can be incorporated into existing ICE design and value networks, they do not present a challenge towards the way that each company does their business. For example, turbochargers can be used to make more power out of smaller engine displacements, but do not require any dramatic changes to the fueling infrastructure. Usage of these Sustaining Innovations has rapidly increased in recent years as carmakers look to maintain or increase car performance while improving its fuel efficiency ("Fact #658", 2011). Increased transmission gearing has also been another example of Sustaining Technologies that gradually improve a car's efficiency along an established trajectory. On average, cars in the US had transmissions with only 3.3 gears in 1979, while by 2012 that number had increased to 5.7 gears ("Fact #803", 2013).

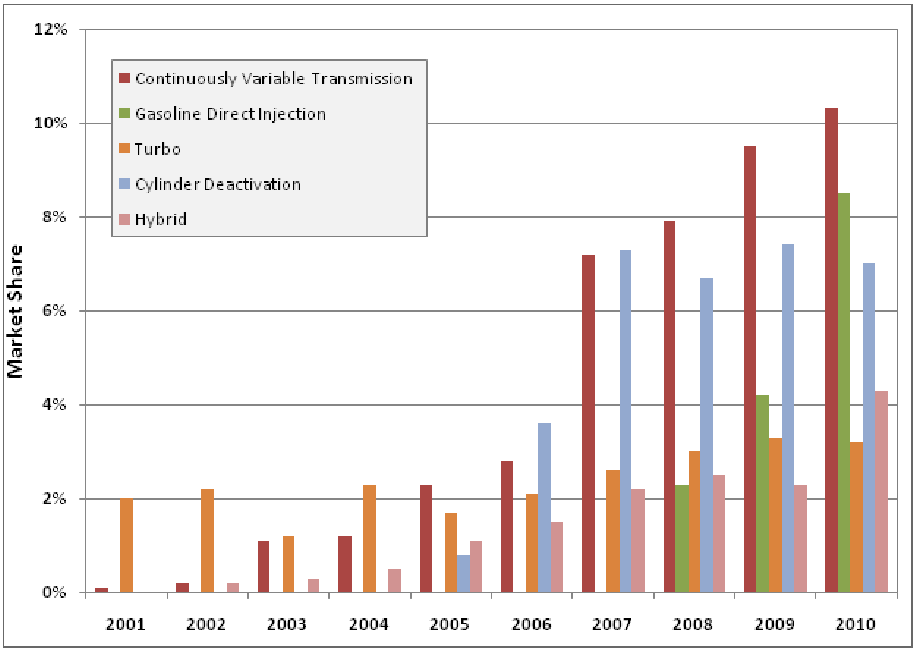

Figure 3: "Fact #658: Increasing Use of Vehicle Technologies to Meet Fuel Economy Requirements"

Analysis: Tesla's Top-Down Product Strategy

Traditional DI theory says that disruptive production should start at the low end of the market, and then gradually move upwards over time. One classic example is steel "minimills", which started out making simple rebar and then gradually moved upmarket towards sheet steel (Christensen, 1997). Where would Tesla fit into this framework? Tesla has not targeted Low-End or New-Market type disruptions. With the sporty Roadster, the company started at the highest-end, most demanding supercar segment, and then with the Model S moved slightly downwards towards a relatively less-demanding luxury sedan market. For the Model X, the company hopes to further broaden the company's appeal by selling a car in the popular crossover SUV market. This is planned to be followed by another move downward in terms of market position with its mainstream Model 3 sedan.

With these moves, Tesla is going after lucrative customers in major, mainstream markets against entrenched, well-established incumbents that are well-motivated to protect their turf. According to Christensen (1997), this is the kind of strategy that should lead to failure time and time again.

Yet there is some theoretical precedent for this pattern of product development. Van der Rhee, Schmidt and Van Orden (2012) have identified the possibility of new products to "encroach" on the high end of the market first and then gradually move downwards to the mainstream. Such an approach has been further explained by Schmidt and Van der Rhee (2014), who used Tesla's Roadster as an example of a new kind of technological approach to new product introduction that starts at the high end of the market and eventually moves downwards.

When comparing Tesla's products to other automobiles, it quickly becomes apparent that they have extremely high performance in two areas: performance (in this case, acceleration), and efficiency (in this case, fuel mileage through Miles Per Gallon [MPG] or the energy-equivalent electric Miles Per Gallon [eMPG]). If these two performance metrics are put onto a simple graph, the Model S and Roadster's unique value proposition becomes clear: no other car can offer the same amount of performance and energy efficiency. This is the kind of novel value that would allow Tesla to have more "pricing power" and allow them to create demand at the high end of the market (van der Rhee, Schmidt & Van Orden, 2012; also Hardman et al 2013).

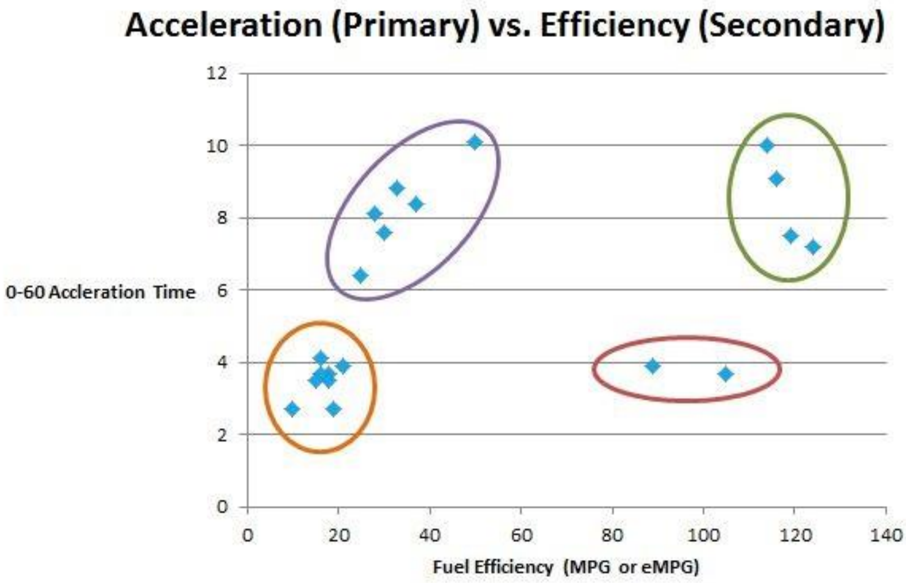

Figure 4: Comparison of Automobile Performance Attributes
Source: Acceleration, *Motor Trend* website; Fuel Efficiency, fueleconomy.gov.

Through the analysis in Figure 4, four groups of cars become clear. First, in the lower left quadrant, are high-end ICE sports cars with high performance but poor fuel efficiency. Next, in the upper left quadrant, are conventional ICE or hybrid automobiles that offer a practical balance between speed and efficiency. In the upper right quadrant, competing EVs from incumbent carmakers have high efficiency, but at the cost of performance. Finally, in the lower right quadrant, Tesla's automobiles offer a unique value proposition- acceleration comparable to high-end sports cars, but with a much higher efficiency. Tesla's products also offer much greater range than competing EVs.

There is a clear downward trajectory line to be drawn from the Roadster to the Model S to the upcoming Model 3 mainstream sedan. Critical to this strategy, as pointed out by Van der Rhee et al (2012), is the need to rapidly achieve cost reductions in their move down-market. This fits directly into the company's plans to construct their "Gigafactory" with a large enough scale of economy to drive down battery costs. Doing this should create a “virtuous cycle” of increasingly lower costs, improvement from learning effects, and higher sales volumes.

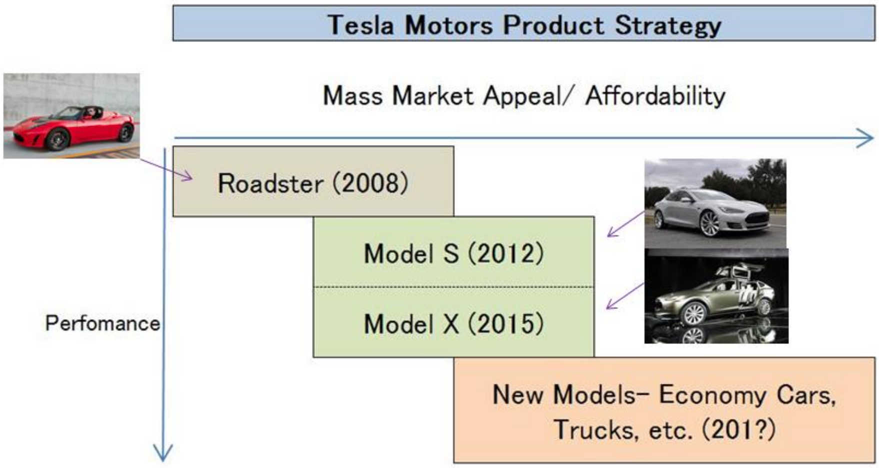

Figure 5: Tesla Motors Product Strategy

Sales & Distribution Networks. The RPVs of existing car distribution networks would not appear to support the introduction of a new technology such as EVs. Traditional dealers are dependent on the business model of ICE automobiles. ICE automobiles can be sold relatively quickly to consumers who are already familiar with the technology, and re-servicing ICEs provides revenues from activities such as oil changes and periodic maintenance. A 2013 McKinsey study found that new car sales only have a 2% profit margin for traditional dealers, and these dealers are dependent on financing and maintenance in order to turn a profit (“Innovating”, 2013). The simpler electric motors found in EVs do not need maintenance such as oil changes or belt replacements. As such, EVs do not fit into existing dealer’s RPV model of making money.

Similarly, while ICEs are familiar to customers, EVs are relatively new to most of the population and sale of these EVs requires significant time and effort from salespeople to explain the ins and outs of ownership. For instance, in a 2011 consumer survey, 70 percent of respondents said that either “did not understand EVs enough to consider them when making my next car purchase” or that “I understand about EVs, but need to know more before I can consider them” (“Plug-in”, 2011). As a result, a salesperson has to devote more time to each customer. From tax breaks and rebates to charging times, driving ranges, specialized equipment and battery warranties, there are a variety of additional factors that must be considered and discussed when purchasing EVs. This is at odds the traditional commission-based income structure, which favors relatively quick sales to a larger number of customers. So from both the manager and employee standpoint of traditional dealers, EVs do not match their RPV preferences. The new technology is at odds with how they are used to making money.

There has been anecdotal evidence from a variety of sources that salespeople at traditional dealerships are downplaying or actively discouraging customers that are interested in EV purchases, such as in the case of the EV1 (Paine, 2006). Further reports exist of BMW dealerships being unable to properly prepare their sales force to sell their new line of i3 EVs (Noland, 2014). In another example, a *Consumer Reports* survey found that some dealer salespeople were not knowledgeable about electric vehicles and often steered customers who asked about EVs towards more conventional automobiles (Evarts, 2014).

The Resources/Processes/Values (RPV) paradigm helps explain the rationale behind Tesla avoiding the traditional dealership model found with established carmakers. Its showroom retail model is a much better fit as there is no need to worry about distracted salesmen, or competing for attention against other ICE models on the same dealer lot. In the company's own words, "Selling directly allows us to most effectively communicate the unique benefits of electric cars to potential customers" (Musk & Ahuja, 2014). This fits well with Christensen's DI theory (1997), which states that disruptive innovations often need to develop their own, independent distribution network.

Corporate-Level RPV. Even though incumbent carmakers such as Nissan and BMW have produced EVs, these models tend to be similar in size and performance to traditional mainstream products and are sold through existing dealership networks. This approach allows incumbents to use their existing expertise and resources from ICE production in the EV market. Additionally this allowed the incumbents to target segments with higher production volumes (Sierzchula et. al, 2012). This emphasis on established incumbents targeting large markets and existing customers fits exactly with Christensen's (1997) theories. Such an emphasis could be seen with GM's early apprehension to the EV market, where the company would only be interested if it was a "billion dollar business" (Fletcher, 2011, pg. 36).

Meanwhile, startup carmakers, which were not as constrained by existing RPV models, were much more likely to produce EVs in a variety of ranges including niche markets such as low-speed vehicles and sports cars (Sierzchula, et. al 2012). Resource allocation also played a role in the development of the cars through the type of employees that would work on EV projects. For example, in the 1990's, being assigned to an EV project in General Motors was avoided and seen as a "career killer" by engineers (Fletcher, 2011, pg. 70). On the other hand, Tesla Motors was made from the very beginning with the goal of spreading EV technology throughout the industry, even if it meant that that company failed (DeMatio & Zenlea, 2012). This divergence in corporate outlooks can be seen as an example of "asymmetric motivation" as explained by Christensen, Anthony, & Roth (2004). While it would be far too easy for GM to disregard the nascent EV market, for Tesla the entire future of the company was at stake.

Nissan has shown that it is possible to integrate EVs into currently existing incumbent manufacturing processes as the Leaf can be assembled on the exact same line as conventional ICE models such as the Juke. Furthermore, as a standard sized hatchback with conventional performance, the overall design of the Leaf has been made to fit in with traditional carmaker design concepts. This follows the findings of Wells and Nieuwenhuis (2012), who state that "the industry overall prefers to make electric vehicles as traditional as possible, even if this does compromise performance".

The "Jobs To Be Done" Model. In analyzing transportation options, Christensen & Raynor (2003) tend to look at the "job" of transportation as simply moving from one location to another. The car itself is seen as a utilitarian form of transport, little more than a tool to complete the "job". This is not limited to Christensen and his co-authors; forecasts of EV sales often portray consumers as "rational agents" making "utility-based" decisions, yet drivers are often concerned with gaining enjoyment or making identity-based decisions with their automobiles (Graham-Rowe, Gardner, Abraham, Skippon, Dittmar, Hutchins & Stannard, 2012). Yet a quick look at the marketplace shows that cars are "hired" for a variety of reasons, such as to be status symbols, for the fun of driving, or to be a good parent.

Consumer surveys have backed up this sentiment. A 2013 study suggests that "marketing a brand image is just as important as building reliable vehicles" ("J.D. Power and Associates", 2013). The same study also states that "one third (33%) of shoppers avoid a model because they do not like its exterior look or design", and "nearly one in five (17%) of new vehicle shoppers avoid a model because they don't like the image that it portrays". Furthermore, 25% of new-vehicle shoppers avoid hybrid or electric vehicles because of exterior styling. As a result, carmakers need to avoid actively "turning off" potential EV customers through awkward or polarizing designs. As stated by Graham-Rowe, et al (2012), the image of explicitly environmentally-friendly or "green" cars is actually a negative for many consumers. Tesla engineers used this outlook when designing the Model S, which achieved a low 0.24 drag coefficient, better than the Toyota Prius or Chevrolet Volt, yet "without those cars' gawky styling" (Zenlea, 2012).

The "Jobs To Be Done" model also affects how consumers would approach the issue of EV driving ranges. According to Pearre, Kempton, Guensler, & Elango (2011), the vast majority of needed daily range is 50 miles or less. Using a low-end disruption framework, carmakers should then focus on having just enough performance to meet that typical daily need. However, as their own literature review shows, "travelers are likely to want a vehicle to cover most of their own heterogeneous needs over time, not the needs of the average driver, nor even their own average travel profile" (Pearre et at, 2011). Even if the average driver only needs a range above 150 miles for nine days each year, many consumers will no doubt balk at driving a second car or getting a rental, as Pearre et al (2011) suggest. Simply put, the "Jobs to be Done" model does not account for many consumer's real-world range anxiety issues.

CONCLUSIONS

As a result of analyzing Christensen's (1997) theories in the field of electric vehicles, I have found mixed levels of success, with some results matching DI theory, while others went against what should have happened. Overall, while many parts of the theory remain strong, there are a few points for improvement that may be worth further consideration.

I have found evidence for the following assertions that match with Christensen's theories: the use of Sustaining Innovations by established carmakers; Corporate Level Resources, Processes, and Values that either encourage or inhibit development of disruptive products; and the importance of developing independent distribution channels for disruptive products.

For the use of Sustaining Innovations, over the history of the ICE there has been a clear pattern of established carmakers gradually creating faster, more powerful, and more efficient engines through incremental technological improvements and sustaining innovations such as turbochargers. Meanwhile, Corporate Level RPV has played a large role in encouraging or inhibiting the development or electric vehicles. Perhaps most visibly in the case of GM, conflicting RPVs inside the massive company lead to great difficulty when selling and supporting disruptive innovations such as the EV1. Meanwhile, Tesla, as a new company with a clear vision and much more nimble structure, was able to focus on high performance Li-ion based EVs from the very beginning.

In regards to distribution channels for disruptive products, Tesla's showroom strategy has shown the importance of developing independent distribution channels for disruptive products. Incumbent carmakers and their dealerships have a deep interest in continuing the standard business model of current ICE-based automobiles. Meanwhile, Tesla's approach shows the benefits of an unfamiliar form of transportation to new consumers, without having to compete with attention from ICE products.

However, there remains the question of the applicability of the "Jobs to be Done" theory in the automotive industry. Marketers and researches alike should ask themselves what "job" drivers are really trying to accomplish. Is it utilitarian transportation on their daily work commute, self-expressive styling, or personal enjoyment? Or is it some combination of all three? The answer probably depends on the driver, and could change day to day. More clarification in this area could lead to a better understanding of suitable disruptive products for the marketplace.

Another point of divergence is Tesla's top-down product strategy. Instead of taking a disruptive innovation and moving upmarket, Tesla has taken the exact opposite approach by starting at the highest, most demanding parts of the market, and then gradually moving downwards towards the mainstream (Schmidt & van der Rhee, 2014). This contradicts directly with standard DI Theory, which states that disruptive products should be simple, cheap, easy to use, and only have the bare minimum level of functionality to meet market demand. Christensen (2006) has shown a willingness to consider this kind of theoretical framework, however he has insisted that it go by a different name and that "high-end disruption" would be a misleading term.

FURTHER RESEARCH

Other researchers, similar to Schmidt and Van Der Rhee (2014) and Utterback and Acee (2005), may be able to search for any other such examples of Disruptive Innovations that have succeeded at "high end" disruptions, instead of at the low end or through targeting non-consumers. If further examples of this phenomenon can be found, it may prompt an addition to Disruptive Innovation theory. As Christensen, Anthony, & Roth (2004) have said, "the discovery of anomalous phenomena is the pivotal element in the process of building improved theory" (pg. 276).

Additionally, depending on future battery technology developments, a low-end disruptive EV of some sort may appear in lower-end markets that do not require the same level of performance of mainstream ones. If this can occur, it would finally fulfill Christensen's scenario of a truly low-end disruptive electric vehicle.

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