

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 have major impacts on industry, the environment, and everyday life for millions of people. The past few years have seen a rapid increase in the number of EVs for sale in the marketplace. 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 was 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. In this analysis, I have found multiple areas where the theory has held up well; however, in other areas such as product performance trajectory and amount of product capability demanded by the consumer, 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.

Introduction

The automobile as we know it 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. Electronic Control Units (ECUs) have already replaced most analog or mechanical systems with digital ones. 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. Additional technologies such as hydrogen Fuel Cell Vehicles (FCV) are also on their way to the mass market as soon as 2015.

All of this is taking place against a backdrop of increased concern over the environment and 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).

In the United States alone, transport accounts for approximately 60% of oil consumption (Stark, Yang, & Shong, 2011). Globally, transportation was responsible for 15% of all greenhouse gas emissions, with road transport making up 73% of that total (Gerssen-Gondelach & Faaji, 2012). Clearly, the world economy is still heavily dependent upon fossil fuels for daily life. A shift in this sector away from petroleum-based energy could have a huge impact on carbon dioxide emissions.

With all of these changes taking place, it is an excellent time to re-examine the potential of new automobile technologies. In particular, 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, which helps to keep fueling costs low (Tilleman, 2013). For example, while a standard ICE car can travel 1.5-2.5 kilometers per kilowatt-hour (kWh) of energy, a battery-powered car travel 6.5 km (“The electric-fuel-trade”, 2009).

Additionally, EVs offer advantages over ICE technology in areas such as torque, noise, acceleration, and required maintenance (Hensley, Newman, & Rogers, 2012). For example, electric motors can achieve maximum torque immediately, while ICEs take time to “rev up” to their peak performance band (Sierzchula, Bakker, Maat, & van Wee, 2012).

One way to examine the potential of these new car technologies is to analyze them using existing technological theories that have proven effective in other industries. The results should therefore be of use in predicting the trajectory of EV technology development. Given the high stakes involved for the automobile industry, the global environment, and society at large, determining whether or not EVs can have a significant impact will be of great importance.

Therefore, I would like to look at the most latest developments in the field of EVs through existing technological theory. In particular, I would like to utilize 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. While hybrids and plug-in hybrids still have some ICE-

based technology in them (either as the main source of propulsion or as a range-extending generator), they do not offer as much disruptive potential as EVs and therefore would be of more limited use in analyzing 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 including its development and applications. 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 write about how these market developments fit into DI theory, what bearing these developments have on DI theory, and what we may be able to expect in the field of EVs in the future based on the concepts of DI theory.

Introduction to Disruptive Innovation Theory

According to Harvard professor Clayton 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 in worse product performance, at least in the near term... (But) bring to market a very different value proposition than 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, 2012). 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 still fell to industry newcomers when new disk drive sizes began to appear. 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. Christensen's concept of Disruptive Innovation has become widely known , and due perhaps in part to the choice of the word "disruptive", it may also be one of the most misunderstood business concepts as well (Christensen, 2006).

Previous examples of disruptive innovation include personal computers displacing mainframes and cellular phones replacing fixed-line telephony (Christensen, Allworth, & Dillon, 2012). The theory has been used by Christensen in a wide variety of industries, from healthcare to higher education, and has been even used to describe a country's national innovation progress (*The Great Disruption*, Christensen, Craig, & Hart, 2001) and as a way to possibly lift millions out of poverty (*The Great Leap*, 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 much more affordable and easier to use than previous products. Much like Low-End products, these New-Market disruptions gradually improve until they have enough performance to appeal to mainstream consumers.

Fig. 1: Graphical Representation of Disruptive Innovation Theory

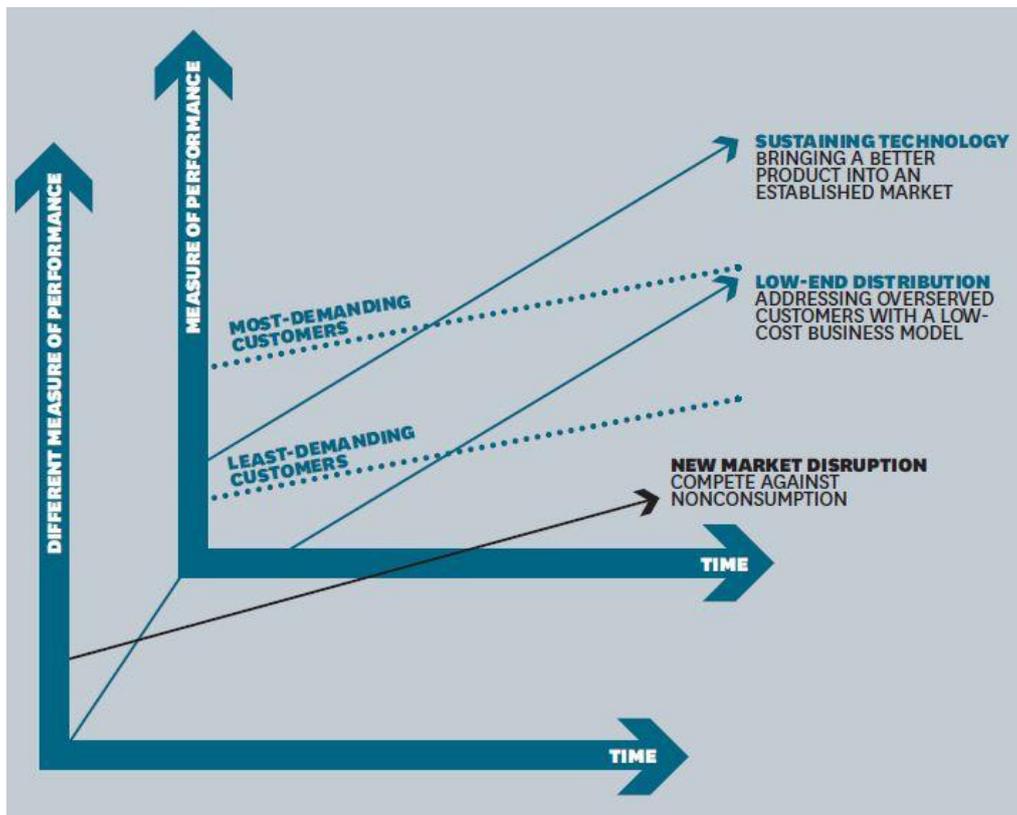


Image Source: Ovans, 2012

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 some companies excel at disruption and some do not. In particular, it has been used to explain why industry incumbents tend to fail at disruption, while industry newcomers are typically much more successful. Incumbents often have significant advantages in things such as resources, but their own 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. As stated in *The Innovator’s Solution*, “the critical unit of analysis is the circumstance, not the consumer” (Christensen & Raynor, 2003 pg. 75).

In *The Innovator’s Solution* (Christensen & Raynor, 2003), the authors identify two types of business strategies: Emergent Strategies and Deliberate Strategies. Simply put, emergent strategies are developed “on-the-fly” in response to changing market conditions, while deliberate strategies are carefully planned out in advance. Emergent strategies are recommended for disruptive innovations, as often these new innovations do not have an existing market and it may take time for them to find their niche with customers that value their non-mainstream attributes.

Christensen (1997) expanded upon his DI theory in relation to automobiles in Chapter 10 of *The Innovator’s Dilemma*, in a case study about the potential of the electric vehicle and how his theories could be applied to its development.

Additionally, in an interview with *Wired* magazine, he states that hybridization, such as the Toyota Prius, is necessary when using a new technology in a mainstream market. In the same interview, Christensen states that “If you want to have a viable electric car, you have to ask if there is a market where the customers want a car that won’t go far or fast” (Howe, 2013). As such, we need to find examples where such limited transportation is needed. The example given in the interview is cars for inexperienced teenage drivers, but there exists the possibility for other developing areas which will be discussed later in this article.

Introduction to Electric Vehicles (EVs)

Why should consumers consider EVs? EVs offer significant advantages over ICEs in terms of performance, especially regarding torque. EVs are also more efficient and waste less energy than ICEs. Additionally, EVs do not require transmissions, clutches, spark plugs, oil changes or filters. The significance of EVs can go beyond simply automotive performance. Since EVs run off of electricity, they can use power generated from a variety of sources, including nuclear, wind, solar, and hydroelectric. These all have the potential to reduce dependence on fossil fuels and reduce the carbon dioxide emissions that

contribute to global warming (Anair & Mahmassani, 2012). As an added bonus, the energy from these sources is typically cheaper than the equivalent amount in gasoline (“The electric-fuel-trade”, 2009).

The use of electric drivetrains opens up many possibilities for a car’s performance and design. For example, Mackenzie (2012) writes that the Tesla Model S is “as smoothly effortless as a Rolls-Royce, can carry almost as much stuff as a Chevy Equinox (SUV), and is more efficient than a Toyota Prius.” The elimination of the conventional engine, transmission and drivetrain creates extra space for car design. According to *Wired* magazine, “Removing the design constraints of a combustion engine opened up the (Model S) sedan to new design possibilities” (Davis, 2010).

However, despite these advantages, there are 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 financial barriers, significantly higher purchase prices, technical barriers and market availability, institutional and administrative barriers, public acceptability,

lack of repair technicians, regulatory or legal barriers, policy failures, social or cultural values, political interests, and physical barriers. “Highly significant” mid-term barriers include public perception of limited driving range and lack of charging points, while “highly significant” long-term barriers include infrastructural challenges and overcoming ICE lock-in and path dependence. As a result, the need to make massive investments to change the infrastructure “tends to promote inertia and the status quo” (Pilkington & Dyer, 2004).

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", along with famous concepts such as Boston Consulting Group's Growth Share Matrix and Porter's Five Forces model (Ovans, 2011). Its reach has been widespread, especially in mainstream publications and usage. 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 some detractors as well. Many writers have found various issues with the theory, ranging from vague definitions to a lack of predictive capability. 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. As Tellis (2006) stated, "If one must wait until the

disruption has occurred, then what predictive value is there in the concept?”

One of the major responses was by Danneels (2004), who examined the influence of Disruptive Innovation theory and 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.

Furthermore, according to Danneels (2004), when some incumbents did fail, it was more due to a failure of marketing competence than other factors. Rather than being unable to identify and develop disruptive innovations, the incumbents’ main issue in this area was using marketing to connect and build new relationships with different groups of customers. Danneels also contends that organizational competence and leadership is overlooked when examining why incumbents fail; in other words, Christensen is being far too charitable towards

failed incumbent leadership when he says that technological development patterns and unpredictable customers are to blame for established firm's failures.

Another analysis came from Henderson (2006), who analyzed the reasons why management in incumbent firms does not respond to disruptive innovations. Her findings are broadly consistent with Christensen's theories in areas such as incumbents understanding their main customer's preferences, but she recommends a few modifications. To Henderson, management's failure to respond to disruption is not cognitive or politically based, and may in fact be a completely rational choice given the circumstances.

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. 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, more demanding 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 digital cameras displacing film, compact discs displacing audio tapes and vinyl records, electronic fuel injectors displacing carburetors, and electric calculators displacing slide rules. These examples included a variety of situations where the new product was either superior or inferior in primary or ancillary performance metrics. Ultimately, regardless of whether the discontinuous changes came from above or below, the authors found that the end result of many of these situations was market expansion.

Tellis (2006) challenges several aspects of Disruptive Innovation theory. He states that technology improvements are usually neither linear nor predictable, and that "success and failure are probably the result of internal cultural aspects of the firm", including "visionary leadership that embraces change". Additionally, firms of all types and sizes introduce new technologies, yet the firms that are able to survive several cycles of technological change focus on emerging mass markets and are willing to cannibalize existing assets for the future if necessary (Tellis, 2006).

Schmidt & Druehl (2008) 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. In some of their examples, for instance mobile phones, it is possible for a low-end encroachment (as determined by measures of performance) to start at much higher prices. However, their usage of the term high-end encroachment simply follows Christensen's "sustaining innovation" model, and does not seem to indicate a new path for high-end products in Disruptive Innovation theory. 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. Finally, in contrast to Utterback and Acee (2005), Schmidt and Druehl do not consider the examples of carburetors or electronic calculators as examples of high-end disruptive technologies; rather, they are explained as simply more advanced ways of accomplishing the same tasks as before.

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” (pg. 22). Markides also points out that while disruptive newcomers often take large market share from incumbents, in many cases the newcomers fail to disrupt the incumbents completely, as opposed to Christensen’s disk drive industry example. As a result, incumbent, high-end sustaining technologies can often maintain market share for some time in the most demanding applications. An example from Christensen’s own work (1997) is the cable-pulled excavator market, which still exists for high-end uses such as large scale strip-mining.

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. Such confusion could be compounded by writers like Schmidt & Druehl (2008), who have written statements such as “a disruptive innovation (in that it disrupts the current market) is not necessarily a disruptive innovation (as Christensen defines it)”.

As far 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 (another such supposed predictive episode in the 2006 article was Kodak’s development of digital camera capability, which does not look as good in hindsight). 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.

To Christensen and his co-authors’ credit, they have shown a willingness to subtly alter their theories over time. For instance, in 2012, Anthony and Christensen argue that in contrast to their earlier findings, there is evidence that

incumbents are improving their utilization of disruptive innovations, and as a result a lower percentage of disruptive innovations are being brought to market by newcomers (*"The Empire Strikes Back"*). Wessel & Christensen (2012) also further elaborated on how the "jobs to be done" model can be analyzed and used by incumbents to find out what customers really "want to do" and accordingly find ways to protect their market position (with "barriers to disruption") from newcomers.

As the concept has come into mainstream usage, it has possibly been abused as much as it has been used properly. For example, writing in the American political magazine *The New Republic*, Shulevitz (2013) contends that disruption "is now slapped onto every act of cultural defiance or derring-do" and that is a buzzword which is "so pervasive" that it has almost become "inaudible". In the same article, the author also criticizes the use of disruptive theory in governmental and social services as pretexts to "spinning off" (i.e. privatizing) government functions. Although in a slightly different field, Utterback and Acee (2005) also criticized the use of Disruptive Innovation theory in the area of services, saying that it "stretches his model too far". Lepore (2014) made a similar point in the application of DI theory to certain non-business uses such as

education, medicine, and journalism, saying that “people aren’t disk drives”. This article prompted a vigorous response from Christensen, rebutting Lepore’s points and saying that most of Lepore’s criticisms had already been addressed in previous follow-up articles (Bennett, 2014).

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) recommend considering a higher-end approach for new technologies, and not just starting at the bottom of the market and moving up. As Schmidt and Van der Rhee themselves note, this goes against what is recommended by Christensen’s theories as explained in his *Innovator’s Dilemma* EV case study.

The automobile industry itself has several distinctive factors that must 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 & 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.

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 (pg. xxx). 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 become 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 (Varynen & Salminen, 2012; "Fact #607", 2010). This means that the EVs of today should have increased performance compared to those of 1997. Indeed, since that time, the technology and market prospects for EVs have changed dramatically. Lithium-ion batteries have replaced previous battery materials and their further development will be crucial to the EV's success. Additionally, mainstream electric vehicles are available on the market today from makers such as Nissan, BMW, and Tesla Motors.

In my research, I plan to analyze the predictive capability of Disruptive Innovation (DI) theory by comparing post-1997 developments in EV markets against what was predicted by Christensen in *The Innovator's Dilemma*. In this way, I also hope to investigate in a descriptive fashion the recent technical and market-based trends towards the potential of EVs to disrupt standard Internal Combustion Engine (ICE) vehicles. In particular, I hope to study 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.

I believe that analyzing EVs through the DI context will allow insight in order to understand the successes and obstacles faced by today's EVs as well as to analyze the latest developments in the field.

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 contribute to the development of DI theory as a whole. I plan to use historical and current data to test the assumptions found in DI theories. I intend to accomplish this through reading journal and mainstream news and magazine articles about innovation theory and EV development, as well as analyzing publicly available environmental, performance, and sales data. I have also interviewed public officials and company representatives, as well as visited several automotive factories. Based on this information, I will draw conclusions about the trajectory of the EV market and compare that against what is found in Christensen's theories.

In Christensen's own words, "A good theory doesn't change its mind. It doesn't apply only to some companies or people, and not to others (pg. 12)... good theory can help us categorize, explain, and, most important, predict" (Christensen, Allworth, & Dillon, 2012, pg. 14). I hope to utilize Christensen's

theory to analyze the potential of the EV car market. Additionally, I hope to contribute to further development of DI theory by showing that while Tesla and its automobiles share many aspects of disruptive innovation, their high price and target market go against basic tenets of DI theory and may be an exemption to DI theory.

Hypothesis

In order to examine the predictive power of Disruptive Innovation theory and its applicability to the development of EVs, I plan to test two hypotheses.

H1: For industry incumbent carmakers, Disruptive Innovation theory applies well to the development (or lack thereof) of electric vehicles in the automotive industry.

H2: Startup industry newcomer Tesla Motors is an exception to many Disruptive Innovation principles.

These two hypotheses examine the role of Disruptive Innovation from two viewpoints: that of industry incumbents, and that of industry newcomer Tesla Motors. Comparing and contrasting these two business categorizations, and their respective sustaining or disruptive innovations, should yield worthwhile insights into the application of DI theory in this field.

Methodology

Much of this report is based on the concepts of Disruptive Innovation, found mainly on three books by Clayton Christensen and his coauthors: *The Innovator's Dilemma* (1997), *The Innovator's Solution* (2003, with Michael Raynor), and *Seeing What's Next: Using Theories of Innovation to Predict Industry Change* (2004, with Erik Roth and Scott Anthony). A wide variety of other sources were also utilized in order to produce this report. Contemporary mainstream automotive publications such as Motor Trend, Road & Track, Automobile, Car & Driver (USA) along with Car Top, Best Car, and Holiday Auto (Japan) were referenced to keep up with the latest industry and technological developments. Online databases such as Emerald, EBSCOhost, JSTOR, LexisNexis, and others were searched for academic and newspaper articles including terms such as Disruptive Innovation, Electric Vehicle development, lithium-ion battery technology, and other related terms.

When applicable, mainstream press reports and resources were used to further develop the themes in this paper, although an effort was made to use academic journal articles when possible. Publications and White Papers from a variety of consulting and marketing research firms were used to in advance

supporting arguments. Official exhibits and materials from the 2013 Tokyo Motor Show were a rich source of company and industry information. Direct interviews with key players were taken from a variety of publications. In order to further understand the potential for EV taxis, the author visited the “Smart Energy Office” in the Environmental Department of the Kanagawa Prefectural government to learn about their alternative energy promotion techniques. Visits to Nissan’s Oppama and Kitakyushu factories were used for additional observations.

Research Discussion

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, which debuted in 1885 (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) and the first car to reach 100 kilometers per hour was electric, not gasoline or steam. In comparison, early internal combustion engines were “unreliable, complicated, loud, and dirty” while electric vehicles of the time were “clean, quiet, and civilized” (Fletcher, 2011, pg.13). 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 led 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 dominant design and business concept of the ICE vehicle as a mass-produced, all-steel body 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).

CARB had decided to take action on ZEVs to overcome air pollution issues in cities such as Los Angeles (Cowan & Hulten, 1996). 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). Nevertheless, the CARB ZEV mandate was credited with created new networks of suppliers for EVs (Pilkington & Dyerson, 2004).

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

battery 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. Li-ion batteries have three times the energy density of competing battery technologies and have higher specific energy and specific power (Catenacci, Verdolini, Bosetti & Fiorese, 2013). 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). 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, as each one took slightly different paths towards bringing an EV to market. For the purposes of this research, and to contrast with Tesla's Roadster and Model S, I have selected four different types of "mainstream" EVs from established companies: the Mitsubishi i-MiEV, 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. Each of these cars comes from established carmakers, yet each has their own unique set of advantages and disadvantages. One of the main reasons for DI theory's existence is comparing the responses and capabilities of industry incumbents and newcomers in the face of a disruptive threat. Therefore, analyzing each company's response through these cars will be useful in later discussion when applying DI theory to the current EV market. Following that, I will discuss the background and product philosophy of Tesla Motors, which should provide a rich opportunity to compare and contrast each company's approach.

Next, I will examine the potential of mini-EVs to have an impact on the marketplace. Mini-EVs are extremely small vehicles that only can usually only carry one or two passengers, and have very limited speed and range. One the other

hand, their small size and convenience give them an advantage in certain situations over larger, more complex and expensive conventional automobiles. Finally, I will discuss the potential of taxi EVs to make an impact on the automotive market.

Mitsubishi i-MiEV

The i-MiEV was one of the first Li-ion based EVs to go on sale in the mainstream market. It was based on Mitsubishi's "i" *kei* car design, which limited the car's dimensions and also its capabilities, although that should have also helped to reduce the car's cost. The i-MiEV has not sold well during its time on the market; the car's looks are similar to the unconventional styling of the original "i" *kei* car, and battery range and capacity has been an issue. For example, while the Tesla Roadster had 1,800 Li-ion battery cells, the i-MiEV only had 88 ("The electric-fuel-trade", 2009). The car has recently received updates and price cuts in order to make it more attractive for consumers (Ingram, 2013).

Nissan Leaf

The Nissan Leaf is a battery-only EV produced by Nissan in Japan and the United States. In many ways, it is a mainstream automobile produced by an incumbent carmaker. The Leaf 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 Kanagawa Prefecture, 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 i3 is available with an optional 2-cylinder range extender gas engine, but for the purposes of this report, only the pure battery electric version will be considered.

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). BMW has developed a process that allows the car’s chassis to be made of mostly carbon fiber, which greatly reduces the car’s weight, thereby increasing the car’s range

and drivability.

Compliance Cars

There are 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. This led to instances such as when Fiat CEO Sergio Marchionne pleaded with consumers not to buy his company’s loss-making Fiat 500e and swore to sell “the minimum of what I need to sell, and not one more” (Beech, 2014).

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. These include the Toyota RAV4 EV (which contains Tesla Motors drivetrain components), the Fiat 500e, the Chevrolet Spark EV, and the Honda Fit EV, among others. Often these are existing ICE models that have been modified to use electric drivetrains. In DI theory, such usage of

disruptive innovations in 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 (for example, dealership networks), customer management, and capital” (Hensley, et al 2012). In addition to barriers to entry and exit, 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). As a result, it has been decades since a new car company succeeded in the United States. Nevertheless, the advancement of Li-ion battery technology has opened the door to new companies that are looking to make an impact on the market (Sierzychula, et al 2012). Perhaps the most successful of these is Tesla Motors.

Headquartered in Palo Alto, California, Tesla Motors was founded in 2003 with the goal of producing electric cars powered by lithium-ion batteries. Elon

Musk, the founder of PayPal and later SpaceX, became the controlling investor, chairman, and head of product design in 2004. Musk's stated 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; Pelly, 2014). Musk later became CEO after the financial crisis of 2008 (Davis, 2010).

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 cheaper, 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 Polk, “just as many Prius as Porsche 911 buyers purchased the Tesla Roadster”. This high-end approach was also reflected in the incomes of these consumers; over 80 percent of Roadster buyers had incomes over \$100,000 (Gallon, 2009).

A major event in the company’s history happened in 2009, when the company received a \$465 million dollar loans from the United States Department of Energy (DoE). This money was critical to improving Tesla’s cash flow and continued investment towards production of future automobiles (Davis, 2010). Another key event was an investment in Tesla by Daimler in late 2008, which Musk has credited with helping to save the company (Pelley, 2014). Tesla also agreed to a strategic partnership with Toyota Motors in May 2010, agreeing to cooperate together in areas such as electric powertrain technology. This partnership was punctuated by Toyota President Akio Toyoda visiting Tesla in 2010 (Davis, 2010). Additionally, Tesla has completed an agreement with Panasonic for the development and production of nickel-based lithium-ion battery cells (“Panasonic”, 2011).

In 2010, Tesla took their next step in becoming a major automobile

manufacturer with the acquisition of the shuttered NUMMI car factory in Fremont, California, across the bay from Silicon Valley. The 5.5 million square feet plant was obtained from Toyota for only \$42 million dollars in the aftermath of the financial crisis. This factory, which previously was used to produce 450,000 vehicles annually for GM and Toyota, has more than enough capacity to build Tesla's models for the near future (Davis, 2010).

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 NUMMI factory (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. This is the first time in the magazine's 64-year history that the Car of the Year featured a non-internal-combustion engine and it was also the first time

that the winner of the award was selected unanimously. The magazine's editors praised the car's performance, acceleration, luxury, style, handling, and roomy cabin in addition to its highly efficient and eco-friendly powertrain. Additionally, the magazine's editors validated the Model S as more than "just" an electric car, stating that "the fact that the Model S is an electric car is not the reason that it is *Motor Trend's* Car of the Year" (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. It is currently targeted to go on sale in 2015. Beyond the 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 in the future, 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 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 somewhere in the American Southwest 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 "Third Generation" lower priced model (Trop & Caldwell, 2014).

In addition to its own model line, Tesla also manufactures electric powertrains for other automobile companies. Examples include the Mercedes A-Class E-Cell, the Smart fortwo Electric Drive, and an electric version of Toyota's compact RAV-4 SUV. (However, Toyota has since announced that it will end its sourcing agreement with Tesla as it plans to shift their alternative energy focus to hybrids and hydrogen FCVs rather than battery EVs [Greimel, 2014]).

Tesla Motors: Product Philosophy

From the beginning, Tesla Motors wanted to be seen as a company that made more than “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 quality and 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, Tesla’s cars could be just as stylish, attractive, useful, sporty, and fun as other automobiles. This strategy could be seen in the Roadster and Model S, which combined conventional sports or luxury car styling with rapid acceleration from its electric

drivetrain.

The company's long term goal is mass-market acceptance of affordable electric cars in order to reduce reliance on fossil fuels. But 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). While the Mitsubishi i-MiEV and Nissan's Leaf certainly look different from conventional automobiles, the Model S's styling is more compatible with the common image of a luxury sedan. This is supported by one 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 it is also "aggressively anonymous" and "generic" and its design approach is meant to "hide the technical radicalism in a cloak of invisibility" (Cumberford, 2012).

Tesla Motors: Core Competencies

Tesla's core competency revolves around its use of electric-powered engines and drivetrains in automobiles. Tesla was designed from the ground up as

an electric car company, and as such has devoted all of its time and resources towards this technology. Likewise, Tesla's experience and expertise with battery technology has allowed them to produce cars with driving ranges well in excess of other EVs. The Model S, with its maximum available 85 kWh battery, 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). The car's widely different retail prices also surely play a factor in this difference. Extended driving range is crucial to the acceptance of EVs; one survey stated that 53% of consumers wanted to EV range equal to a full tank of gas ("Plug-In", 2011). The company 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 from the ground up 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, 2013)". 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. There is enough extra room in the rear of the car that optional rear-facing jump seats can be installed to make extra seating for children.

Tesla's product design philosophy can also be seen in the car's interior. Perhaps the most notable feature of the Model S is its high-definition 17-inch touch display screen mounted in the center dashboard. This is used to handle all of the car's control panel inputs and is fully upgradable through software updates. It also has Wi-Fi connectivity to further increase its potential uses, such as streaming radio and web surfing. Another unique feature is that the car is designed to start automatically once the driver sits down in the driver's seat. There is no need to push an engine start button.

Another advantage that Tesla engineers have been keen to use is the performance aspect of electric drivetrains. Electric engines have on-demand torque and do not need to be revved for maximum performance like conventional engines. What this means for performance oriented-drivers is instantaneous,

powerful, and smooth acceleration at almost any speed. The Model S (85-kWh Performance 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. As a result, while many other green carmakers have focused mainly on green credentials at the expense of other areas, Tesla has succeeded with both performance and emissions-free operation.

Tesla's lithium-ion batteries are essentially the same as the ones that power the world's laptop computers and portable electronics, simply scaled up to the amount of energy necessary to power a large automobile (Fletcher, 2011). This fits with Christensen's (1997) theory that disruptive innovations usually use existing technology in a new way. These types of batteries have several advantages over previous ones, with a high energy density, no memory effect, and a slow loss of charge. Energy density is particularly important to automotive applications due to the significant amount of power necessary to move a large car. If the battery is too large or too heavy, it will be impractical for automotive use. Tesla's battery engineers need to be able to find the proper balance between size,

weight, and range necessary to make a practical automobile.

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, including some from investors such as Google founders Larry Page and Sergey Brin. 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).

Musk has taken a very active role in the company and the car's development, and is known for having significant input into the design process. He has invested tens of millions of dollars of his own money in the company, and has been an active spokesman. His involvement with product design is further signified by his title of "Product Architect" at Tesla. Although technically not the founder of the company, he has been the driving force behind it almost since its

inception. It is his so-called “Secret Plan” that sets the long term goal for the company to speed to development of and acceptance of EVs (Musk, 2006). This fits with DI theory, in that company founders and leaders are more likely to successfully implement disruptive processes and values in their companies (Christensen, 1997).

One way for Tesla Motors to quickly improve its products was to recruit talented employees and workers from other companies. This follows the “Open Innovation” paradigm introduced by Chesbrough (2003), where the availability and mobility of skilled workers opens up opportunities for new development. For example, the Model S’s styling was handled by ex-Mazda designer Franz van Holzhausen, and when Tesla acquired the NUMMI factory from Toyota, it quickly hired many of NUMMI’s former employees as well (Reynolds, 2012).

In general, large, incumbent automobile companies would seem to have an advantage against new upstarts, for reasons outlined by authors such as Wells & Nieuwenhuis (2012) and Cowan & Hulten (1996). However, as Christensen (1997) has shown, the size of incumbent companies can be a disadvantage when dealing with new, disruptive technologies. GM, for example, has dozens of models, multiple divisions and factories to contend with, yet Tesla, on the other

hand, currently only has two car models and integrates almost all of its production at its single Fremont factory. If GM wanted to make a widespread change to electric engines, it would take much longer than the more nimble Tesla.

Tesla has learned from experiments quickly, using the earlier Roadster model as a way to refine their production and battery technology for the Model S. They have avoided going for the market all at once, instead starting out by focusing on very specific areas, with the Roadster targeting the high-performance sports car market and the Model S going after four-door luxury sedans. They have also utilized and understood the role of government, working with the DOE to receive a large loan and utilizing federal tax breaks to make their cars more affordable.

Tesla Motors: Retail Strategy

Tesla has 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, over the phone, or in special retail showrooms. Comparable to Apple Stores, these stores 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. These stores also better reflect Tesla's Silicon Valley origins, as the company recruited George Blankenship, who had previously designed the Apple's successful store concept, to create their showroom design.

EV Market Summary

As opposed to the CARB-mandated regulatory environment of the 1990's, the introduction of EVs from firms such as Nissan and BMW show that "the EV market is now viewed as a commercial opportunity instead of a regulatory requirement" (Sierzchula, et al 2012). Consumers purchased over 200,000 EVs and PHEVs globally in the year 2013, although these sales still

typically represent less than one percent of the total automotive market in each individual country (Mock & Yang, 2014). The EV market is expected to continue its expansion in 2014, as total production is forecasted to increase 67 percent, from 242,000 vehicles in 2013 to over 403,000 in 2014 (“Global Production”, 2014). Nissan has stated plans to double Leaf deliveries in 2014 (Ohnsman, 2014) and BMW has also increased production of the i3 by 43 percent (Rauwald, 2014). Based on numbers like these, it is safe to say that the EVs are slowly but steadily gaining momentum in the marketplace.

Discussion: Mini EVs as Low-End and New Market Disruptions

According to Christensen & Raynor (2003), Disruptive Innovations usually take root as either low-end disruptions or new-market disruptions. In order for these types of innovations to be successful, entrant companies need to target two types of customers: “overshot” customers, who do not need all of the functionality found in mainstream products, and “non-consumers”, who typically do not consume a good or service because it has been historically either too complicated or expensive.

In these customer categories, we can find the kinds of customers who

may value a new type of Disruptive product, such as mini Electric Vehicles. At the 2013 Tokyo Motor Show, many companies (both large and small) displayed their products in a special exhibit called “Smart Mobility City”. Mini EV models such as Honda’s MC-Beta, Toyota Auto Body’s COMS, Nissan’s New Mobility Concept, and Toyota’s i-Road all made appearances at the show. All of these automobiles have extremely small dimensions, can only carry one or two passengers, have limited range and power, and most do not exceed 80 km/h (50 mph). However, for a low-end or new market potential disruptive innovation, such limitations may not be a deterrent if there are customers who are “overshot” and do not use all of the functionality found in standard automobiles. For these “overshot” customers, even a small amount of functionality may be enough. In such a situation, the “basis of competition” would move from performance to other metrics such as convenience or cost (Christensen & Raynor, 2003).

Examining one of these micro EVs in detail should further explain the properties of this product market. One such example, the COMS vehicle from Toyota Shatai (Toyota Auto Body), has a single seat, no doors, four wheels, a rudimentary windshield, and a small rear storage compartment (on some models). It can travel around 50 kilometers on a single charge and has a top speed of

around 60 kilometers per hour. Clearly, these capabilities are less than what the mainstream market demands for road-going automobiles. Yet, it could be enough to find a certain niche in consumer or business markets as a city delivery or transportation automobile. The car's small dimensions (roughly 2.4m high, 1.5m tall, and 1.1m wide) and tight turning radius (3.2 meters) should make it an excellent fit for crowded Japanese cities. Its onboard battery can be fully charged in about 6 hours at an estimated cost of only 120 Yen, and its purchase price of around 800,000 yen before options (approximately \$7,800 US) is less than even the most basic *kei* class ICE minicar ("Toyota Auto Body", 2014). From this perspective, running costs, convenience, and "green" considerations could become ancillary measures of performance that would appeal to certain consumers.

In the COMS, we have what should be a textbook example of a potentially disruptive innovation. The car is smaller, lighter, cheaper, and has much lower levels of performance and utility than mainstream products. Despite its low performance, though, its capabilities may be enough for consumers that do not need all of the functionality of standard automobiles. Furthermore, it may be possible that over time, the underlying battery and EV technology in a COMS

automobile would improve over time and start to challenge mainstream products.

But to this date, micro EVs such as the COMS have failed to catch on in the marketplace. Nevertheless, there exists the potential for this kind of concept to become more popular in the future. Pilot programs to utilize this Mini EVs are currently underway in several cities in Japan, including Yokohama and Toyota City in Aichi Prefecture (“EV-PHV”, 2013). Yamaha’s “Motiv”, designed by McLaren F1 creator Gordon Murray, is another potential entrant into this area (Ingram, 2014).

Discussion: Electric Taxi Potential

Another possible situation where people “do not need to go very far, very fast” would be taxi service in crowded Asian cities. Most taxi rides are only for a few kilometers or less, and often in urban stop-and-go traffic. This low demand for high speed, long-distance performance would seem to open the door to the possibility of EV taxi fleets. Indeed, during the early “Golden Era” of EVs in the early 20th century, companies in London, New York, and Paris used EV taxis (Hoyer, 2008).

Several Japanese cities have instituted pilot programs for EV taxis with

the goal of their eventual widespread utilization. One such example is Kanagawa Prefecture in Japan, just south of Tokyo. The program established by the prefecture involved 27 different taxi companies that operated a total of 43 different EV taxis (“Kanagawa EV”, 2013). It is important for municipal and government officials to take an active role at this stage in the EV’s development, as they are the actors that are best able to coordinate diverse actors and directly engage local residents (“Plug-in”, 2011). Kanagawa Prefecture runs the program through its “Smart Energy” office, which is responsible for promoting alternative energy throughout the prefecture. The prefecture accomplished its goals by having more than 4,000 EVs in the prefecture by March 2013, as well as 159 charging stations (“Kanagawa Ken”, 2013).

In an interview with prefectural personnel, it was conveyed that the goal was not necessarily to spread the use of EVs as taxis, but rather to increase their overall availability and exposure in the prefecture. The hope was that as more people see EVs on the road or experience them as taxi passengers, they will become more open to the idea of owning EVs themselves. In this way, EV diffusion could be spread throughout Kanagawa Prefecture. Surprisingly, despite the fact that Nissan is headquartered inside the prefecture in Yokohama city, the

program itself was not sponsored by Nissan and was a government/taxi company initiative (Personal Interview, November 25, 2013).

In order to promote the usage of these EV taxis, special EV-only taxi lanes were established near Japan Railways' Yokohama Station, and discount coupons were also made available. Additionally, a 2/3 subsidy was provided to the taxi operators. As a result of these programs, 83% of riders said that they wanted the number of EV taxis to increase, and over half (55%) said that the car had a comfortable ride ("Kanagawa EV", 2013). Another positive was that the taxi companies found electricity to be much cheaper than gas, and were able to charge at night at very low rates. On the other hand, there have been some difficulties with customers who wanted to travel long distances, and in some situations drivers have had to turn away customers due to driving range issues. Other difficulties included limited luggage space and difficulty for some elderly or disabled passengers to ride in the Leaf's higher back seat, which is raised to make room for the car's Li-ion battery (Personal Interview, November 25, 2013).

In a survey of EV taxi riders in neighboring Tokyo Prefecture for a separate but similar program, there seemed to be a positive reaction on the part of passengers, with solid majorities agreeing with the statements that "I want to use

EV taxis more in the future”, “I want the number of EV taxis to increase”, and “It would be good if the number of EV taxi stops increased”. However, in the same survey, the taxi drivers had some negative responses. For example, nearly half (45.2%) of respondents said that they had to refuse service to customers over range concerns, and nearly one in ten (9.7%) saying that they have had their battery cut out on them while driving (“EV Taxi”, 2012).

Despite some promise, it is clear at the current stage that charging times, driving range, and costs are all still major obstacles to EV taxi adoption. A group called TUM Create, from Germany’s Technische Universitat Munchen and Singapore’s Nanyang Technological University, is developing a prototype EV taxi for tropical cities that would solve some of those problems (“EVA”, 2014). Supported by various companies such as Continental, Samsung, and BMW, the project looks to solve many of the problems previously found in EV taxi applications. For example, the larger lithium-ion battery should eliminate costly charging downtime, and an improved storage area should be enough for a traveler’s luggage. Regardless, this is only one pilot program, and its ideas are probably years away from usage. However, one day findings from programs like these may one day be found in EV taxi fleets all over the world.

Analysis of Automotive Market Developments through DI Theory

Analysis: Finding Examples of Sustaining Innovations in the ICE Automotive Industry

As far as ICE technologies are concerned, DI Theory in regards to Sustaining Innovations fits very well with incumbent 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 overall structure and design of the ICE did not undergo any drastic changes. Nor were there any major changes to the structure of the automotive industry. Despite innovations such as the Toyota Production System and increased supplier outsourcing, "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).

Fig 2: "Fact #800 Characteristics of New Light Vehicles Sold, 1980-2012"

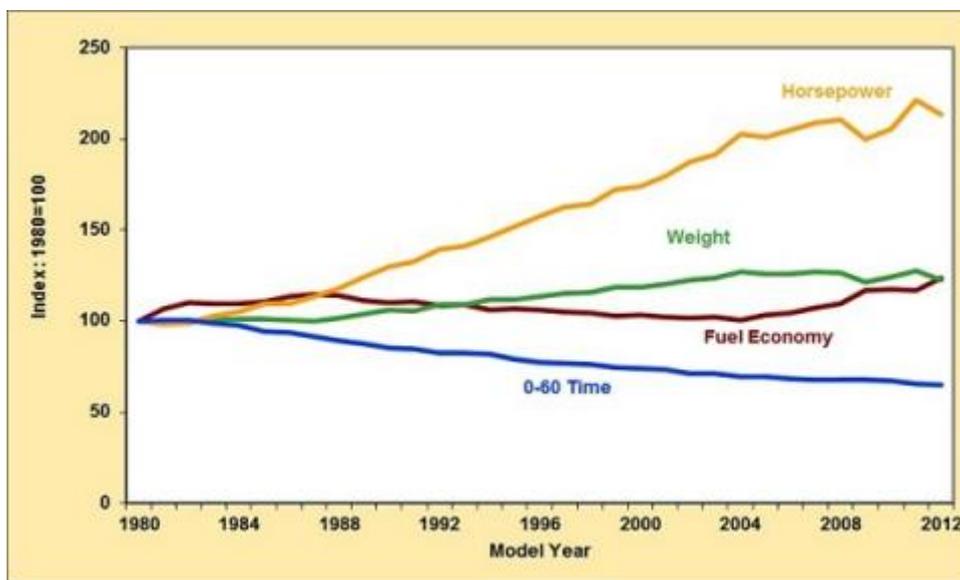


Image Source: "Fact #800", (2013)

How did carmakers achieve these consistent, sustaining innovations in speed, horsepower, and (recently) fuel efficiency? Beyond standard advances in engine design and efficiency, they employed 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 Innovation.

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, a CVT does not require a complete rethinking of the support structure for the automobile; it simply allows for a more efficient utilization of engine's power band. In another 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 or the industry's value structure. As shown by the United States Department of Energy, usage of these Sustaining Innovations have 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).

Fig. 3: “Fact #658: Increasing Use of Vehicle Technologies to Meet Fuel Economy Requirements”

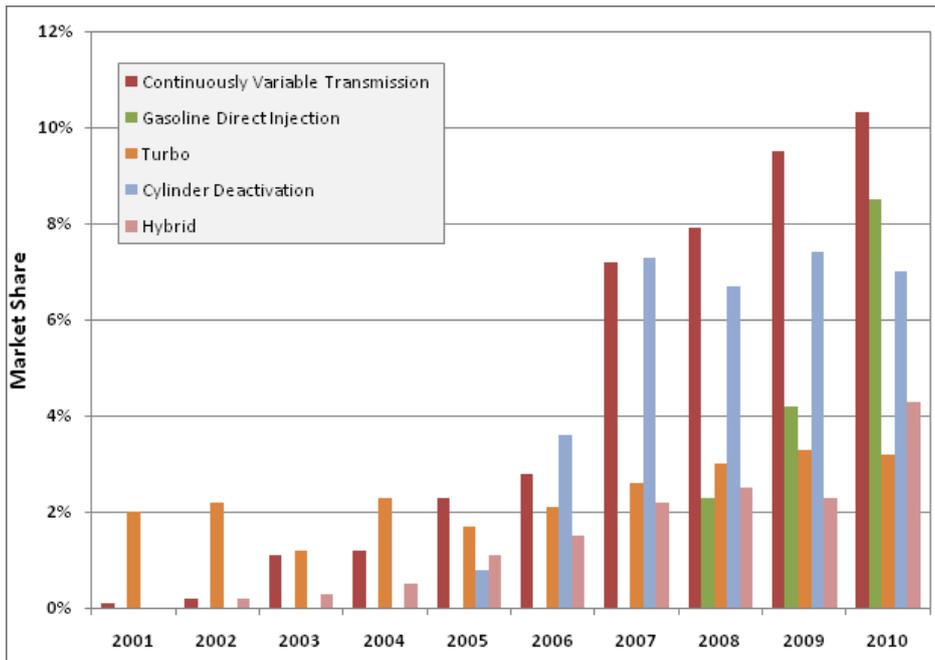


Image Source: <http://energy.gov/eere/vehicles/fact-658-january-17-2011-increasing-use-vehicle-technologies-meet-fuel-economy>

Analysis: The Case of Hydrogen FCVs as a Sustaining Technology

The development of Hydrogen Fuel Cell Vehicles (FCV) would seem to follow many of the principles of a Sustaining Innovation. While Hardman, et al (2013) argue that FCVs are a candidate disruptive technology in two out of three parts of their framework, I would argue that FCVs are actually more sustaining

than disruptive. The technology has been developed by the leading industrial incumbents at tremendous development cost; for example, GM's hydrogen fuel cell expenses were estimated at over \$1 billion dollars (Fletcher, 2011). Furthermore, FCVs would fit much better than EVs into incumbent automaker business strategies. These cars would be filled much like conventional gasoline ICE vehicles at roadside filling stations. Usage of these cars would be also be very similar to existing conventional cars and business plans, thereby easily fitting into incumbent carmaker's RPV frameworks. Customers could drive until their gas tank (or in this case, hydrogen) was empty and then simply refill at the closest station in a matter of a few minutes. The range of a fully-fueled FCV is also much more comparable to existing ICE models. Car performance, size, and design would all mostly remain unchanged.

Perhaps for these reason, Toyota has shifted away from battery EVs towards a hydrogen-based alternative fuel strategy. Another possibility is that Toyota has an advantage in technology patents in this area ("Chizai", 2013). Still, much like many other alternative fuels, fueling infrastructure for FCVs also remains an issue. Despite these difficulties, both Toyota and Honda have elected to pursue the FCVs, with Toyota set to release a mass-market FCV by 2015

(Griemel, 2014).

Analysis: Kei Cars and the Tata Nano as Potential Low End ICE Disruptions

Is it possible to find examples of low-end ICE automotive disruption?

One possible example is Japan's category of *kei*, or light, automobiles. These cars are limited by law in areas such as engine size and overall dimensions. In return, kei cars often have lower taxes, tolls, inspection and insurance costs, and are often exempt from parking regulations that apply to normal-sized automobiles. This category has become a huge part of the Japanese auto market, with a market share of 36.6% in 2012 ("Shireba", 2012). As the engines are limited in size to 660cc, the cars do not go very fast or have a lot of power. However, they are extremely efficient, convenient, low-cost, and easy to drive on Japan's narrow roads. An even further example would be the class of vehicles known as kei trucks. These are spartan, small pickups that are subject to the same limitations and advantages of regular kei cars and are often used for small-scale agricultural use in rural areas all over Japan. As such, this would be a potential disruptive market for cars that "do not need to go very far or fast".

Nevertheless, the regulatory origin of kei cars calls into question whether or not they can be considered truly disruptive to the mainstream. Kei cars have by

and large failed to catch on outside their home market, leading them to being called “Galapagos Cars” (Takahashi, 2013), and the Japanese government has recently changed kei car incentives in order to make Japanese car companies more competitive overseas (Tabuchi, 2014). It is doubtful that the kei market would have developed as it has without significant government intervention.

Attempts to electrify kei cars have been both few and unsuccessful. Mitsubishi’s i-MiEV, which is based on their “i” series kei car, has failed to catch on in the Japanese market, with sales of only 1,491 units in 2013 (“2013 Nen”, 2014). One major issue is likely the i-MiEV’s short driving range, which falls below competitors such as the Nissan Leaf. Another factor could be the original ICE version of the i-MiEV, which was unable to compete against market leaders for top sales position. The car’s unusual styling may also be a deterrent to potential buyers.

If there was one conventional Internal Combustion Engine (ICE) car that would have seemed to fit the definition of a Disruptive Innovation, Tata Group’s Nano would come to mind. The car was designed from the ground up as a new-market type disruptive innovation to get “non-consumers” (pedestrians, bike and motorcycle riders) to purchase a car, while simultaneously approaching the low

end of the market by only offering the absolute bare minimum of equipment and options. Ray & Ray (2011) analyzed the Nano and stated that it was an example of Disruptive Innovation due to its new combination of existing resources to make a unique product designed for the economic Base of the Pyramid (BoP).

The car was expected to such a hit product that there were concerns over increased air pollution due to the car's popularity among new drivers (Ray & Ray, 2011). However, sales of the car have not met expectations, with styling and safety issues being major concerns (McLain, 2013). In response, Tata has been forced to add features and styling features in order to make the car more attractive, especially to younger customers. In the case of the Nano, there does seem to be a limit to how "cheap and slow" customers are willing to go.

Analysis: The "Jobs To Be Done" Theory and Car-Sharing Programs

If one subscribes to Christensen & Raynor's "Jobs To Be Done" marketing model, as found in *The Innovator's Solution* (2003), then one promising solution that would fit into DI theory would be urban electric car sharing programs. Theoretically, most urban dwellers only need to get from point A to point B reasonably quickly and efficiently. There is no need to travel long

distances or carry large amounts of cargo. From this perspective, people simply “hire” transportation to get them where they need to go. It then follows that people could “hire” a shared EV for whatever transportation needs they have, and then return it when they are finished.

An argument for these kinds of EVs was put forward by Hodson & Newman (2009), who stated that “by focusing on specific driving missions of consumers, a company can match a vehicle’s energy storage requirements to a consumer’s particular needs”. As a result, these “driving missions” such as commuting or just driving around town, could be the basis to determine how much capability (and therefore cost) to include in mass-market EVs. If only lower levels of capability are necessary, then models with suitably limited utility could be a reasonable solution.

Under a traditional Disruptive course, these shared EVs for quick, basic, urban transportation could start at the very bottom of the market, aiming for “overshot” customers who do not need large, fancy automobiles; or it could move to “non-consumers” which have previously biked, walked, or taken mass transit to their destination. Once this “foothold” at the low of the market is established, car-sharing companies could gradually expand their offerings to larger and more

capable vehicles in more diverse locations. Through their short-term rental model, these companies could find a way to make money in a different way (and at possibly lower margins) than traditional automakers. Such an approach would also be attractive to urban consumers in that it would also eliminate the need to pay expensive parking fees. All of these factors mesh well with existing DI theory.

There have been some successes. One such example is the Kandi car-sharing project in China, which is reportedly profitable and expanding within the country (“Kandi”, 2014). Such an approach however, it still limited to only major cities. In the United States, Uber and Zipcar have emerged as conventional ICE car-sharing companies, again mainly focused in major cities. In Japan, Kanagawa Prefecture has established its “Choi Mobi” car-haring service in Yokohama city, utilizing mini EVs from Nissan/Renault (“Nissan and Yokohama”, 2013).

Still, consumer attitudes may be hard to change. In one survey, 73 percent of respondents said that they would rather buy and own their car, instead of leasing it or participating in a subscription program. This represents consumers “sticking with what they know” rather than trying the untested waters of subscription services (“Plug-in”, 2011). As the average car spends more than 95 percent of its time parked (Heck & Rogers, 2014), there exists great potential for

car-sharing programs to greatly increase the efficiency and utilization of personal transport. Despite this, however, EV car sharing is currently limited and does not appear to be viable in suburban or rural settings.

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 (Christensen, 1997). One example given is steel minimills, which started out making simple rebar and then gradually moved upmarket towards sheet steel (pg. 104). Where would Tesla fit into this framework? Tesla does not match the Low-End or New-Market type disruptions. The company has not targeted those types of customers or markets. Instead, with its moves into the high-end sports car and luxury sedan markets, 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.

Instead of targeting the lowest, least demanding consumers and then using that know-how to move upmarket, Tesla has done almost exactly the

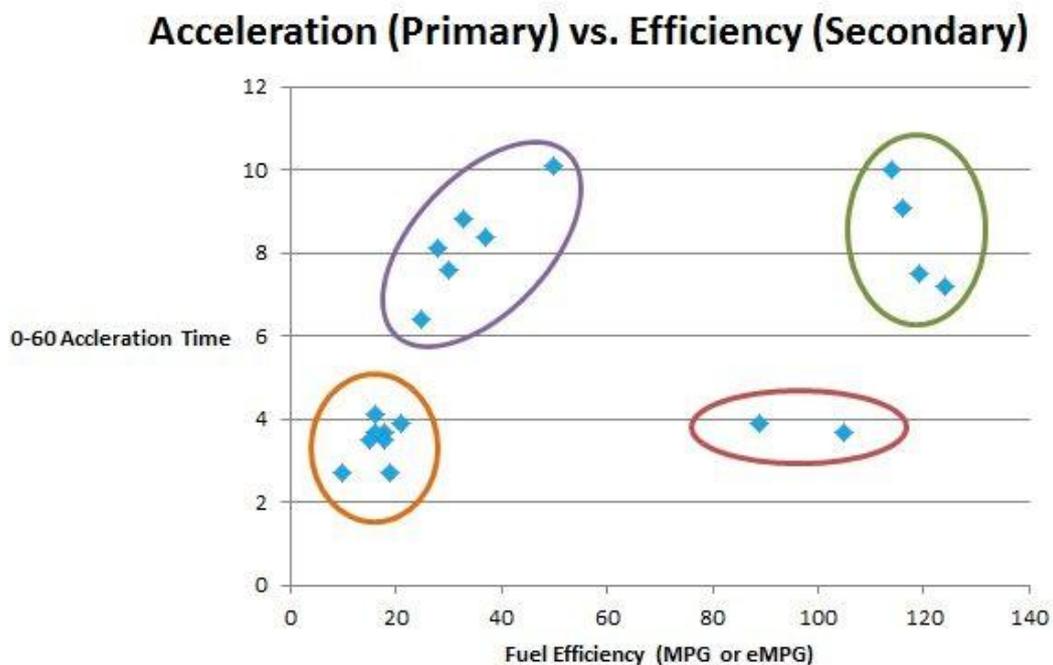
opposite. With the ultra-sporty Roadster, the company started at the highest-end, most demanding supercar segment, and then with the Model S moved slightly downwards towards a somewhat less demanding luxury sedan market. For the Model X, the company hopes to further broaden the company's appeal by selling a car in the popular crossover SUV market. This is planned to be followed by another move downwards in terms of customers and technology in its "Third Generation" mainstream sedan, which is expected to retail somewhere in the \$30,000-\$40,000 dollar range (DeMatio & Zenlea, 2012).

Again, this is exactly what DI theory recommends against doing. Yet, it would appear that Tesla's strategy has succeeded to this point. The company has sold tens of thousands of cars and its stock price has surged. There is some theoretical precedent for this pattern of product development. Van der Rhee, Schmidt, & 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 & Van der Rhee (2014), who have 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. The authors also

explicitly state that this goes directly against what is recommended by existing DI theory.

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 green-friendly 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).

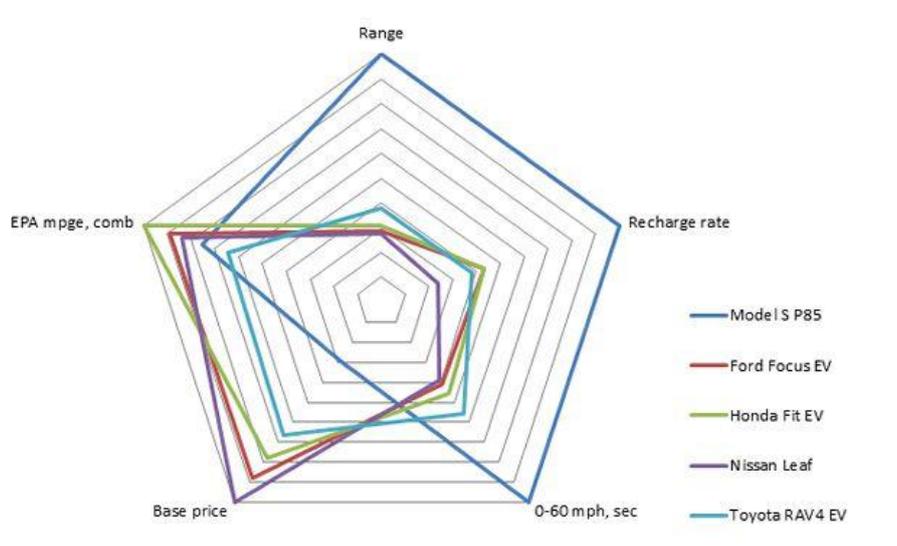
Fig. 4: Comparison of Automobile Performance Attributes



Data Sources: Acceleration, *Motor Trend* website; Fuel Efficiency, fueleconomy.gov. See Appendix A for details. Note: Plug-in Hybrid Vehicles were not included in this graph due to variances between operation in gasoline and electric-only modes.

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 equal to high-end sports cars, but with a much higher efficiency. Tesla's products also offer much greater range than competing EVs.

Fig. 5: Comparison of Tesla Model S with other EVs

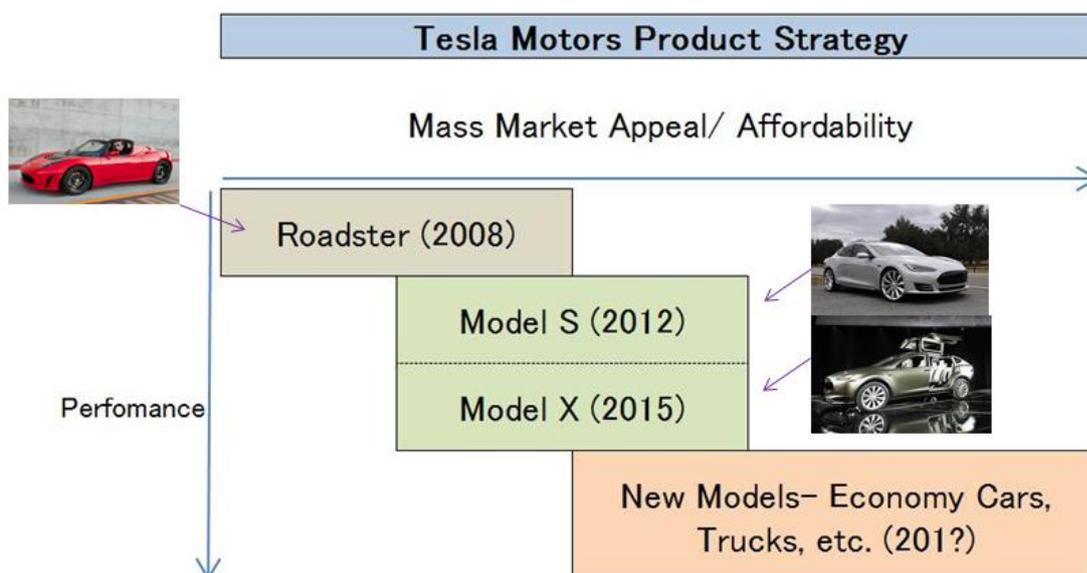


The Model S has significant advantages in Range, Recharge rate, and 0-60 acceleration over competing EVs- although this performance comes at a much higher price. Image source: Reynolds, 2012

Since the time of the original article’s publication in 2012 (see also Schmidt & Van der Rhee, 2014), Tesla’s strategy has further developed along this top-down trajectory and confirmed the article’s positions. There is a clear downward trajectory line to be drawn from the Roadster to the Model S to the upcoming third-generation “economy” car. 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 downmarket. 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.

Fig. 6: Tesla Motors Product Strategy



Analysis: Importance of Reducing Battery Costs

As shown, battery cost reductions are critical to Tesla’s product strategy. Li-ion battery costs are expected to decrease over time; the only question is, how much? Process improvements, economies of scale from higher production volume, new battery materials, and increased energy density are all expected to

play a role in reducing costs (Catenacci et al 2013; Tilleman, 2013). While the Model S was under development, one quick estimate had predicted its battery costs at \$504 per kWh (Reynolds, 2011), while a U.S. DoE estimate had placed battery prices at above \$400 per kWh as of 2012 (Tilleman, 2013). Gerssen-Gondelach & Faaji (2012) predicted a cost of \$350-\$500 per kWh by 2020 and \$200-\$300 per kWh by 2030, although current cost breakdowns indicate a lower limit of \$300 per kWh based on current technology. Meanwhile, a 2013 survey of European Union battery experts by Catenacci, et al (2013) found a high level of variation in the predictions, although half of the experts consulted predicted a cost between \$200 and \$400 per kWh by 2030. One prediction states that batteries will become cost-competitive with gasoline when prices reach \$250 per kWh (“Global Production”, 2014). With its massive predicted scope, the success or failure of Tesla to “scale up” production via its Gigafactory will certainly also play a large role in determining future battery prices.

Analysis: Emergent Strategy and Finding unexpected new markets

Christensen (1997) uses the case of Honda motorcycles in the USA as an example of the importance of developing Emergent and Deliberate strategies.

Originally, Honda had intended to enter the US market selling large, expensive bikes up against established competitors such as Harley-Davidson. This would essentially be taking on a well-established incumbent with sustaining technologies, which is not recommended by DI theory. However, when that strategy failed, Honda management found almost by accident a different market for small, inexpensive scooters and off-road motorbikes. This is a low-end or new-market disruptive strategy. For Honda, selling large bikes was their deliberate strategy. But when that failed, the company was nimble enough to start selling smaller bikes as part of an emergent strategy.

In the case of Tesla Motors, it is interesting to note that there are some examples of both emergent and deliberate strategies. In one way, the top-down business model was an emergent strategy dictated by the high cost of Li-ion batteries. As a result, Tesla Motors founders Martin Eberhard and Marc Tarpenning made the deliberate decision to “compete on performance rather than price” (Fletcher, 2011, pg. 62). As Tesla had no choice but to make expensive cars, they were forced to start at the very high end of the market with the Roadster. This choice was critical, as “a firm’s most important decision- and the one it gets wrong most frequently- is the selection of its initial target market”

(Christensen, Anthony, & Roth, 2004, pg. 193). The original goal of the Roadster was to take a Lotus Elise “glider” chassis and simply drop in an electrical drivetrain. However, the design of the Roadster had to be radically reworked after production issues began to occur. According to Musk, all sorts of problems popped up when changing the car over to the Roadster drivetrain: “We had to do a massive redesign... It ended up costing like \$150 million to get the Roadster into series production” (DeMatio & Zenlea, 2012). On the other hand, the Model S which was designed by Tesla exclusively as an EV would much more represent a deliberate strategy to attack the luxury sedan market.

One possibly unexpected and potentially “emergent” point of appeal in disaster-prone Japan is the EV’s ability to serve as a source of electrical power for home usage in the event of a power outage. In one Japanese survey, nearly 60% of respondents cited the ability to power their homes in an emergency as a reason they would like to buy an EV (“EV wo”, 2013) For some car models, the home can connect directly to the car’s batteries and use that electricity for electronics and utilities. Similarly, bus and truck maker Hino has developed a medical bus that would use batteries to carry its own power supply to the field where it can support medical devices (“Exhibition”, 2013). Could this be the kind of

unexpected, yet beneficial feature that could drive EV adoption as part of an emergent-type strategy? If it proves to have appeal with previously non-EV consumers, then automakers should pay attention and incorporate this as a potential way to increase EV sales.

Analysis: RPV Sales & Distribution

The RPV of a company like General Motors and their dealership model would not appear to support the introduction of a new technology such as EVs. Traditional dealers typically make their money on sales commissions and maintenance of previously sold vehicles; in other words, they 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. These services typically make up a major portion of the dealership's profits. However, the simpler electronic motors found in EVs do not need maintenance such as oil changes, belt replacements, and the like. 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). 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, each salesperson has to devote more time to a single customer. From tax breaks and rebates to charging times, driving ranges, specialized equipment and battery warranties, there are a wide variety of additional factors that must be considered and discussed when purchasing EVs. This is at odds the commission 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 2006 documentary *Who Killed the Electric Car?* (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 should help to explain the rationale behind Tesla's retail strategy. Tesla needed to find a way to make money that would uniquely fit its own Resources, Processes, and Values. It would therefore be appropriate that the company does not subscribe to the traditional dealership model found with established carmakers. Its showroom retail model, on the other hand, is a much better fit for the company. Customers can visit retail showrooms, often located in high-end shopping malls or urban population centers. There is no need to develop a complex independent dealer network. Additionally, the company does not have 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.

This new approach, which eliminates the need for the dealership model, has unsurprisingly found heavy resistance among traditional dealerships in many U.S. states. Lawsuits and lobbying from dealers in Texas, Arizona, and North Carolina have focused on eliminating or prohibiting Tesla showrooms from selling cars to customers in their states. Most recently, New Jersey has banned the direct sale of cars, severely limiting Tesla’s capabilities in a key urban sales region (Maynard, 2014). It could arguably be said that this aggressive response is proof that the showroom concept has potential and therefore is seen as a threat by dealers. Time will tell if their efforts to block Tesla’s showrooms will be successful.

Analysis: 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 as seen in *The Innovator's Dilemma*. 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). It would be far too easy for GM to disregard the nascent EV market, while 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. At Nissan’s Oppama plant, the Leaf can be assembled on the exact same line as conventional ICE models such as the Juke. Nevertheless, there may be the possibility of other design sacrifices made to get the Leaf to conform to ICE line production: the size of the battery pack, for example, may have been dictated by whether or not it would be compatible with the existing conventional ICE manufacturing infrastructure. Regardless, 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 & Nieuwenhuis (2012), who state that “the industry overall prefers to make electric vehicles as traditional as possible, even if this does compromise performance”.

Tesla has shown some of the advantages of designing their own car from the ground up to be an EV. While the Roadster was based on a modified Lotus sports car frame (which led to several engineering headaches), the Model S was

conceived from the ground up as exclusively electric. This led to an opportunity to completely revamp the car's design, as there was no need to consider space for a conventional ICE engine, transmission, or drivetrain. All that was needed to propel the car was the battery, located under the car's floor, and an electric motor and inverter, located behind the battery, near the rear wheels. This led to all sorts of new design possibilities: the space in the front of the car, usually utilized as an ICE engine bay, was turned into a trunk space, and discarding the transmission and drivetrain led to an open, airy cabin design. As stated by *The Economist*, "once the engine block and the gearbox are gone, the game of car design changes" ("The electric-fuel-trade", 2009).

Analysis: Low End EVs and "Jobs To Be Done"

Despite their potential, low-end and new market EVs such as car-sharing and EV Taxis have so far failed to reach their potential in the marketplace. Even when these vehicles and programs do exist, they are often limited in scope and/or heavily dependent on corporate or government support. Why has this been the case? Why have these classic types of disruptions not taken place in the automobile market?

I believe the answer to this lies with Christensen & Raynor's own "Jobs to be Done" model. In analyzing transportation options, Christensen & Raynor tend to look at the "job" of transportation as simply moving from one location to another. The car itself is seen as just 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). A quick look at cars available on the marketplace will show 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 shown that car buyers "hire" cars for more than just transportation. A 2013 study by J.D. Power and Associates 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. If EV car companies hope to reach large portions of the market, they need to work to overcome the image of EVs as nothing but "glorified golf carts". 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 may actually be a negative for many consumers.

Throughout the design and development of the Model S, there are several cases where Tesla engineers wanted to make a car that was more than "just an EV". For example, its styling achieved a low 0.24 drag coefficient, better than the Toyota Prius or Chevrolet Volt, yet "without those cars' gawky styling" (Zenlea, 2013). In another interview, Musk stated that "The Model S is a primary car... You've got to have a compelling product. Otherwise, you're just going to address a very small segment of the population" (DeMatio & 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, or alternatively Hodson & Newman's (2009) segmentation framework, carmakers should then focus on having just enough performance to meet that typical daily need. However, as Pearre et al's (2011) 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" (pg. 1172). 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.

Additionally, while a sober analysis of running costs over the life of the vehicle may show that EVs run cheaper on electricity than ICEs on gasoline, consumers are prone to incorrectly estimate fuel savings and tend to purchase products with lower purchase prices but higher lifetime costs. Indeed, corporate owners may need to lead the way in EV ownership, as they are usually much better than households in correctly calculating the total cost of ownership (Sierzchula et al., 2012).

Analysis: Is DI Theory Industry-Agnostic?

Why have these smaller, less capable automobiles failed to catch on? Is there something different about the automotive industry, or are customers unwilling to sacrifice beyond a certain baseline level of safety and practicality? According to Christensen, Anthony, & Roth (2004), these possible differences should not affect the application of DI theory to the automotive industry as “good, circumstance-based theory is industry-agnostic” (pg. 180). In fact, as tempting as it may seem to want to exclude certain industries, Christensen writes that all industries should be subject to DI theory and none should be excluded from its conclusions. After all, “the forces of innovation affect every industry” (Christensen, Anthony, & Roth, 2004, pg. 199).

However, the results so far show that there is room for doubt as to the applicability of DI theory to the automobile industry. As shown by the sales struggles of the ICE Tata Nano, there may in fact be a baseline level of safety and quality that consumers are not willing to cross, regardless of the car’s price, styling, or performance. Additionally, as seen in surveys from companies such as J.D. Power (2013), customers have shown more hesitation in purchasing cars that they do not consider to be stylish or fitting the personal image that they want to

project. This may be more of an issue than in other products and industries, where style is not as much of a concern. Driving range issues for EVs remain a sticking point for many consumers (“Plug-In”, 2011). A robust used car market may also mean that people would rather buy a conventional used car than try a new disruptive one. Finally, even purchasing the cheapest automobile is still a significant expense for consumers, which may cause them to think twice when it comes to taking a risk and selecting cars with disruptive potential.

Conclusion & Summary

In this paper, I intended to analyze the predictive capability of Christensen's (1997) Disruptive Innovation theory using the field of electric vehicles. As a result of this research, I have found mixed levels of success for the theory. Therefore, while many parts of the theory remain strong, there are possibly a few points for improvement that may be worth further consideration.

I have found some 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; the importance of developing independent distribution channels for disruptive products; and the important of using both emergent and deliberate strategies when introducing new disruptions.

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, quieter, more efficient engines (64). While at times the ICE suffered setbacks due to the Oil Shocks or increased emissions regulations, since the late 1970's incumbent car companies and their engineers have again and again found

ways to overcome those difficulties and continue on their sustaining trajectory. With increasing emission regulations in the near future, this trend will have to continue in order to meet both market and governmental expectations.

Corporate Level RPV has played a large role in encouraging or inhibiting the development of electric vehicles (86). 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, has pursued disruption and focused on high performance Li-ion battery based EVs from the very beginning. As a result, Tesla has succeeded, where incumbent car makers have either ignored EVs, pursued a sustaining hybrid approach, or released EVs that were “crammed” into existing ICE-based business models, which limited their performance and disruptive capabilities.

For Tesla, a major strategic decision was their choice to develop an independent showroom-style sales model that completely bypassed traditional car dealerships (83). This approach 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. Any deviation from this business model is likely to be met with indifference, annoyance, or in the case of state dealership laws, outright hostility. Tesla took the correct approach in order to best show the benefits of an unfamiliar form of transportation to new consumers, without having to compete with attention from ICE products.

When choosing how to develop EVs, Tesla was forced to take an “emergent”, high-end strategy due to the high cost of Li-ion batteries (80). This strategy, when turned into a deliberate model to develop high performance sports and luxury cars, has guided the company’s product strategy since its beginning. The company’s relatively small size and strong leadership mean that it is well positioned to adapt its strategy to an emergent one if conditions change. Likewise, an emergent strategy such as power backups in disaster-prone Japan could also be an opening for an assertive, forward-looking disruptive company.

However, there have been exceptions to Christensen’s theories. First of all, there is the question of whether or not car consumers are “overshot” or do not need all of the functionality found in today’s cars. The evidence on this point seems to contradict DI theory. Contrary to Christensen (1997, pg. 237), the performance trajectory of consumer demands in the automobile market is not flat-

consumers have been eager to purchase increasingly powerful and faster automobiles for decades (“Fact #800”, 2013; **65**). Attempts to introduce low-end or new-market innovations, such as the Tata Nano (**69**) (or going farther back, perhaps, the Yugo) have failed to make an impact. Safety and personal image may also play important roles in this phenomenon.

Similarly, even though most drives are short (as pointed out by Hodson & Newman, 2009; also Pearre, et al, 2011), consumers still want to have the option of longer drives whenever they want. Instead of being concerned with a product that is “good enough”, which is normally an opening for disruption, many customers seem to ask “what if” and are concerned about not having enough functionality in their automobile whenever they might need it. The higher driving range of the Model S is certainly an advantage in this regard (**50**).

Even where low-end disruptions exist, such as in the case of Japan’s *kei* cars, their existence may due as much to government regulations as it is to natural market forces (**69**). Similarly, minicar or urban car sharing services have yet to find a widespread foothold in the market. Post-recession, there has been somewhat of a movement towards smaller, more fuel-efficient cars powered by smaller displacement engines, but the fact remains that today’s car is substantially

faster and more powerful than before (65). As a result, there is some doubt as to whether consumers truly are “overshot” and are looking for an automobile or EV that would only be “good enough” to support their most basic, everyday transportation needs.

Also, there remains the question of what to do about the “jobs to be done” mode (89)- is it necessarily a good fit for this situation? Should this framework be reconsidered or modified? Much like DI theory itself, there is some room for ambiguity. For example, what “job” are car drivers really trying to accomplish? Is it utilitarian transportation on their daily work commute, self-expressive styling, or for 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 major point of divergence is Tesla’s top-down product strategy (79). 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

Disruption 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.

Conclusion: Hypothesis Results

For Hypothesis H1, it appears that the actions of incumbent carmakers can generally be explained through established DI theory. For example, the importance of Sustaining Innovations and company-wide RPV are strongly supported by the findings in this paper. Incumbent carmakers clearly either had difficulties in committing to EVs, or tried to “cram” EV technology into existing ICE models with varying results.

As for H2, there do in fact appear to be some notable exceptions to DI theory in Tesla Motor’s success to this point. First, the top-down product strategy favored by Tesla goes against the basic principles of low-end disruptive innovations as described by Christensen (1997). Additionally, there is room for doubt as to whether car consumers are “overshot” and are looking for cars with

lower performance in exchange for improved secondary attributes. Third, regarding the “Jobs to be Done” model, it is also not clear that this method is sufficient for determining whether or not consumers would be interested in low-end disruptive automobiles.

On the other hand, some aspects of DI theory have stood up very well in regards to Tesla’s actions. The importance of developing independent distribution systems was shown by Tesla’s showroom model and through the difficulties in getting traditional ICE auto dealers to sell EVs. Likewise, correctly utilizing Emergent and Deliberate strategies still remains important when deciding how to sell disruptive products. The corporate RPV framework also explains the ability of Tesla to focus exclusively on EV development. Therefore, the result of H2 is mixed.

Thesis Limitations

This report has several limitations. First, it focuses mainly on the United States and Japanese markets. This excludes markets which may have different market conditions, such as developing countries, or countries with higher levels of government subsidies, such as Norway or the Netherlands (Mock & Yang, 2014). Additionally, as with any global economic discussion, the impact of the Chinese market will also be significant. However, as Japan and the United States are two of the larger automotive markets in the world as well as home to many of the industry's largest carmakers, it is hoped that the findings in this report will be broadly applicable to other countries as well.

Furthermore, this report mainly looks at the use of electric vehicle technology in personal automobiles, and for the most part overlooks the use of EV technology in areas such as motorbikes, non-taxi mass transit such as buses, industrial uses, and watercraft. (For the purposes of this report, the difference between a motorbike and a micro EV is the use of a covered traveler compartment as well as three or more wheels). Analysis of these other segments may yield different conclusions and interpretations of the efficacy of DI theory.

For the purposes of research and discussion, only “pure” battery powered

electric vehicles were considered, as these would likely be the most “disruptive” way to develop a completely new value network relative to industry incumbents. As a result, gas-electric hybrid vehicles such as the Toyota Prius and plug-in hybrid vehicles with onboard gas engines such as the Chevrolet Volt were not considered in this research. Midler & Beamue (2010) describe hybrids as “not including any revision to the industry business model”, which would fit the description of a Sustaining Innovation. Furthermore, hybrids are produced by major ICE car producers (Hoyer 2008), which is a further sign that hybrids are Sustaining rather than Disruptive. This is further supported by Wells & Nieuwenhuis (2012), who state that it is “unsurprising” that the industry is much better able to support ICE hybrids than accept radical changes. Ultimately, including hybrid vehicles would alter the field of discussion and is probably worth addressing separately in a research context as they would shift the basis of technological change.

Additionally, conventional ICEs are constantly improving in areas such as efficiency and fuel mileage (Hensley, et al 2012) so it would also be a mistake to overlook their continued improvement. These efficiency improvements are taking place along with steadily decreasing levels of average greenhouse gas

emissions per vehicle (Stark et al, 2011). According to the International Energy Agency, the mostly likely scenario for the future of the automobile is one with a wide mix of fuels and energy sources including FCVs, EVs, PHEVs, Natural Gas, and conventional diesel and gasoline (“The Great Powertrain Race”, 2013). Therefore, at this stage it would not be recommended to overlook the ability of ICEs to achieve continued improvement in performance and emissions.

Another key point to consider is the oft-repeated statement by Christensen (2006) that disruption “is a process, not an event”. In other words, we should not expect disruptions to occur immediately; typically they are part of a process that takes time. As the world population gradually becomes more urbanized and battery costs fall, there may in fact be more of a movement towards a low-end or new market micro EV solution. Or, as proposed by Kimble & Wang (2012), these types of vehicles may just be simply looking for an acceptable business model. Alternatively, this shift could happen not in personal transportation, but as part of mass transportation such as buses or taxis. It may just be too early to determine whether these types of transportation will be a success or not.

The EV market is an incredibly fast moving one, with constant changes

and developments. While efforts were made to keep the information in this report up-to-date, future developments could render its findings obsolete. Technological breakthroughs such as advancements in battery technology could also change the landscape of the industry relatively quickly. Lithium-Air batteries, for example, have the much higher potential energy density than current Li-ion batteries, yet several technological hurdles remain in their development (Lu, Li, Park, Sun, Wu & Amine, 2013). In the mid-term future, lithium-sulfur and zinc-air batteries may also be an option (Gerssen-Gondelach & Faaji, 2012). However, for the near term, some form of Li-ion batteries appears to remain the energy storage unit of choice for most EV applications (Sierzchula, et al 2012).

Also, in such a volatile industry, the success of young companies is not a guarantee. To this point, Tesla Motors has had several remarkable achievements for a new automaker, but any number of dramatic developments (such as problems with dealership franchise laws, Gigafactory construction issues, lithium supply issues, macroeconomic considerations, or a massive drop in stock prices) could occur that would rapidly change the company's fortunes. Alternatively, a company that currently has a low profile could emerge from the shadows to become a major player. While we can try to make predictions to the best of our

abilities, only time will tell which approaches prove to be a success.

Further Research

Through my research, I hope to contribute to discussion and development of DI concepts by applying them to recent EV market developments. In particular, I hope to show that certain low-end automobiles (both ICE and electric), along with Tesla Motor's product strategy, may be exceptions to current DI theory. Although Tesla's innovations match with many characteristics of Disruption, the company's business model has targeted the most demanding customers, as opposed to standard DI practice of going after the low end of the market. Other researchers, similar to Schmidt & Van Der Rhee (2014) and Utterback & Acee (2005), may be able to search for any other such examples of Disruptive Innovations and companies 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 changes in 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).

Other research opportunities include expanding this research to other markets, beyond focusing on just Japan and the United States. Some candidates

include Scandinavian countries such as Norway which have very favorable government policies towards EVs (Mock & Yang, 2014). Any discussion of the future of the automobile industry should also include the massive potential of the Chinese and Indian markets.

Also, while this paper has focused strictly on ICE and Battery EVs, analysis of Plug-in Hybrid Vehicles (PHEVs) could be another source of insight. The ability of PHEVs to switch from electric-only to hybrid operation complicates matters, but another researcher may be able to apply this technology to existing disruptive frameworks. Alternatively, analysis of Hydrogen FCVs as disruptive (rather than sustaining, as has been argued in this paper) may also be another potential avenue.

The main example of an industry newcomer in this report was Tesla Motors, which has had an uncommon level of success in developing and selling brand new automobiles. Such success has certainly been the exception, rather than the rule, for new car companies. Therefore, research and analysis into other EV newcomers, whether they were successful or failures, may also add new insights.

The efficacy of the “Jobs to be Done” model of marketing Disruptive Innovations may also be another potential area for future research. A more

marketing-focused look at this topic could reach valuable insights. However, as it is a key part of the foundation of Christensen's DI theory, modifying it may prove to be difficult.

Additionally, further marketing research and surveys could be undertaken to see if consumers really are experiencing "performance oversupply" with current automobiles, and under what circumstances they would be willing to drive a car that "doesn't go very far or very fast". Other topics could include just how far consumers are willing to go before they consider a small, cheaper automobile as unsafe or not fitting their personal image. Such an answer could unlock the key to a breakthrough for mini EVs.

Depending on future battery technology developments, a true 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 disruptive electric vehicle. Until that time, researchers will have to keep an eye out for technology developments that could make this a reality.

Appendix A. Data for Figure #3 (Fuel Mileage & Acceleration)

Make	Model	MPG/eMPG	0-60 Accel.
BMW	M5	16	3.7
BMW	i3	124	7.2
Bugatti	Veyron	10	2.7
Cadillac	CTS-V Wagon	16	4.1
Chevrolet	Corvette	21	3.9
Chevrolet	Spark EV	119	7.5
Fiat	500e	116	9.1
Honda	CR-Z	37	8.4
Honda	Civic	33	8.8
Honda	Accord (4-cyl)	30	7.6
Mercedes	S63 AMG	18	3.7
Nissan	Leaf	114	10
Nissan	GT-R	19	2.7
Porsche	Panamera Turbo S	18	3.5
SRT	Viper	15	3.5
Subaru	BRZ	25	6.4
Tesla	Roadster	105	3.7
Tesla	Model S (85 kwh P)	89	3.9
Toyota	Prius	50	10.1
Toyota	Camry (4-cyl)	28	8.1

Sources: www.fueleconom.gov, *Motor Trend* website

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http://www.motortrend.com/roadtests/oneyear/wagons/1212_2011_cadillac_cts_v_sport_wagon_verdict/viewall.html
http://www.motortrend.com/roadtests/coupes/1301_2014_chevrolet_corvette_stingray_first_look/
http://www.motortrend.com/roadtests/alternative/1309_2014_chevrolet_spark_ev_2lt_first_test/
http://www.motortrend.com/roadtests/alternative/1304_2013_fiat_500e_quick_drive/
http://www.motortrend.com/roadtests/coupes/1202_mini_cooper_vs_scion_tc_vs_honda_crz_vs_volkswagen_beetle_vs_hyundai_veloster_vs_fiat_500_comparison/viewall.html
http://www.motortrend.com/roadtests/sedans/1401_2014_honda_civic_ex_l_first_test/
http://www.motortrend.com/roadtests/sedans/1305_2013_honda_accord_sport_toyota_camry_se_2014_mazda6_grand_touring/viewall.html

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http://www.motortrend.com/roadtests/oneyear/coupe/1401_2013_subaru_brz_limited_verdict/viewall.html
http://www.motortrend.com/roadtests/convertibles/112_1004_2010_tesla_roadster_sport_2011_porsche_boxster_spyder_comparison/viewall.html
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