INERROGATING VARIABLES AFFECTING CONSUMERS' EV PURCHASING DECISION

Unsupervised Classification and Ethnographic Decision Tree Approach

By

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Abstract

Interrogating Variables Affecting Consumer's Electric Vehicle Purchasing Decision: Unsupervised and Ethnographic Decision Tree Approach.

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Masters of Business Administration (MBA), 2015

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This paper takes a multi-step approach to answer the research question “What are the factors that affect the consumers’ EV purchasing decision-making process and how do they affect it?” In order to answer this question, this paper studies consumer data from the last 15 years. Using Hierarchical cluster analysis, this paper shows how the importance of the factors changes over time. A predictive model has been developed using Ethnographic Decision tree Modeling (EDTM) for the decision-making process of the owners of the 4 top selling EV. The top selling EVs includes models of Nissan Leaf, Tesla, Chevy Volt, and Toyota Prius, from year 2009 to 2014. This EDTM model indicates that while consumers prefer variables such as gas requirement, performance and mile coverage over other variables when deciding to purchase an EV, when given several options of EV they consider other variable such as the environment, brand and country of vehicle production to be more important.

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Chapter 1: Introduction

This paper presents the study of the variables affecting consumers' Electric Vehicle (EV) purchasing decision-making process. This chapter discusses how the evolution of the car leads to air pollution and how EVs, along with other methods such as gas taxation and environmental laws, became a means to reduce pollution.

The need for transportation may have triggered the invention of the automobile in the 1700s but in time it has grown to be much more than just a mode of transportation. The car is an evolution of ideas and action (Dutton, 2006). There is no fixed point in history where the car was invented (Dutton, 2006). Leonardo da Vinci and Issac Newton may have theoretically invented self-propelled vehicles, but most historians attribute the honor of the first motorized vehicle to Nicolas Joseph Cugnot, an engineer and mechanic in the French Military (Dutton, 2006). Nicholas came up with a steam engine powered vehicle to transport cannons in 1769 (Dutton, 2006). In the late 19th Century, America started adopting automobiles. With a skilled and crafty labor process and elaborate aesthetic appearances, the prices of these cars were sky high. With the power of geographical mobility and an element to represent the social class, automobiles quickly became a unique signature for the upper class. This symbolism faced strong resentment from the lower-class; by the farmers, whose land was damaged by the wealthy auto owners' reckless driving on the land and livestock; and by the working class in the cities, who were disregarded by the wealthy automobile owners. But in the early 20th century the automakers started adding less expensive automobiles to capture the lower class. Gradually the mass production of automobile started. Fords and Olds were the most prominent mass producers of these cars (Gartman, 2004). With the mass adoption of automobiles, the status related to the ownership of a car transferred to the model of car, as the mass produced automobiles were clearly distinctive from the luxury cars in terms of design, quality, horsepower and materials.

In 1914 Henry Ford introduced a $5-a-day program in return for workers acquaintance to mass production. It was a transition from an agricultural economy to an industrialized economy which is referred as Fordism (Schoenberger, 1988). Fordism was often criticized as a dehumanizing and exploitative system due to its associated excessive work hours. To compensate for that criticism and make mass produced vehicles more acceptable to the mass population, the automotive industry implemented the luxury look into mass produced cars. In the 1960s, the government became aware of the environmental effect of Fordist auto mobility and in 1965 passed the Motor Vehicle Air Pollution and Control Act. The automobile industry was under pressure from both the consumers and the government and had to move away from a Fordist's production method to offer more vehicle choices to the consumers. The new rising diversified, non-class society demanded uniqueness. Hence a post-Fordist production method was developed where the automotive industry focused on economies of scope instead of economies of scale (Gartman, 2004).

Although the automobile had been around for centuries, the concept of the private car on a mass scale developed in the 20th century by the industrialized society. It started as an element of social status and prestige and by the end of the century it became a necessity, where it was more noticeable if a person did not have a car (Dant & Martin, 2001). In the last century one billion cars have been manufactured and as the number of cars increased, the effect of the car on the society and human became an area of interest to the social scientists. The car is a “good illustration of putative globalization” and is as important as other twentieth century technological cultures such as cinema, television and the computer contributed to global cities (Sheller & Urry, 2000). By the end of 20th century the automobile became a part of everyday life for different reasons. The number of passenger cars has increased sevenfold over the last 60 years and is showing signs of exponential growth with corresponding implications in air pollution and economy (Figure 1) (Renner, 2013).

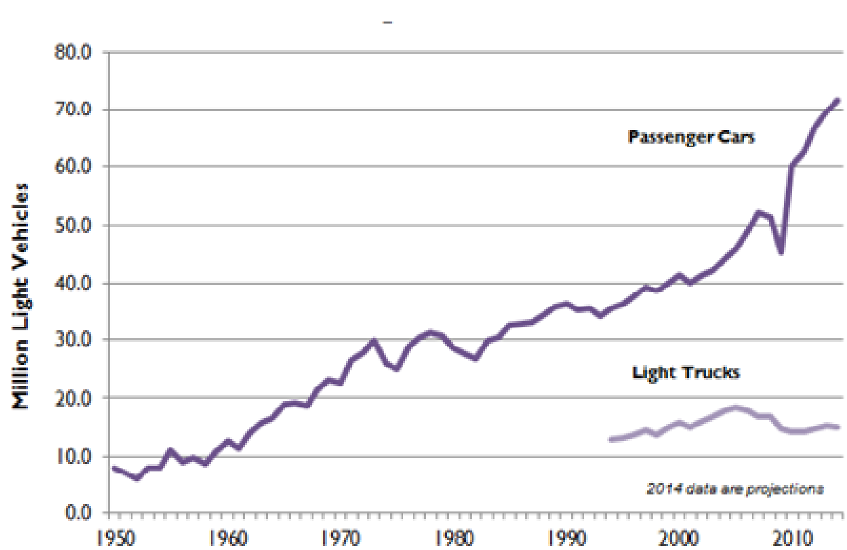

Figure 1: World Light Vehicle Production (1950-2014).

Source: AAMA; DRI-WEFA; IHS Automotive (Renner, 2013).

The first thing the private cars provided was the mobility. Auto mobility allowed people to travel longer distances in shorter periods of time. It provided people with the freedom to travel distances at their own convenience and in shorter time compared to the previous means of distance travel by train or boat. This simple innovative technology did not just changed the structure of the roads, it also changed the structure of the cities and the lives of people living in them. This simplicity divided workplace from the home, a shift that eventually led to the split between residential and business districts (Kunstler, 1994). Ultimately it led to the super-modern city car only environment where it is neither urban nor rural nor local nor cosmopolitan. It consists of a large geographical area where the drivers are insulated inside the car (Augé, 1995). Such an environment does not just affect the air quality of that area; it also affects human health (Augé, 1995). As a result, the effect of the automobile on the environment became a growing concern.

The rapidly increased number of the super-modern city car only environment led to the decrease in the air quality globally. Pollution is not a new problem to cities; pollution can be dated back to the middle ages, where air quality was affected by coal burning (Mosley, 2014). The industrialization of the 19th century, which was primarily based on coal energy, only accelerated the degrading urban air quality (Mosley, 2014). In the 20th century, along with coal power plants, internal combustion engine-powered vehicles added particulates and gaseous contaminates to the environment, making the air quality worse globally (Ponting, 1993). In 2004 transportation was responsible for 13% of global greenhouse gas emission (Figure 2) (United States Environment Protection Agency, nd). According to the EPA 35% of the 13% greenhouse gas that comes from transportation is largely from the gasoline and diesel (U.S. Environemental Protection Agency, nd).

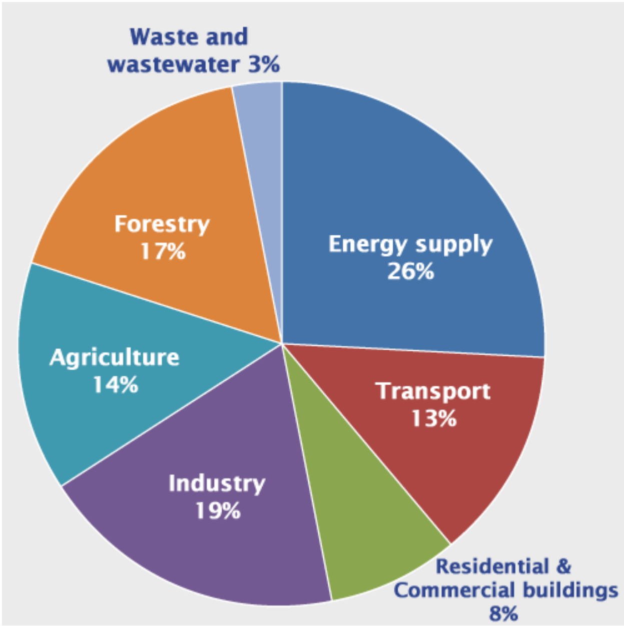

Figure 2: Global Greenhouse gas Emission by Source.

Source: IPCC (2007); based on global emissions from 2004. [1]

Increased air pollution gradually started affecting human health. Even before the role of transportation in air pollution became so prominent, the effects of air pollution were not unnoticed. The Clean Air Act of 1970 addressed the mobile sources of pollution. Several scientists found adverse effects of air pollution on human health, including increased mortality, increased child mortality, low birth rate, work loss and morbidity. Moreover, air pollution affects multiple

[1] Details about the sources included in these estimates can be found in the Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (United States Environment Protection Agency, nd)

organs of a human body including the respiratory, nervous, cardiovascular, urinary, and digestive systems (Wang, Ding, Ryan, & Xu, 1997). Maternal exposure to extreme air pollution leads to low birth rate, pre-term delivery, spontaneous abortion and eventually infant mortality (Bobak & Leon, 1992). A relationship between morbidity such as lung cancer, asthma, bronchitis and atherosclerosis to air pollution has also been shown to exist (Künzlia & Tagerb, 2005). Apart from human health, agriculture and wildlife are also affected by the increasing air pollution (Grulke, et al., 2008; Newman, Schreiber, & Novakova, 1992; Heagle, Body, & Heck, 1972; Fuhrera, Skärby, & Ashmore, 1992).

Because of such adverse effects of air pollution, which became worse with the increased number of the automobiles, the need to take an action against it became prominent. One of the ways it could be done was to reduce the emission from transportation sector that contributed to the air pollution significantly. Governments in North America have taken several steps to try to decrease the pollution caused by the transportation sector. Gasoline taxation is one of the approaches; but gasoline taxation has almost little to no effect on the use of gasoline driven vehicles, as the price of gasoline is still well under mass consumers' affordability. U.S. Energy information Administration shows a comparison between the demand for car travel and change in gasoline price (Figure 3).

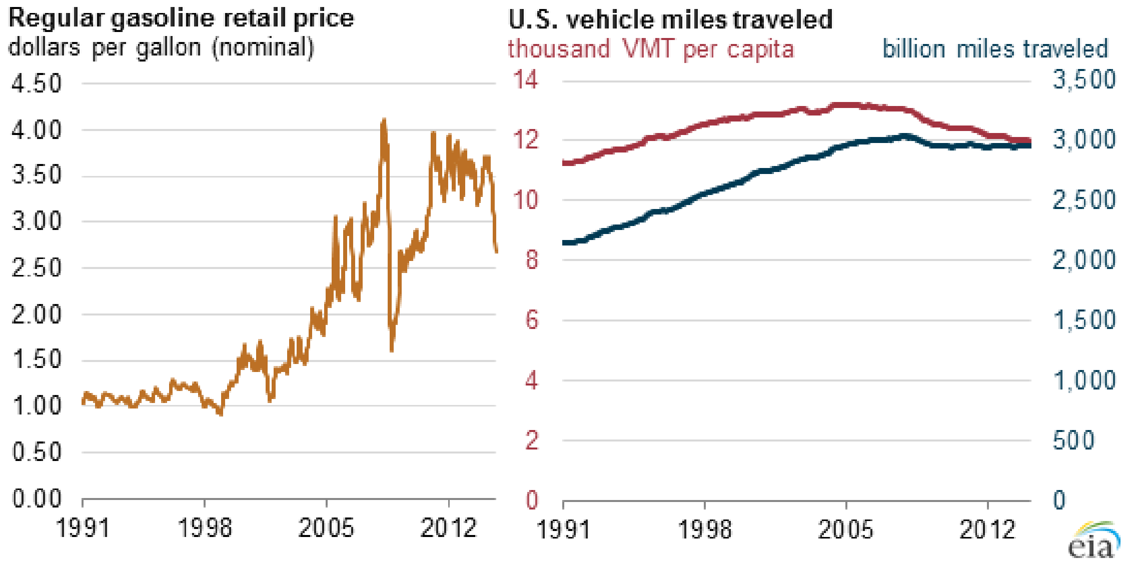

Figure 3: Gasoline prices tend to have little effect on demand for car travel.

Source: U.S. Energy Information Administration, based on Federal Reserve Bank of St. Louis (Morris, 2014).

Even if we consider more recent data from 2014, in the US the gasoline price fell 28% from $3.70 per gallon in June to $2.68 in December, however the price did not have much effect on automobile travel or gasoline consumption. In other words, in this economy, gasoline is an inelastic product hence change in price has little to no effect on demand (Morris, 2014). In contrast, Sipes and Mendelsohn believe that gasoline taxation is an effective way to manage air pollution because the higher gasoline price will encourage people to drive fewer miles and ultimately motivate consumers to purchase more fuel efficient cars (Sipes & Mendelsohn, 2001). This conclusion is based on 500 complete surveys. From these two contradictory arguments it can only be inferred that in a short period of time, increased gas taxation may not have an immediate effect on demand; however in the long run if the taxation continues, consumers will consider more fuel-efficient or alternatives to gasoline vehicles. However in order to actually motivate the consumers to consider the alternate or more fuel efficient vehicles, subsidy for those vehicles needs to be combined with gasoline taxation (Fullerton & West, 2010).

Fullerton and West found that gas taxation, also referred as pigovian taxation in the study, with the combination of new car subsidy and size subsidy can have 71% of the pigovian gain (Fullerton & West, 2010). A pigovian tax refers to “a special tax that is often levied on companies that pollute the environment or create excess social costs, called negative externalities, through business practices. In a true market economy, a pigovian tax is the most efficient and effective way to correct negative externalities” (Investopedia, nd). Pigovian gain in the study refers to the expected outcome of a pigovian Tax. However the choice of policy also depends on the welfare effects, distributional effect and administrative cost (Fullerton & West, 2010).

Along with the gas taxation and other approaches to reduce air pollution from the transportation sector, EV seemed to be a promising long term solution. Nonetheless to have the desired effect on a large scale, more consumers need to adopt EV over fossil fuel powered vehicles. The major barrier to EV adoption at a large scale seems to be how the consumers perceive EV as a means to reduce negative environmental impact. Hence the necessity to study the factors that affect the consumers’ decision to purchase the EV is vital in order to use EV as an effective method to reduce pollution and the negative impacts of pollution.

This paper takes a multi-step approach to answer the research question "What are the factors that affect the consumers' EV purchasing decision-making process and how do they affect it?" In order to answer this question, this paper studies consumer data from the last 15 years. There has been studies that analyzed the consumers' car purchasing decision making process for all types of vehicle in general including ICEs and EVs. For instance, McFadden, Daniel and Kenneth use a mixed multinomial logistic regression on a dataset that includes all types of vehicles in order to study the factors that affect the consumers' car purchasing preference. In this paper I take a closer look at the factors that affect the decision making process of only the EV owners. Using Hierarchical cluster analysis, this paper shows how the importance of the factors changes over time. A predictive model has been developed using Ethnographic Decision tree Modeling (EDTM) for the decision-making process of the owners of the 4 top selling EV. The top selling EVs includes models of Nissan Leaf, Tesla, Chevy Volt, and Toyota Prius, from year 2009 to 2014. This EDTM model indicates that while consumers prefer variables such as gas requirement, performance and mile coverage over other variables when deciding to purchase an EV, when given several options of EV they consider other variable such as the environment, brand and country of vehicle production to be more important.

Chapter 2: Literature Review

This chapter includes the background of the EV, what are the current technologies and why it is an important instrument to reduce pollution. This chapter also includes discussion on past studies on EV that help to understand that although there has been a significant number of studies in the area of consumers' perception, attitude and behavior; there is still a need for the study of the variables that affect their purchasing decision making process.

The most popular and widely used vehicle after gasoline vehicles is electric or hybrid cars. The purpose of the origin of electric cars was not to reduce pollution rather it was a stage in automobile evolution. It is believed by many that electric cars were invented over 100 years ago, then again lost its position of dominance to the gasoline cars or internal combustion engine (ICEs). There are many arguments regarding the effectiveness and efficiency EVs over ICEs. Both positive and negative opinions about the effect of EV on the environment exist in the industry of EVs; mostly because the environmental benefit of EV is still unclear (Hawkins, Singh, Majeau-Bettez, & Stromman, 2013). But the success of an EV depends on the acceptance by the consumers, not solely on the opinion about the environmental effect of EV. Factors such as vehicle price, acceleration, range, refueling cost, home refueling cost (the increased cost of electricity for charging the EV at home), and the size of the car matter to consumers when making their choice of an EV (Tompkins, et al., 1998). Additionally the factors that have importance in consumers’ EV purchasing decision-making process might not have the same importance after a few years.

2.1 EV Background

A review of the background of the electric vehicle suggests that similar to the automobile, there wasn’t a single point where EV came into existence. Different factors contributed to the series of evolution of EV and different countries developed the technology over different periods of time. Currently there are several technologies available for EV globally. This paper concerns the technologies that are used to compete with ICE vehicles. These EV technologies have been developed either with the combination of ICE to reduce the gasoline consumption, or completely replacing the ICE and the need for gasoline. The main types of technologies EV uses are Battery Electric Vehicle (BEV), Plug-In Hybrid Electric Vehicle (PHEV), Hybrid Electric Vehicle (HEV), and Extended Range Electric Vehicle (ER-EV) (Table 1) (Types of Electric Vehicle, 2014).

Battery Electric Vehicle (BEV) Example: Nissan leaf, Tesla Model S, Mitsubishi	
Plug-In Hybrid Electric Vehicle (PHEV) Example:, Ford Fusion Energi, Toyota Prius Plug-In	

Hybrid Electric Vehicle (HEV) Example: Ford Escape Hybrid, Toyota Prius Hybrid, Ford-C MAX	
Extended Range Electric Vehicle (ER-EV) Example: Chevy Volt	

Table 1: Types of Electric Vehicle.

Source: CAA

There are several other EV technologies that provide the vehicle with a maximum speed of 25 mph. Such vehicles are mostly used as campus vehicle, golf cart, or neighbourhood vehicles (Tennessee Valley Authority, nd). The use of the EVs and hybrid vehicles exist at a smaller scale compared to the petrol and diesel powered vehicles. However, in the long run, the EVs and hybrid vehicles are predicted to be on the rise. On the other hand the petrol and diesel fuel powered vehicles and the alternate fuel powered vehicles are predicted to decrease (Figure 4).

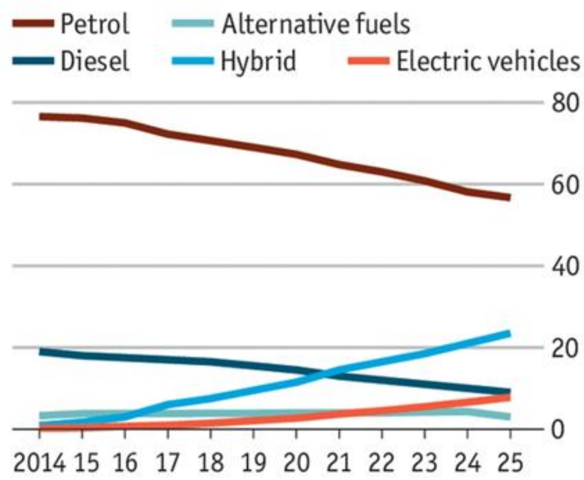

Figure 4: Global Car Sales by fuel type, Forecast. % of total.

Source: Exane BNP Paribas (The Economist, 2015).

2.2 EV as a means to reduce pollution

The transportation sector contributes to CO_2 emissions because of the use of ICE vehicles as the primary mode of transportation. According to the United States Environmental Protection Agency, CO_2 emissions from the transportation increased by 18% since 1990 (U.S. Environmental Protection Agency, 2012). The EPA recommends the electric or hybrid vehicle provided that the greenhouse gas emission from those vehicles is lower due to lower carbon or non-fossil fuel. According to the World Wildlife Fund (Canada's largest international conservation organization) in Canada, the greenhouse gas emission from the transportation has increased by 35% since 1990. WWF aims to replace all ICEs with EVs by 2050 in order to drastically reduce the greenhouse gas emission from transportation (World WIldlife Fund, n.d.).

According to the US department of Energy in North American EV industry, after several ups and downs in the late 1960s, the gas shortage sparked the interest in EVs. Then in 1990s, environmental concern drove the EV forward. US department of Energy recognizes that it is not easy to tell where the future will take EVs, but it is insistent that the EV has a lot of potential for creating a sustainable future. They also recognize that increasing EV dependency, US alone could reduce foreign oil dependency by 30-60 percent and pollution from the transportation sector by 20% (U.S. Department of Energy, 2014). In the first 10 years of 21^{st} century, there has been a significant increase in EV sales (Figure 5)

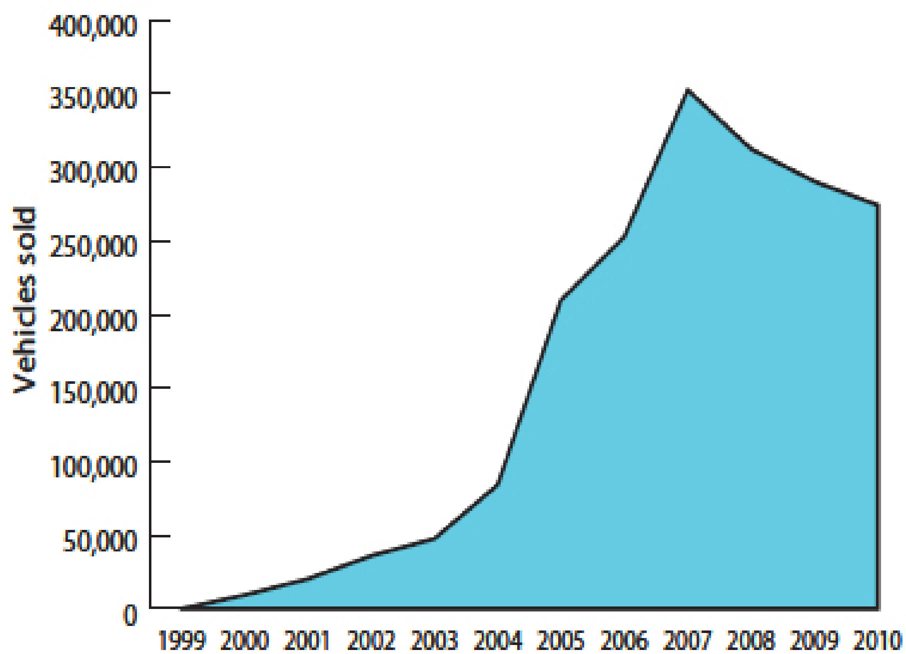

Figure 5: Sales of Hybrid Electric vehicles, 1999-2010.

Source: US Department of Energy, National Renewable Energy laboratory (Hamilton, nd).

To increase the sale of EVs in the US, the government has initiated an incentive program, where, if an EV is purchased on or before 2010, the owner is eligible for Federal tax credit up to $7500, depending on the technology, manufacturer, size and year of make of the EV (US Department of Energy, nd). In Canada, the rebate amount differs from province to province. In Ontario the rebate amount is up to $9500 (Canada Business Network, 2014) and in Quebec the amount is up to $8000 (Vehicules Electriques Quebec, 2014). Not only that, there are other incentives for EV charging stations and there are free parking spaces along with other initiatives to motivate Canadians to drive EV.

There are definitely controversies regarding the role of the electric vehicle on reducing global warming. For example, an all-electric car produces 3.6 times more soot and smog deaths than a regular gasoline power car (CNBC, 2014) so the pollution form the electricity production needs to be considered to make EVs more effective in reducing the pollution. The effectiveness of EV as a means to reduce pollution depends on the carbon emission of electricity production. If we look at carbon emission of the grid powered EV in different countries, Canada seems to produce the lowest carbon emission per km with grid powered EV with lightly fossil power dependency, whereas Mexico and US produces more with heavy fossil power dependency (Figure 6).

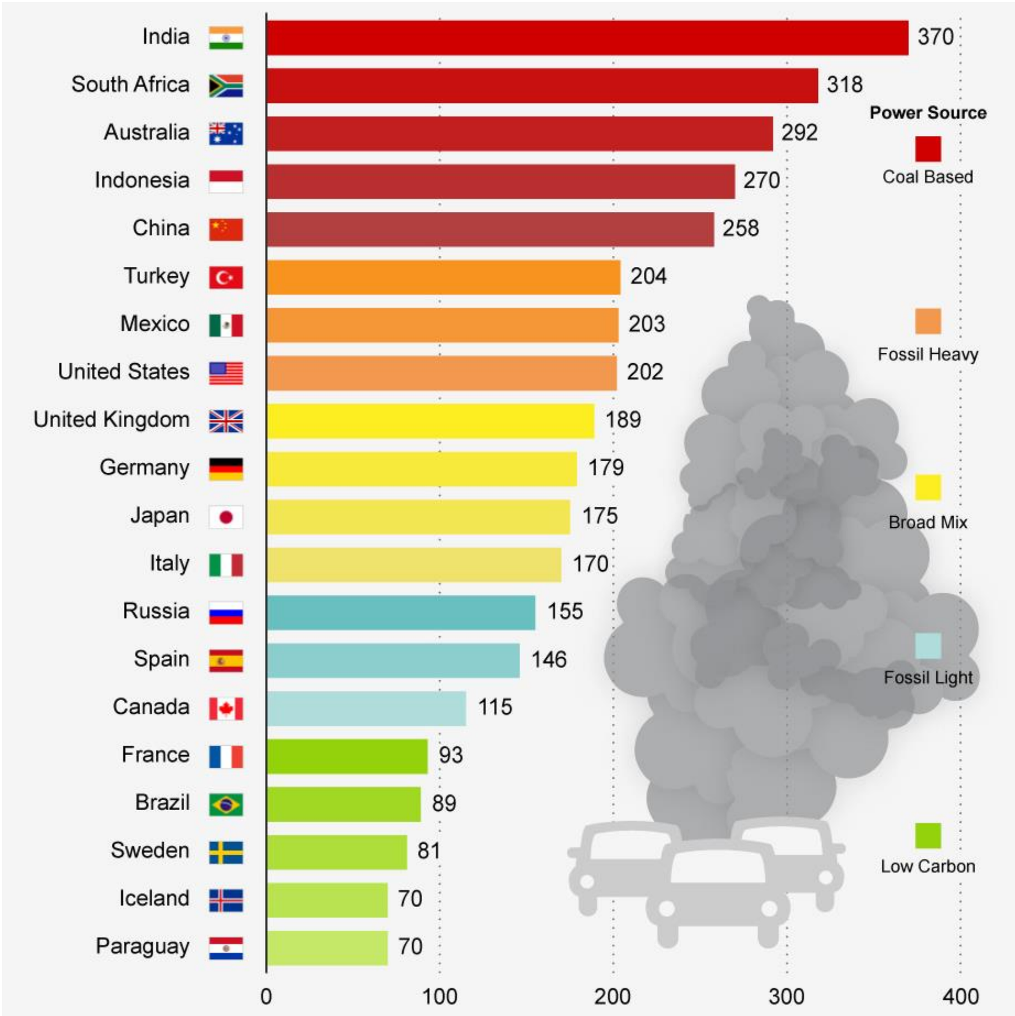

Figure 6: Carbon Emission of grid-powered EV by country (g Co2e/km).
Source: Statistica (McCarthy, 2013).

This means along with the Government incentives and rebates, it is also necessary to reduce fossil fuel dependency for electricity generation, in order to make EV an effective instrument to reduce pollution.

2.3 Existing studies on EV

Till today many studies had been done focusing on the consumers' attitude, perception, acceptance, buying behavior, and loyalty towards the alternate fuel vehicles. In 1981 Beggs, Cardeland Hausman used ordered logit model for their survey to assess the demand for EV and concluded that range is the variable that distinguishes EV from other vehicles according to survey respondents (Beggs, Cardel, & Hausman, 1981). In 1993, Bunch et al. found that the range and fuel cost are the most important factors in terms of fuel preference and depends on range between refueling, and fuel availability (Bunch, Bradley, Golob, Kitamura, & Occhiuzzo, 1993). However in 1994, in an exploratory study of EV demand in hybrid household, range did not appear to be an issue to adopt an EV. The range became "simply an artifact of consumer conservatism" when presented with a new technology (Kurani, Turrentine, & Sperling, 1994). In 1996 the environment started to get more attention in terms of choosing an EV while consumers started to relate range with their necessity. Kurani et al. suggests that positive environmental image of EV will make them more desirable to the consumers (Kurani, Turrentine, & Sparling, Testing Electric Vehicle Demand in Hybrid Household using a Reflexive Survey, 1996).

The government subsidies and government initiatives were introduced in the consumer preference of clean fuel vehicles studies in 2000. This study not only considers the government subsidies to promote EVs to consumers, but also the government initiatives to advance the EV industry by improving the technology (Ewing & Sarigollu, 2000). Kurani and Turrentine studied fuel economy in car purchasing behavior in 2006. Along with the monetary value of fuel price, they also identified an interesting fact that policymakers, automobile manufacturers and consumers pushed the EV design towards greater power, size, fuel consuming option and accessories assuming that “what consumers want” is the general. But in their study with the assumptions of their model they found that economic rationality is not a general concept in the population studied and it is not a sole sufficient model for car purchase and gasoline consumption (Kurani & Turrentine, 2007).

Looking at more recent studies, in 2011, Glerum et al. developed a model to estimate the future market share of EV in Germany by creating a choice situation involving EVs and ICEs and suggested the need for further studies on factors that drive consumers’ purchase choice (Glerum, Themans, & Bierlaire, 2011). In the same year, a study conducted on UK consumers, by Ozaki and Sevastyanova identifies the consumers’ motivation and adoption of EV as a complex picture and states the need for policy for a positive image of the EV to encourage EV adoption (Ozaki & Sevastyanova, 2011). In 2012, Moons and Pelsmacker extended the Theory of Planned Behavior with the emotional reaction and identified emotions as the strongest determinants for the EV usage intention in Belgium (Moons & Pelsmacker, 2012).

From all these studies on EV it is noticeable that the factors affecting the consumers’ intention, motivation or attitude towards EV changes over time.

In this paper I study the factors under consideration by consumers in EV purchase from 2000 to recent years and recognize the changes in the important factors over time. This does not only confirm the change in past consumers' decision making process but also indicates that it will keep evolving as EV technology develops and consumers include new variables to the process. I also developed a predictive model in order to understand why the top 4 selling EVs are consistently popular to consumers when the only thing that is common among them is that they are categorized as Electric. This study presents the fact that all EV owners do not think or prioritize the same way while making the decision to purchase an EV. Additionally there are multiple decision-making processes that lead to one specific type of EV. This represents the complexity and dynamics of consumers' decision-making process in purchasing an EV. The predictive model maps out the decision process of the consumers who own a Nissan Leaf, Toyota Prius, Tesla and Chevy Volt in the last couple of years. This study can be a guideline for other types of EV manufacturers to understand their consumers' decision-making process as well.

Chapter 3: Research Approach and Methods

This chapter includes the approach and methods that have been taken to understand the phenomenon related to the variables that affect the consumers' EV purchasing decision-making process. It also includes the scope of the research and a framework summarizing the research approaches.

3.1 Research Approach

To investigate the variables that affect consumers' Electric Vehicle decision-making process I have adopted a multi-step approach. There are 3 steps in total in this study. The first two steps give the reader an idea that the importance of variable changes over time and that is consistent with the findings in the literature review. The third study presents how the variables plays in the decision making process of the top 4 selling EV.

3.1.1 Scope of Research

This paper contains two studies, and an ethnographic decision tree. Study 1 is explanatory in nature and is based on quantitative data from 2000 to understand the relations among the variables that affected the purchasing decision of EV at that point of time. Study 2 is based on qualitative data and is used to understand if the importance of variables that affect EV purchasing decision, changes over time. Study 2 also helps to develop a predictive model to understand which variables are the best predictors of what type of EV a consumer will own. This paper also include a Ethnographic decision tree modeling based on the factors that affect the consumers' EV purchasing decision making process for the top 4 selling EV. This decision tree will allow EV manufacturer to better understand how their consumer is thinking in terms of choosing an EV and what specific variables play into that process and develop strategies to differentiate EV features from their competitors.

3.1.2 Research Question

Since the EV is used as a means to reduce the emission from transportation, the primary assumption of this paper is that the environment has a significant effect on the consumer's EV purchasing decision-making process. However with time the EV manufacturers are emphasizing on several factors other than just the vehicle being environmentally friendly. This paper tries to recognize the factors that affect the consumers' EV purchasing decision and to what extent it changes over time. It also tries to develop a predictive model that will explain how consumer choose a specific type of EV, and identify the factors that lead them to their decision. In summary with this paper, I attempt to answer the question "What are the factors that affect the consumers' EV purchasing decision-making process and how do they affect it?"

3.1.3 Research Framework

To answer the research question I take a multi-step approach. The multi-step approach of this paper includes two unclassified hierarchical cluster analysis and one Ethnographic Decision Tree Modeling. Several experiments with different parameters needed to be run to find the classification tree that best represents the hierarchical cluster. Then the variable importance of the clusters of both qualitative and quantitative studies has been considered to test the first hypothesis. I then develop a predictive model using Classification tree and identify the variable importance in the predictive model. Then I compare the variable importance of the predictive model with the variable importance of the cluster analysis of the qualitative data. This allows to test if the variables that affect the purchasing decision the most, are the same as the variables that can predict the type of EV or not. The framework of the research approach is presented in figure 7.

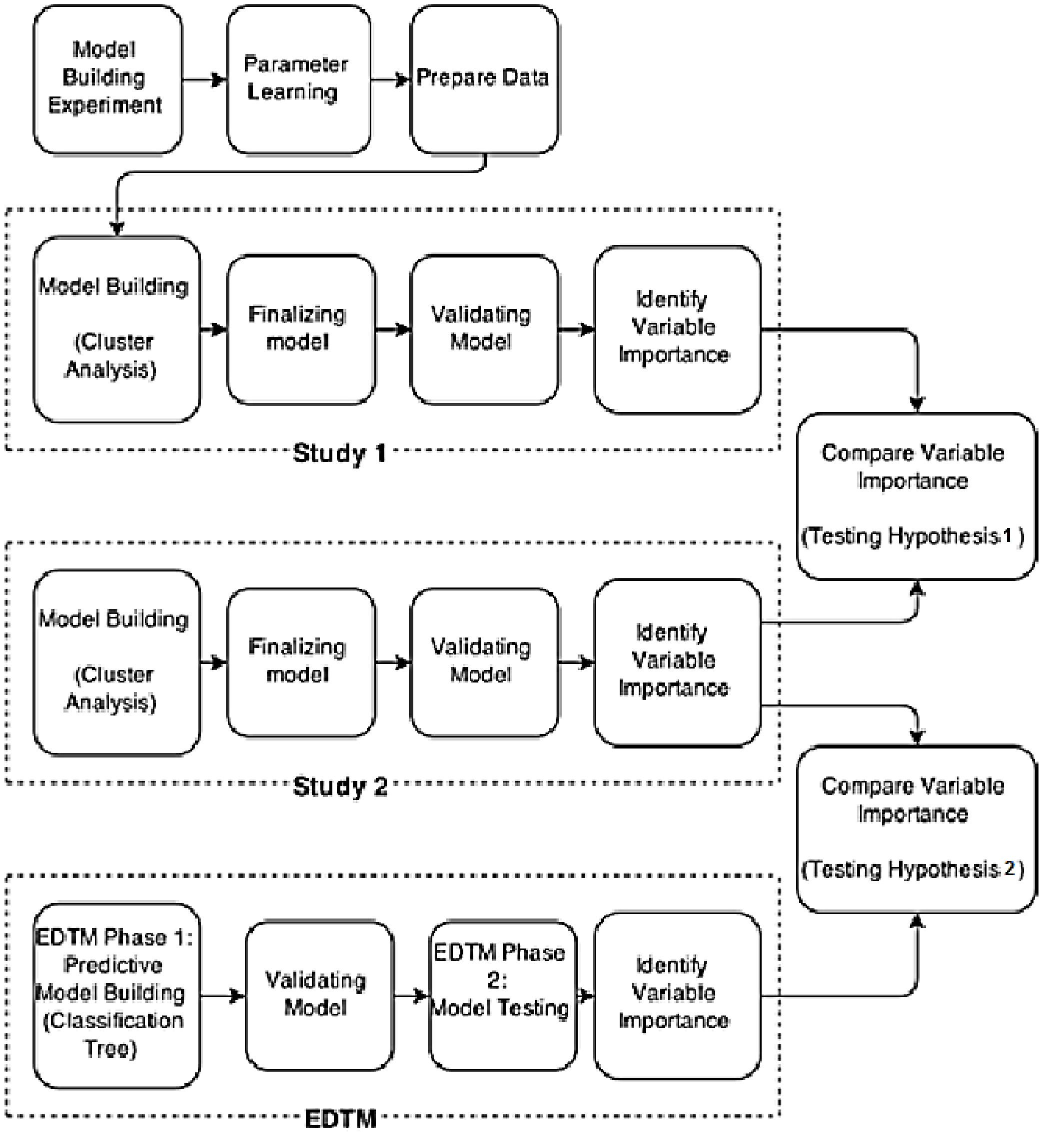

Figure 7: Research Framework.

3.2 Research Methodology

This paper uses a multi-method approach to interrogate the variables that takes part in the consumers' EV purchasing decision. I use a combination of Hierarchical Cluster analysis or unsupervised classification for the first two studies and compare the variable importance derived from these studies. I also use Ethnographic Decision Tree Modelling approach (EDTM), to develop a decision tree to better understand the roles of variables in the decision making process of top 4 selling EV.

3.2.1 Cluster Analysis

For study 1 and 2 the Hierarchical Cluster Analysis (also known as the Unsupervised Classification or hierarchy classification method) is used; with this method I was able to rank the variables that the consumers hold important with respect to EV.

Cluster analysis is an exploratory/inductive technique that classifies the data into groups without explaining the reasons behind the existence of the groups (Boslaugh, 2008). Cluster analysis divides a data set in to a number of subgroups based on the similarities of the objects within the groups (Gath & Geva, 1989). It is a widely used fundamental knowledge discovery process (Smyth, 1996). The application of cluster analysis in some areas is controversial mostly because it has the potential of finding inaccurate relationships in the groupings in a sample where there is no similarity in the sample. However, there is no other method available today that can provide an in-depth description of a data set without oversimplifying the model (Ketchen & Shook, 1996). The use of cluster analysis exists in consumer segmentation by their attitude (Machauer & Morgner, 2001), in identifying genome-wide expression pattern (Eisen, Spellman, Brownt, & Botstein, 1998), in biomedical engineering using microarray data (Sturn, Quackenbush, & Trajanoski, 2002). All of the studies aim to build a better understanding of a phenomenon by trying to understand the pattern and the relationships of the variables within the datasets.

Many algorithms have been produced in past research for cluster analysis. In general they can be divided into two classes: supervised and unsupervised clustering. In supervised clustering predefined vectoring is used and usually the researcher has prior knowledge of the cluster. On the other hand, in unsupervised clustering (which is used in this paper), no predefined vectoring is used and there is little to no prior specification or knowledge of the cluster (Kohonen, 2000; Eisen, Spellman, Brownt, & Botstein, 1998).

The Variable Importance and Variable selection are the two approaches that help in the choice of variables in cluster analysis. The variable importance assesses the relative importance of the variables as a discriminant variable or an interpoint distance. The variable selection approach is selecting a group of initial variables (Gnanadesikan, Kettenring, & Tsao, 1995). Green, Kim and Carmone used K-means clustering in order to identify important variables in 1990 in two separate data sets, wherein one of them identifying the important variable was dependent on the starting value (Green, Kim, & Carmone, 1990).

For the purpose of studies 1 and 2, I use a hierarchical clustering method (unsupervised classification). Charles Romesburg suggested a 4-step process for hierarchical cluster analysis (Romesburg, 2004).

Step 1: Collect data matrix

Step 2: Standardize data matrix

Step 3: Compute values of resemblance coefficient

Step 4: Use a clustering method that will result in a dendrogram or a tree.

In this paper for studies 1 and 2 I choose unsupervised hierarchical cluster analysis as I intend to group the respondents based on the factors they choose to purchase an EV.

3.2.2 Ethnographic Decision Tree Modeling

Hierarchical Cluster analysis helps to identify the important variables that affect the consumers' EV purchasing decisions, but that does not explain how the important variables affect the decision making process. In order to understand the effects of the variables I decided to develop an Ethnographic Decision Tree Model.

The EDTM approach is a method that is used to understand the criteria that affect the decision making process of a defined group (Gladwin C. H., Ethnographic decision tree modelling, 1989; Galdwin, 2001; Beck, 2005). It is a method for investigating, describing and predicting group behavior (Johnson &

Williams, 1993; Beck, 2005). The application of this modeling approach ranges widely in social, psychological, automotive, and medical studies (Beck, 2005). The EDTM model has flexibility to be used in diverse areas of studies and situations: Healthcare choice treatment of cancer patients (Montbriand, 1995), injection drug users; needle sharing (Johnson & Williams, 1993), treatment choice of childhood diarrhea (Ryan & Martínez, 1996), choice modeling of hurricane evacuation (Galdwin, 2001), modeling of auto choice (Gladwin & Murtaugh, 1984), etc.

Christina Gladwin suggested a two-stage process of decision-making (Beck, 2005).

Stage 1: Pre-attentive process, where the decision-makers eliminate the decision criteria unconsciously. In this stage the decision-makers are left with a smaller number of criteria (Gladwin C. H., Ethnographic decision tree modelling, 1989).

Stage 2: Maximization subjects to constraints, where the decision makers choose from the remaining criteria consciously. This is based on a choice principle of microeconomics where the alternative that passes all of its constraints gets chosen, if not the second alternative gets chosen (Gladwin C. H., 1976).

EDTM is based on the principle that decision-makers are the experts on the process of their decision. So the EDTM tries to understand their perspective rather than the researchers' perspective on the process. Gladwin proposed a two-step method for EDTM.

Step 1: Model Building, where the researcher:

- identifies the decision to be studied
- specifies a set of decision options or alternatives,
- conducts interviews,
- takes into account the participants' observation,
- decides on the number of observations to build the model
- selects decision criteria
- builds individual decision model using the criteria, and
- combines individual decision models to develop a group decision model

Step 2: Model Testing, Where the researcher:

- designs questionnaires to test the model
- decides on the sample size to test the model
- eliminates data about the decision outcome before the participants are asked the survey questions.
- identifies when the model is in error
- calculates error rates and success rate
- analyzes error, and if needed then modifies the model
- tests the modified model, and compares the model performance with the original model

Galdwin recognizes that people sometimes do complicated tradeoffs and occasionally has only one option to accept without calculation (Galdwin, 2001). Beck recognizes that the inclusion of both positive and negative cases helps in valid classification of decision criteria (Beck, 2005). However, in many cases real life decisions are not limited to positive and negative options only. In terms of this study, at one decision point consumers might consider whether or not to buy to buy an EV. But once they are past that point they have the option of which one to buy. Hence in this paper I attempt to develop a predictive model based on the EV owners' reviews to predict the decision making process that leads to a specific types of EV.

3.3 Research Hypothesis

Consumers have options to switch to EV more now than ever. With the increased concern of environmental sustainability, manufacturers are also emphasizing reduced greenhouse gas emissions. The tailpipe emissions for all types of EV are not the same (U.S. Environemental Protection Agency, nd). It is true that in the 1990s, environmental concern drove EV technology forward (U.S. Department of Energy, 2014). But ultimately it is consumers who decide if the environment is truly an important factor then purchasing an EV. If not the most important factor, with the growing concerns of greenhouse emission and EV technology advancement, the environment should be one of the most important variables that affect the consumers' EV purchasing decision. I present the hypothesis as:

H1: Environment is one of the top 3 criteria for choosing an electric vehicle regardless of time.

To test this hypothesis, this paper compares variable importance in the cluster analysis from two different studies.

Apart from environmental factors, there are other factors that affect a consumers' EV purchasing decision. Each EV has its own underlying features and consumers' demand for each EV depends on the consumers' evaluation of the features. Several studies presented the consumers' stated preference and attitude on alternate fuel vehicles including electric vehicle in order to forecast their demand (Train, 1980; Brownstone, Bunch, Golob, & Ren, 1996; Alvarez-Daziano & Bolduc, Canadian consumers' perceptual and attitudinal responses toward green automobile technologies: an application of Hybrid Choice Models, 2009). Alvarez-Daziano and Bolduc went one step further. They did not just forecast the individual preference; they also recognized the importance of cognitive factors (Alvarez-Daziano & Bolduc, Canadian consumers' perceptual and attitudinal responses toward green automobile technologies: an application of Hybrid Choice Models, 2009). Later they incorporate pre-environmental factors in their previous discrete choice model, and shows that the results of the hybrid model does not only performs better but also build a profile for consumers who are concerned about the environment (Alvarez-Daziano & Bolduc, 2010). So environmental factors are important, however other factors play important role on their preference too. There is also a difference between EV consumer preference and what they actually buy. In other words, the factors or the reasons consumers' consider to be important to buy an EV do not always have the same importance while they are purchasing an EV. Lane and Potter address this issue by identifying poor knowledge as a reason for the gap between attitude and action regarding EV (Lane & Potter, 2007). Then again, when the knowledge gap does not exist, the general perception and factors considered to be important in order to purchase an EV differ from the actual combination of the factors that leads the consumers to a certain types of EV. I simplify the hypothesis as:

H2: The most important variables are the best predictors of which type of EV a consumer will own.

This hypothesis will allow to test the existence of the difference between the EV owners' general perception about why they bought the EV and why they bought a particular type of EV. It will also allow us to understand the role of the variables in the constantly top 4 selling EVs.

Chapter 4: Empirical Studies

In this chapter I present the empirical analysis procedure of the two studies of this thesis. To avoid repetition I present the data analysis procedure once, the reader will recall that study 1 and 2 investigates if Environment is one of the top 3 criteria for choosing EV, regardless of time. To test the hypothesis, Unsupervised Classification and regression tree method were used, including both qualitative and quantitative data from two different time point to understand the importance of the factor “environment” in their decision-making process.

Study 1 and 2 - Data Analysis Procedure

Tree Building:

To build the trees for study 1 and 2, I use the unsupervised Classification and Regression Tree (CART) in order to find the clusters of similar sets of groups without over specifying the model. In cluster analysis the software will group the related variables together minimizing the statistical variance within the group but maximizing the statistical variance among the groups (Ketchen & Shook, 1996).

In unsupervised learning, which is also known as Breiman’s scrambled Column there is no need to set the target variable.

The tree growing method is set to default for classification, which is Gini index, simply because it is recognized as the best splitting rule. Morgan recognizes Gini as the best single measure of inequalities (Morgan, 1962) and

Gastwirth shows that the correlation of the accuracy of Gini index and the proper grouping of the data is high (Gastwirth, 1972).

The minimum nodes are selected through trial and error. The parent node and terminal node are selected small enough to include all variables and large enough to keep the tree simple and easy to read.

To find the importance of the variables this paper does not do any independent testing on the first two studies. The trees on the first two studies are exploratory trees.

Tree Validation:

First, the relative cost/relative error curve needs to be considered to validate the tree. The Relative cost ranges from 0 to 1; 0 indicates that the tree is a perfect fit with no error and 1 represents random guessing. The relative cost can exceed 1, which means the performance of the tree is worse than random guessing. A tree with 0 relative cost is too good to be true and usually includes an inappropriate predictor in the model.

The area under the ROC curve also needs to be considered. The ROC stands for Receiver Operating Characteristics. The value of the ROC curve also ranges from 0 to 1, the higher value indicates to a better performing model (Kareem, Raviraja, Awadh, Kamaruzaman, & Kajindran, 2010). The minimum acceptable ROC is 0.70. 0.80 - 0.90 is considered to be excellent ROC, and 0.90 is considered to be outstanding ROC (Curtis & Drennan, 2013; Hosmer & Lemeshow, 2000).

In the unsupervised learning and cluster analysis a copy of the original data is made by shuffling the variable to make sure that there is no correlation (linear or nonlinear) in the data. A good model should be able to predict which observation belongs to a copy set and which observation belongs to the original set (Steinberg, Unsupervised Learning and Cluster Analysis with CART , n.d.).

Chapter 5: Study 1 - Quantitative study

The first study is used to test hypothesis 1. The purpose of this study is to compare the differences in the importance of variables that affect the consumers' EV purchasing decision. The dataset is quantitative in nature.

5.1 Dataset

The dataset used for this study is a subset of the dataset used in Mixed MNL models for discrete response study by McFadden, Daniel and Kenneth in 2000 (McFadden, Daniel, & Kenneth, 2000). The original dataset consists of 4654 observations from the United States. For the purposes of this study, only the 1492 observations that are electric by fuel type were used. There are 8 variables used in this data set. For the purpose of comparing study 1 and study 2, some of the variable names were changed.   The format of the dataset is presented in table 2:

Variable Name (original dataset)	Variable Name (Study Dataset)	Operational definition
Price	Price	Price of the vehicle divided by the logarithm of income of the respondents.
Range	Mile coverage	Hundreds of miles vehicle can travel between recharging/refueling
Acceleration	Acceleration	Tens of seconds required to reach 30 mph from stop.
Speed	Speed	Highest Attainable speed in hundreds of mph.

Pollution	Environment	Tailpipe emission
Size	Size	-Ranges from 0 to 3 where 0 represents mini -1 represents subcompact, -2 represents compact and -3 represents mid-size or large vehicle.
Cost	Fuel Cost	Cost per mile of travel
Space	Interior space	Space for luggage inside the vehicle.

Table 2: Study 1 dataset format

Source: (McFadden, Daniel, & Kenneth, 2000)

5.2 Findings

With the unsupervised learning the software made a copy of 1491 observations by scrambling the variables so that no correlation exists in the data set. Then the tree is built on 2982 observations, 50% of which is the original data and 50% of which is the copy data.

With parent node minimum cases set to 20 and terminal node minimum cases set to 10, I get a tree that has a relative cost of 0.50973. It is acceptable as it is not too close to 1 or 0. 0.80770 represents a good ROC, which makes the model acceptable. The overall misclassification rate is 0.25486 which means approximately 25.486% observations under the curve are misclassified. Summary of the model error measures are presented on table 3:

Name	Learn
Average Log Likelihood (Negative)	0.52003
Misclassification rate Overall	0.25486
ROC (Area Under Curve)	0.80770
Lift	1.69909
Class Accuracy (Baseline Threshold))	0.74514
Relative cost	0.50973

Table 3: Summary of Model from Study 1.

Variable Importance

The variable importance represents the measurement of the importance of a variable in construction of the tree. It includes the frequency of the variable that has been used in the tree and the fraction of data passes through the certain variable node (Steinberg, 2013; Gnanadesikan, Kettenring, & Tsao, 1995). To calculate the variable importance, the score for every split is computed, then the scores across all splits are added and then the final score is normalized so that the highest scoring variable is scored 100 (Steinberg, 2013).

The normalized variable importance of the quantitative data are presented on Table 4:

Variable	Score
Size	100.00
Environment	42.2649
Price	29.6872
Speed	12.9772
Mile Coverage	4.5732
Acceleration	2.4801
Fuel Cost	0.9969
Interior Space	0.00

Table 4: Variable Importance from study 1.

From the normalized variable importance, it is apparent that in this dataset of 1491 observation from 2000, environment is one of the top 3 variables that affect the reason for purchasing an EV.

Other details for this cluster analysis are presented on the Appendices (Table 14, 15, and 16).

Chapter 6: Study 2-Qualitative Study

Study 2 is based on qualitative data. This study is used to test hypothesis 1 by comparing with the findings from study 1. It is also used to test hypothesis 2 by comparing with the findings from the EDTM study.

6.1 Dataset

I have used qualitative data for study 2. To collect the data, I started with this question in mind: what are the criteria a buyer considers before buying an electric vehicle. From this preliminary search I have found seven responses where the consumers mentioned their reasons for buying an EV regardless of the vehicle type or brand. This preliminary search has also helped me to narrow down the choices of vehicles most consumers prefer, which are Toyota Prius, Nissan Leaf, Chevy Volt and Tesla (Regardless of the year and models). And according to Inside EV, an organization that tracks the monthly sales of all EV worldwide, these 4 vehicles were the top performer in 2014 in the US alone (Inside EV, 2014)(see Appendices Table 12). I then steered my search to these 4 models and collected the reviews that specifically mention the reasons why consumers bought these vehicles, and/or what they like about these vehicles. I excluded the responses that were related to other aspects of the vehicle, such as technical reviews, complaints and comparisons with other vehicles. The reviews are dated from 2010 to 2014. Table 5 shows the structure of the dataset.

Data Type	Number of Reviews	Data Source
General Electric Vehicle Review	7	1. Inside EVs 2. Eco Car Forum 3. Clean Technica 4. Tesla Motors 5. Consumer reports.org
Reviews on Toyota Prius	40	1. Prius Forum 2. Cars.com 3. Consumer reports.org
Reviews on Nissan Leaf	55	1. My Nissan leaf 2. Cars.com 3. Consumer reports.org
Reviews on Tesla	70	1. Tesla Motors 2. Cars.com 3. Consumer reports.org 4. Teslamotorsclub.com
Reviews on Chevy Volt	40	1. GM volt 2. Cars.com 3. Consumer reports.org

Table 5: Study 2 Dataset overview.

6.2 Data Coding

To code the narrative reviews and find out the reasons for buying EV I used HyperRESEARCH software. First, I examined each of the cases carefully to look for the key words or the themes of the key words. Then I coded the themes in each responses using Hyper Research Software. I then categorized the codes according to the concepts of the frameworks. To ensure reliability table 6 presents the primary codes, operational definition of the codes and examples.

	Primary Code	Operational Definition	Example
1	Affordability	Affordability of an EV includes Monthly payment amount, Down payment amount, Finance Rate (APR), and the Contract Length. (Car Max, n.d.)	- After researching the Electric Vehicles (EVs) I was impressed with the low cost of the Nissan Leaf with the government rebate and low sticker price.
2	Battery Life	Battery life of an EV indicates the longevity of the Battery installed in the Vehicle till it needs to be replaced. (Cobb, 2014)	- The Model S lithium-ion battery (the "Battery") is an extremely sophisticated powertrain component designed to withstand extreme driving conditions. You can rest easy knowing that Tesla's state-of-the-art Battery is backed by this Battery Limited Warranty, which covers the repair or replacement of any malfunctioning or defective Battery, subject to the limitations described below.
3	Brand	Refers to the consumer's loyalty to the manufacturer or the concept of the manufacturer of the vehicle as being prestigious or reliable.	- Elon & Tesla's vision, totally bought into it.
4	Design	The appearance, color, structure or aesthetic value of the vehicle.	- "Many people have stopped me while I am parked and asked if this was the new Tesla and that it looked so cool."
5	Ease of Charging	Ease of charging includes the availability of a charging points, and the frequency of the need for charging. It is also relatively connected to the distance traveled and the frequency of use of the vehicle.	- "Easy to recharge at home or on the road"
6	Environment	Consumers' concern regarding greenhouse gas emission from	- "I have been to the gas station ONLY once since I

		both the tailpipe of the vehicle and from electricity production.	purchased the vehicle nearly 1 month ago and my carbon footprint has been lowered.”
7	Functionality	Functionality refers to the consumers’ transportation necessity met by the vehicle.	- “We drive ours 30-60 miles per day running errands, getting groceries, picking up kids, visiting parents... and this car is PERFECT for that use scenario”
8	Gas Requirement	Gas requirement refers to the frequency of fossil fuel required by the vehicle. Fossil fuel includes natural gas or petroleum such as gasoline, diesel or fuel oil.	- “Since I got it in July I've only put gas in 2 times, which seems great to me”
9	Government Incentive	Incentives provided by the government to encourage the use of EV. These incentives can be rebates, tax credit, or free parking. (Electric vehicle incentives arroud the world, n.d.)	- “When you take into account the federal tax credit and, if you're lucky, state tax benefits, buying the standard model Prius PHV is actually competitive with a regular Prius III-V.”
10	Interior Design	Interior design refers to the placement; texture, pattern, material and color contrast used and shape of panels, seats, and door trim. Although consumers are able to customize and upgrade the interiors, the manufacturer or the dealer needs to make these options available.	- “The all 4 1-touch up & down windows are a plus and all the controls and displays are superb.”
11	Interior Space	Interior space refers to the number of seats, comfortable seating and storage space in the vehicle.	- “It is comfortable and quiet (except for the backup warning sound- which is still a good thing!)”
12	Maintenance	Maintenance refers to the need to visit the vehicle dealer for inspecting, servicing or testing the car to ensure reliability, drivability and longevity of the vehicle.	- “We never have to stop at a gas station or get a tune up or OIL change.”
13	Mile Coverage	Miles covered in a single charge	- “ I am easily getting 85

		and/or without refueling the vehicle.	miles out of a full charge, and that includes highway driving with the A/C on in AZ”
15	Performance	The overall positive driving experience the consumer gets from driving the car.	- “performance - P85+ for me – WOW”
16	Political	The political statement a car represents both domestically and internationally.	- “I'm a Republican and Tea Party member and I love the car, love innovation and love this planet more than I do politics”
17	Price	The book price of the vehicle.	- “price...and am I really the only one? for me there isn't another car available, for the same TCO, that comes even close to delivering what my MS delivers.”
18	Safety	Safety refers to both the condition of the car and the passenger after a collision and the consumer’s belief of the car being safe even if the consumer did not face any collision or accident.	- “Safety. After the Consumer Reports review, and subsequently (after delivery) the NHTSA and the Tesla fire results - the car is a tank.”
19	Savings on Gas	Refers to the amount of amount of money the consumer saves per month or per year by switching to electric vehicle even after considering their electric bill.	- “Even After Paying for the electricity to fuel it, I am saving $350 per month on gas.” - “…And I am now saving $3200 PER YEAR by not buying gas.”
20	Speed	This includes both acceleration and speed the driver experiences with the Electric Vehicle.	- “My real love is its ability to accelerate at highway speed.” - “The acceleration of the electric motor from a stop is amazing”
21	Technology	Primarily refers to the type of electric vehicle but it also includes	- “Awesome leading-edge

		the use of other technologies that makes the vehicle more convenient and enjoyable.	technology”
22	Warranty	Warranty refers to the guaranty provided by the dealer or the manufacturer for the repair or remedy of the vehicle for a certain period for free of charge. (Car Warranty, n.d.)	- “I purchased a brand new 2012 Volt Premium at a heavily discounted price. Nonetheless, the vehicle came with a full warranty and the tax credit”
23	Where Produced	The place where the vehicle manufactured. It is in many cases related to the international political statement an electric vehicle represents.	- “North American made by new company with new revolutionary business model.”

Table 6: Concepts, definition and example of Study 2 Dataset.

6.3 Findings

Similar to the unsupervised learning with the quantitative data analysis, in qualitative data analysis, the software made a copy of 205 original observations by scrambling the variables.

With parent node minimum cases set to 10 and terminal node minimum cases set to 1, I get an explanatory tree with a relative cost of 0.38537. This explanatory model has ROC of 0.88884, which is considered to be a good ROC. A summary of model error measures are presented on table 7:

Name	**Learn**
Average Log Likelihood (Negative)	0.40725
Misclassification rate Overall	0.19268
ROC (Area Under Curve)	0.88884
Lift	2.0000

Class Accuracy (Baseline Threshold))	0.80732
Relative cost	0.38537

Table 7: Study 2 Model Summary.

Variable Importance of the qualitative data:

As I have already described how the variable importance is calculated, I will skip the description in this chapter. The variable importance of the qualitative data are presented in table 8:

Variables	**Score**
Gas Requirement	100.0000
Performance	57.7888
Mile Coverage	46.6649
Affordability	13.7204
Design	12.1403
Govt. Incentive	10.2075
Technology	9.1682
Maintenance	5.0589
Environment	3.8281
Speed	3.1850
Safety	2.9934
Brand	2.8728
Warranty	2.4509
Price	2.1466
Interior Space	1.9904
Battery Life	1.8812

Savings on Gas	1.8415
Interior Design	1.8184
Where Produced	0.8963
Ease of Charging	0.5074
Functionality	0.3565
Political	0.2010

Table 8: Variable Importance from Study 2.

From the variable importance table it is prominent that environment is not one of the top 3 variable that affect consumers' EV purchasing decision.

Other results of the qualitative data analysis are presented on the Appendices (Table 17, 18, and 19).

Chapter 7: EDTM

In the EDTM the research process is driven by the surveyed responses, not the researchers' hypothesis. It is a two-step approach where the process starts with the decision-makers eliminating the options that usually have a negative aspect on the decision-making process. Then the decision maker analyzes the remaining options and moves forward with the alternatives that best meet their needs (Gladwin C. H., Ethnographic decision tree modelling, 1989).

7.1 Data Analysis

EDTM Stage 1 Model Building:

As a part of developing the group model, first I decide that the decision options are the 4 types of EV that are Nissan Leaf, Tesla, Chevy Volt, and Toyota Prius. Then from the 205 reviews that I have used in the qualitative data analysis, I build the model. The details of the operational definition and examples related to this dataset are presented in Study 2 Qualitative Analysis dataset section.

The predictive model with 205 reviews has a relative cost of 0.24405, a ROC of 0.96765 and overall prediction success of 80.49%. This means that the model covers 96.77% of data and 80.49% accurately predicts the type of electric vehicle based on the variables. The details of the prediction success of the model are presented in the Appendices. The predictive model is quite large considering it contains 64 nodes, so I only discuss the testing of the model on a smaller data set.

For the simplicity of this paper I randomly choose the Chevy Volt to test the predictability of the model. To test the model for Chevy volt owners I develop a questionnaire:

Question 1: Is Design Important to you? Yes____ No____

Question 2: Is Battery life Important to you? Yes____ No____

Question 3: Is Technology Important to you? Yes____ No____

Question 4: Is Environment Important to you? Yes____ No____

Question 5: Is Gas Requirement Important to you? Yes____ No____

Question 6: Is Govt. Incentive Important to you? Yes____ No____

Question 7: Is Maintenance Important to you? Yes____ No____

Question 8: Is Safety Important to you? Yes____ No____

EDTM Stage 2: Model Testing

Since the accuracy rate of the model is relatively high, I decide to test the model by applying the model to a smaller data set of 59 reviews that I have set aside from before for testing purpose. I found that the relative cost is 0.14242 and the ROC is 0.96667. The prediction success is 86.44%. An adequate model for individual decision-making process can predict 85-90% of the individual choices in a group (Gladwin C. H., Ethnographic decision tree modelling, 1989). So based on the prediction rate this model is acceptable.

To test the model I start with the first decision point. Out of 59 observations, 16 EV owners considered design to be an important factor, and 43 people did not consider design as a first point of decision. From the 16 EV who said design is an important factor 68.8% of them are predicted to be Tesla Owner, 18.8% of them are predicted to be Toyota Prius owner, 6.3% are predicted to be Chevy volt and 6.3% are predicted to be Nissan Leaf owner.

Moving with the left side of the tree, after design I ask the second question and that is about Battery life. Of the 16 respondents who prefer design, none of them said they are bothered about battery life.

Then I ask the 3rd decision criteria, where 6 respondents said that they care about technology and 10 of them said they don't care about technology.

Moving forward with respondents who answered "No" to technology, next I ask the 4th question, environment. Of the 10 respondents, only one of them who didn't care about Technology did care about environment and that person is predicted to own the Tesla. 9 of the 10 respondents said "No" to environment, 1 of them are predicted to be a Chevy Volt owner.

Then I add the 5th Criteria where the respondents are asked about Gas requirement. 3 of the 3 respondents said they care about gas requirement. 1 of them is predicted to be Chevy volt owner and 2 of them are predicted to be Tesla owners.

Then I add the 6th criteria Govt. incentive, none of the 3 respondents said yes to Govt. incentives.

Adding the 7th criteria maintenance, 1 of the 3 respondents said they care about maintenance and that respondent is a Tesla owner. Of the 2 respondents who said maintenance is not important one of them is a Chevy Volt owner and one of them is a Tesla owner.

Finally I add the safety criteria, where the respondents who said safety is not important is predicted to be a Chevy Volt owner and the respondent who said safety is important is a Tesla owner.

The tree grows in different direction ending up with a terminal node with a prediction of the type of EV the respondent owns. It is 86.44% correct; the prediction success is presented on Table 9:

Actual Class	**Total Class**	**Percent Correct**	**Nissan Leaf N= 17**	**Tesla N= 17**	**Chevy Volt N= 8**	**Toyota Prius N= 17**
Nissan Leaf	15	86.67%	13	0	1	1
Tesla	22	77.27%	3	17	0	2
Chevy Volt	7	100%	0	0	7	0
Toyota Prius	15	93.33%	1	0	0	14
Total	59					
Average	89.32%					
Overall % Correct	86.44%					

Table 9: EDT Prediction success summary.

Chapter 8: Summary of Findings from Hypothesis

In this Chapter I test the Hypotheses based on the findings from the two studies and the EDTM.

H1: Environment is one of the top 3 criteria for choosing an electric vehicle regardless of time.

To test H1, I need to compare the variable importance of study 1 and study 2:

Rank	Variable importance of Study 1		Variable importance of Study 2	
	Variable	Variable importance	Variable	Variable importance
1	Size	100.00	Gas Requirement	100.0000
2	Environment	42.2649	Performance	57.7888
3	Price	29.6872	Mile Coverage	46.6649

Table 10: Comparison of Variable Importance from Study 1 and Study 2.

Table 10 shows that Environment is not one of the top 3 criteria for choosing EV regardless of time. Therefore I reject Hypothesis 1. In study two, the variable importance of Environment is 3.8281, so the importance of environment in forming the cluster in recent qualitative data is much smaller than the one in quantitative data from 2000.

H2: The most important variables are the best predictors of which type of EV a consumer will own.

To test this hypothesis I compare the variable importance of study 2 and variable importance of EDTM (see Table 21 in Appendices):

Rank	Variable importance from Study 2		Variable importance of EDTM Study	
	Variable	Variable importance	Variable	Variable importance
1	Gas Requirement	100.0000	Environment	100.0000
2	Performance	57.7888	Brand	99.2201
3	Mile Coverage	46.6649	Where Produced	93.4664
3	Affordability	13.7204	Technology	91.1443
4	Design	12.1403	Interior Design	88.8583
5	Govt. Incentive	10.2075	Maintenance	83.7270

Table 11: Comparison of Variable Importance from Study 2 and EDTM.

Table 11 shows that the most important variables are not necessarily the best predictors of what type of EV a consumer owns. Hence I reject hypothesis 2.

8.1 Discussion

I reject both hypotheses based on the comparison of the variable importance of the clusters.

The testing of the first hypothesis shows that with the development of the EVs, environment is not always an important criterion to the consumers. With time, changes in life-style, changes in the structure of the cities, and changes in competition within the automobile industry, consumers are presented with more criteria to consider now than they were before. To the consumers, the importance of those criteria are valued more now than the criteria that used to matter before. And from the overall literature review and the studies conducted in this paper, it is apparent that there is a very high possibility that not only the importance of these criteria will change in the future but also more new criteria will emerge in the consumers' EV purchasing decision making process.

From the second hypothesis it is clear that the consumers give importance to some criteria that they think are important to buy an EV, but when it comes to choose from several options where the EV differs in technology, price, size, mile coverage and in many other ways, consumers shift the importance to other criteria. So the decision-making process to buy or not to buy an EV is very different from which type of EV to purchase. Another important finding from this study is that different consumers follow different decision-making processes, although the end result may be that they own the same type of EV.

Chapter 9: Conclusion

Since the early age of EV development, EVs have had to compete with ICE vehicles in order to gain market share as a means of transportation. As EV developed over time, the consumers' preferences changed and so did their priorities not just for EVs, but for any type of vehicle they buy. The consumers' decision-making process is becoming more complex and it is no longer the case where EV owners' decision-making process is distinctively different than those of ICE owners'. From my observations it was clear that many consumers, who own an EV also own an ICE vehicle. The availability of EVs with different types of technology, size, shape, price range and other attributes has made any single type of EV equally competitive with the ICE vehicles; yet certain types of EV are constantly the top selling EV, despite their differences in technology, price, size and other features. It is clear that environment may not be one of the top 4 reasons to buy an EV, but to choose a certain type of EV, consumers' do consider the environmental impact of the vehicle.

In summary, this paper presents the role of environment as a factor in the EV consumers' decision-making process before and now, and gives a hint that the importance of the environment in the consumers EV purchasing decision making process will change in the future as well. This paper recognizes the difference in the decision making process of different types of EV owners. It also recognizes that one type of EV owner does not necessarily follow a unique decision making process. The predictive model presented in this paper, will allow the automotive companies to understand the decision making process of EV owners in North

America and also develop their EV models in the future by addressing the factor they lack now. Some factors such as Government incentives or political may not be within the manufacturers' influence but they certainly can improve their image by using the research to address factors such as safety, emission or range in product research and future marketing campaigns.

9.1 Limitations of this study

This study is not without its limitations. First of all the dataset for the first study doesn't have the equal number of variables used in the data set for Study 2. The reason for that is that in the study 2 data set, consumers had the options to add more variables that they thought was important to them to choose an EV. Secondly, Study 2 dataset doesn't differentiate if the EV is a primary or secondary vehicle although Hidrue et al. found that income and owning multiple vehicles is not important to consumers of EV (Hidrue, Parsons, & Willett Kempton, 2011). Thirdly, in this paper I only use data sets from 2 points of time to understand the difference in the importance of the environment due to the unavailability of specific consumer data related to the EV. Fourth, the geographical, financial and time limitations also led to collecting online reviews instead of conducting face to face interviews with EV owners. Finally, it was not possible to follow the size of observation to build the EDTM suggested by Gladwin, where she suggested using 20-60 observations to build the model, mainly because the choice in targeted variable was 4 instead of 2 and more observations needed to include in order to get the overall picture of the decision making process.

9.2 Future Research Recommendation

This paper may act as a guideline for future research on the EV purchasing decision-making process and EV development. For future research I suggest a comparison between motivational factors and purchasing factors. By comparing the factors that motivates the consumers to buy an EV, and the factors that drives the consumers' purchasing decision-making process; it be tested if the alignment of the factors at both stage will increase EV adoption.

I also suggest conducting the interviews including demographic factors such as age and sex with a structured and open-ended questionnaire where the consumers will be able to add more factors if they want to. Adding more factors to the studies will not only provide a broader perspective on the EV purchasing decision-making process, but also help the manufacturers to identify trends and factors that might affect the EV sales in the long run.

Policy makers should consider repeating such studies frequently to get more updated insights from consumers that will eventually help them to develop effective and efficient regulations and policies.

EV manufacturers should also conduct such studies at a broader scale in order to identify the factors that contribute to their success and failures. This will not only help them to develop their strategies to attract more consumers, it will also allow EV to be used as an effective means to reduce pollution.

Appendices

Table 12: EV sales in 2014 in USA

2014-US	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Nissan LEAF	1,252	1,425	2,507	2,088	3,117	2,347	3,019	3,186	2,881	2,589	2,687	3,102	30,200
Chevrolet Volt	918	1,210	1,478	1,548	1,684	1,777	2,020	2,511	1,394	1,439	1,336	1,490	18,805
Tesla Model S*	800	1,400	1,300	1,100	1,000	1,800	800	600	2,500	1,300	1,200	3,500	17,300*
Toyota Prius PHV	803	1,041	1,452	1,741	2,692	1,571	1,371	818	353	479	451	492	13,264
Ford Fusion Energi	533	779	899	743	1,342	1,939	1,226	1,222	640	686	752	789	11,550
Ford C-Max Energi	471	552	610	525	782	988	831	1,050	677	644	644	659	8,433
BMW i3	0	0	0	0	336	358	363	1,025	1,022	1,159	816	1,013	6,092
smart ED	97	122	186	203	206	278	298	208	182	150	313	351	2,594
Ford Focus Electric	100	129	177	116	177	197	198	264	176	186	191	53	1,964
Fiat 500e**	180*	185*	166	152	167	166	119	166	137	140	100	115	1,793**
Cadillac ELR	41	58	81	61	52	97	188	196	111	152	155	118	1,310
Toyota RAV4 EV	63	101	73	69	149	91	68	228	125	97	83	37	1,184
Chevrolet Spark EV	93	71	108	97	182	85	128	80	51	58	61	131	1,145
Porsche Panamera S-E	141	57	56	63	53	111	63	68	82	97	57	31	879
Mercedes B-Class ED	0	0	0	0	0	0	41	51	65	98	193	326	774
BMW i8	0	0	0	0	0	0	0	9	58	204	126	158	555
Honda Accord PHV	27	24	18	37	46	28	41	46	42	34	43	63	449
Honda Fit EV	30	33	37	50	33	38	42	55	29	23	5	32	407
Kia Soul EV	0	0	0	0	0	0	0	0	0	109	140	110	359
VW e-Golf	0	0	0	0	0	0	0	0	0	1	119	237	357
Mitsubishi i-MiEV	1	3	24	12	35	22	17	20	15	17	18	12	196
Porsche Cayenne S-E	0	0	0	0	0	0	0	0	0	0	45	55	100
InsideEVs	5,550	7,190	9,172	8,605	12,053	11,893	10,833	11,803	10,540	9,662	9,535	12,874	119,710
Worldwide*	14,512	18,528	24,267	23,153	25,016	31,162	27,304	29,804	33,611	29,020	26,825	37,511	320,713

2014 Monthly Sales Chart For The Major Plug-In Automakers *Estimated Tesla NA Sales Numbers – Reconciled on Quarterly Totals from Earnings Report (Q1 Sales reported @ 6,457-3,000 Intl Delivers, Q2 7,579 total-approx reported International registrations, Q3 7,785 total deliveries ~ 3,900 US) *Fiat 500e data estimated for Jan/Feb

Source: (Inside EV, 2014)

Table 13: EV sales in 2013 in USA

2013	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Chevrolet Volt	1,140	1,626	1,478	1,306	1,607	2,698	1,788	3,351	1,766	2,022	1,920	2,392	23,094
Nissan LEAF	650	653	2,236	1,937	2,138	2,225	1,864	2,420	1,953	2,002	2,003	2,529	22,610
Tesla Model S	1,200	1,400	2,300	2,100	1,700	1,350	1,300	1,300	1,500	800	1,200	1,500	17,650
Toyota Prius PHV	874	693	786	599	678	584	817	1,791	1,152	2,095	1,100	919	12,088
Ford C-Max Energi	338	334	494	411	450	455	433	621	758	1,092	941	827	7,154
Ford Fusion Energi	0	119	295	364	416	390	407	600	750	1,087	870	791	6,089
Fiat 500e*	0	0	0	0	0	0	200	360	450	400	430	470	2,310
Ford Focus Electric	81	158	180	147	157	177	150	175	110	115	130	158	1,738
Toyota RAV4 EV	25	52	133	70	84	44	109	231	167	91	62	28	1,096
Mitsubishi i-MiEV	257	337	31	127	91	39	46	30	20	28	12	11	1,029
smart ED	2*	0	0	0	60	53	58	182	137	111	153	167	923
Honda Fit EV	8	15	23	22	15	208	63	66	35	40	23	51	569
Chevrolet Spark EV	0	0	0	0	0	27	103	102	78	66	87	76	539
Honda Accord PHV	2	17	26	55	58	42	54	44	51	71	68	38	526
Porsche Panamera S-E	0	0	0	0	0	0	0	0	0	35	4	47	86
Cadillac ELR	0	0	0	0	0	0	0	0	0	0	0	6	6
InsideEVs	4,577	5,404	7,982	7,138	7,454	8,292	7,392	11,273	8,927	10,055	9,003	10,010	97,507

2013 Monthly Sales Chart for the Major Plug-In Automakers *Estimated Tesla Numbers have been included in this graph. Tesla Total US Sales Based On Quarterly Disclosures (Q1 & Q2 from filings, Q3 based on shareholder letter, and Q4 based on company estimate of half of sales out of North America) *Fiat 500e estimated based on available data.

Source: (Inside EV, 2014)

Table 14: Study 1 Quantitative Data Analysis Misclassification table

Class	N Cases	M Miss-Classed	Pct. Error	Cost
Copy	1491	412	27.63%	0.2763
Original	1491	348	23.34%	0.2334

Table 15: Study 1 Quantitative Data Analysis Prediction Success Table

Actual Class	Total Class	Percent Correct	Copy N= 1427	Original N= 1555
Copy	1491	72.37%	1079	412
Original	1491	76.66%	348	1143
Total	298200			
Average	74.51%			
Overall % correct	74.51%			
Specificity	72.37 %			
Sensitivity/Recall	76.66%			
Precision	73.50%			
F1 Statistics	75.05%			

Table 16: Study 1 Quantitative Data Analysis Root Split Table

	Competitor	Split	Improvement	N Left	N Right	N Missing
Main	Price	4.97431	0.00034	2219	763	0
1	Speed	102.500	0.00019	1447	1535	0
2	Environment	0.500	0.00012	1552	1430	0
3	Fuel Cost	7.000	0.00011	2335	647	0
4	Acceleration	5.000	0.00004	2098	884	0
5	Mile Coverage	375.000	0.00004	2678	304	0
6	Size	2.5000	0.00003	1330	1652	0

Table 17: Study 2 Qualitative Data Analysis Misclassification Table

Class	N Cases	M Miss-Classed	Pct. Error	Cost
Copy	205	38	18.54%	0.1854
Original	205	41	20.00 %	0.2000

Table 18: Study 2 Qualitative Data Analysis Prediction Success Table

Actual Class	Total Class	Percent Correct	Copy N= 1427	Original N= 1555
Copy	205	81.46%	167	38
Original	205	80.00%	41	164
Total	410			
Average	80.73%			
Overall % correct	80.73%			
Specificity	81.46 %			
Sensitivity/Recall	80.00%			
Precision	81.19%			
F1 Statistics	80.59%			

Table 19: Study 2 Qualitative Data Analysis Root Split Table

	Competitor	Split	Improvement	N Left	N Right	N Missing
Main	Gas Requirement	Yes	0.00117	124	286	0
1	Govt. Incentive	No	0.00101	335	75	0

2	Mile Coverage	Yes	0.00048	123	287	0
3	Technology	No	0.00048	277	133	0
4	Speed	No	0.00029	341	69	0
5	Environment	Yes	0.00029	91	319	0
6	Savings on Gas	No	0.00021	246	164	0
7	Ease of Charging	No	0.00021	318	92	0
8	Interior Space	Yes	0.00015	105	305	0
9	Where Produced	Yes	0.00015	35	375	0
10	Maintenance	Yes	0.00010	60	350	0
11	Performance	Yes	0.00010	170	240	0
12	Warranty	Yes	0.00005	7	403	0
13	Price	No	0.00002	378	32	0
14	Functionality	No	0.00002	398	12	0
15	Political	No	0.00002	374	36	0
16	Safety	Yes	0.00002	36	374	0
17	Brand	Yes	0.00002	50	360	0
18	Battery Life	Yes	0.00002	28	382	0
19	Affordability	No	5.94884E-006	347	63	0
20	Design	No	5.94884E-006	299	111	0

Table 20: EDTM Model Prediction Success

Actual Class	Total Class	Percent Correct	Nissan Leaf	Tesla N= 57	Chevy Volt N = 44	Toyota Prius

			N= 66			N = 38
Nissan Leaf	55	87.27%	48	3	1	3
Tesla	70	74.29%	8	52	7	3
Chevy Volt	40	82.50%	5	1	33	1
Toyota Prius	40	77.50%	5	1	3	31
Total	205					
Average	80.39%					
Overall % correct	80.00%					

Table 21: EDTM Model Variable Importance

Variables	Score
Environment	100.0000
Brand	99.2201
Where Produced	93.4664
Technology	91.1443
Interior Design	88.8583
Maintenance	83.7270
Savings on Gas	70.1083
Govt. Incentive	65.6366
Gas Requirement	64.0865
Political	62.6572
Battery Life	61.4779
Ease of Charging	52.5270
Speed	50.4889
Affordability	50.2053
Safety	45.0835

Performance	44.8787
Design	44.8728
Functionality	33.8999
Interior Space	33.7553
Mile Coverage	29.0271
Price	22.3473
Warranty	17.7703

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Reflection on Doing this Thesis

When I started the MBA program, I wasn't sure if I would go for a thesis or a research paper. From my colleagues who had already completed their research project or thesis, I heard lots of both positive and negative things about the process of completion of both. I decided to choose a thesis for two main reasons. First, I wanted to keep my PhD option open; second, since I was back in school, I wanted to get the most out of this program in terms of knowledge and experience. I have always been curious about human behavior: why do people act the way they do, is there any pattern, and can the pattern be used to predict their behaviour. However I did not know the proper way to study human behaviour.

As part of the "Research and communication for today's Managers" course, I learned the basics of research. I learned about thematic analysis, the software that is used for thematic analysis. I also learned to use statistical software for regression analysis. At the end of the course I submitted a research proposal. In the process of preparing a research proposal I came across various models that are used by scientists in Social science. The more I learned in the course, the more I wanted to apply the knowledge in my proposed research.

I pretty much knew what I wanted to find but I still didn't know how to find it. That resulted in gaining knowledge on different methodologies and approaches. The methodologies and approaches not only include the ones that I ended up using in my thesis, but also the ones that I didn't. At that time it was a little disappointing but now after completion of the thesis, I understand that it is all part of the learning process. Now I know which methodology and approach to take or not to take to explain the phenomenon of interest. Now I have the ability to interpret and evaluate both quantitative and qualitative data. Through this learning process I have also developed the ability to systematically approach to understand and explain a social phenomenon.

The learning experience allowed me to develop my skills on couple of statistical software. I learned that the use of a software depends on the different parameter of the data set under observation. That means one software may not provide the best analysis for all data sets, and as a social scientist it is crucial to use the appropriate software in order to analyze and understand the behaviour of the population under observation.

Through all the knowledge and learning experience I was also able to identify my areas of weakness that I need to overcome to be a better social scientist. The most prominent weakness is some minor grammatical mistakes that can be avoided through practice. I also need to work on the organization and expression of my thought process when approaching a social phenomenon. This weakness is a matter of finding and following the best approach that works for me. In time with more similar thesis work I believe I will be able to overcome my shortcomings and become a successful social scientist.