# PERSPECTIVES ON HYBRID ELECTRIC VEHICLES IN THE KINGDOM OF SAUDI ARABIA

**by**

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**A Dissertation**

Submitted to the Faculty

of

Worcester Polytechnic Institute

in partial fulfillment of the requirements for

**Degree of Doctor of Philosophy**

**in**

**Manufacturing Engineering**

Worcester Polytechnic Institute

**May 2016**

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# Dedication

To my country, to my late father: Mohammed, and to my mother: Zahra. Each was still and will always be home.

# Acknowledgements

My dissertation could not have been accomplished without the support of many. I cannot express enough thanks to my advisor, Dr. Amy Zeng, for her support and guidance throughout the past four years, and for giving me the freedom to conduct the research that I wanted. I offer my sincere appreciation for the learning opportunities provided by my committee members: Dr. Richard Sisson, Dr. Joseph Sarkis, Dr. Sharon Johnson, and a special thank-you to Dr. Adrienne Hall-Phillips.

I would like to thank Toyota Abdul Latif Jameel in Jeddah, Saudi Arabia for allowing me to present my work at their office and for their cooperation and constructive feedback. I also want to thank Ali Algarni (a WPI alumnus) who facilitated my communication with Nissan Saudi Arabia. I would like to thank Mr. Siraj Althiga at the Saudi Japanese Automobile High Institute for his time and interest in this research, as well as his effort in distributing the survey. For all those who verified the translation: Dr. Mohammed Albarakati, Abdulrahman Alqahtani, Areeg, Ahmed Alammar and Fahd Alzahrani, I would like to thank them for their valuable contributions! I am also grateful to WPI Writing Center, especially Ria Pereira, for the valuable help in auditing my dissertation. Additionally, I cannot thank enough to everyone that has filled out the lengthy online questionnaire and/or helped distribute it.

I am indebted to the late King Abdullah for his scholarship program that has allowed me to pursue my dreams by covering a large portion of my tuitions and my living expenses

since 2009, and to Albaha University for covering the tuition and expenses of the last three years.

To my children, Mohammed and Dayala – I promise to compensate you for taking many of your well-deserved weekends after I receive my doctoral degree, and thank you for being the source of inspiration whenever I needed. Thank you to my six brothers: DakhilAllah, Saeed, Yahya, Hassan, Ahmed and Hisham, from whom I have never felt far away, despite the thousands of miles separating us.

I offer my caring and supportive wife, Tahani, with my deepest and most special gratitude. I have learned from what we together have gone through, lessons that are as important, if not more than, the lessons I have learned in my PhD journey.

Finally, but foremost, I am always indebted to Allah All Mighty, the Most Beneficent and the Most Merciful, for granting me the capability to achieve what I have achieved.

# HYBRID ELECTRIC VEHICLES POTENTIAL IN THE KINGDOM OF SAUDI ARABIA

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To satisfy the global energy demand while accommodating the rapidly increasing consumption rate in its domestic market, Saudi Arabia must develop and implement fuel efficiency programs in many sectors. Since transportation is a major contributor to fuel consumption and emission levels, introducing Hybrid Electric Vehicles (HEV) provides a viable solution to mitigate the current problems. However, existing studies on the diffusion of innovative vehicle technologies as well as on the understanding of the vehicle ownership and consumer behavior in Saudi Arabia are sparse. To fill this knowledge gap, I have aimed at developing an in-depth knowledgebase about general vehicle ownership and HEV ownership potential in particular for Saudi Arabia in my dissertation. I have achieved the research goal through a comprehensive online questionnaire that contains three different perspectives with each contributing a chapter in my dissertation.

The first perspective provides a general understanding of the vehicle owners' behaviors by analyzing over 600 questionnaire responses. It sheds light on the vehicle ownership determinants of the respondents that currently own vehicles as well as on respondents' future vehicle purchase plans. This research perspective reveals the importance of vehicle

price and seating capacity and points out that seating capacity is not necessarily defined by the household size in Saudi Arabia.

As HEV is not yet available in the Saudi market, the next perspective applies the Theory of Reasoned Action (TRA) by analyzing 847 questionnaire responses to identify factors that might drive Saudis' intention to adopt such technology. The results indicate that, while both subjective norm and attitude are significant in explaining the intention, subjective norm has three times stronger effect on adopting HEV than attitude.

The last perspective contains a three-stage analysis to help identify the profiles of the most potential HEV early adopters and increase the chance for the relevant stakeholders to reach out to an effective range of consumers. Three characteristics of such adopters are identified: at least 35 years old, part of a larger household (more than 6 people), and owning more than one vehicle.

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# ACRONYMS

| | Full name | Acronyms | Remarks |
|---|---|---|---|
| 1 | Hybrid Electric Vehicle | HEV | |
| 2 | Plug-in Hybrid Electric Vehicle | PHEV | |
| 3 | Alternative Fuel Vehicle | AFV | It includes EV, HEV… |
| 4 | Electric Vehicle | EV | |
| 5 | Electric Driver Vehicle | EDV | |
| 6 | Pure Plug-in Electric Vehicle | PEV | |
| 7 | Kingdom of Saudi Arabia | SAUDI ARABIA | Also known as Saudi Arabia |
| 8 | Theory of Planned Behavior | TPB | |
| 9 | Theory of Reason Action | TRA | |
| 10 | Diffusion of innovation | DOI | |
| 11 | Norm Activation Theory | NAT | |
| 12 | Saudi Energy Efficiency Center | SEEC | |
| 13 | National Energy Efficiency Program | NEEP | In Saudi Arabia |
| 14 | The Corporate Average Fuel Economy | CAFE | |
| 15 | Internal Combustion Engine | ICE | |
| 16 | Attitude | A | An item of TRA |
| 17 | Subjective norm | SN | An item of TRA |
| 18 | Adopting HEV Intention | AHEVI | |
| 19 | Systems Dynamics Modeling | SD | |
| 20 | Agent Based Modeling | ABM | |

# 1. PREFACE: HOW IS IT RELEVANT TO MANUFACTURING?

Manufacturing a given product is a response to its demand, while demand is a result of consumers' preferences. Thus, studying consumer demand is essential in developing a market for a new product. One can confidently say that HEV's consumer preference is the backbone of its demand (Ahn, Jeong et al., 2008). The need to study consumer preferences, and therein demand becomes more imperative when the product to be introduced is a new one, meant to challenge the position of a market dominating product. HEV is indeed set to challenge the long lasting market position for the traditional Internal Combustion Engine (ICE) vehicles.

Without sustained HEV demand, there is no market, and ultimately there is no feasibility for manufacturing. This explains why policy makers have used -and are still using- incentives designed to promote HEV, for both demand and supply sides, purchase price subsidy and/or tax credit for the latter and vehicle manufacturers, like the Corporate Average Fuel Economy (CAFE) for the former.

The consumer preference is not confined to the product unit level, but can go deeper to the attribute level of a given product. Consumers might decide to purchase or not to purchase a given product just because of one single attribute of that product. For example, one might decide not to get a HEV because of the number years on the battery manufacturer's warranty. Thus, manufacturers need to have a deeper understanding of their potential consumer behaviors at the product's attribute level. In short, inputs from consumer preference studies feed directly to product design. Ecological design traditionally focused only on product's technical specifications (Behrisch 2013), which inspired some researcher to suggest widening the industrial design practices, specifically the ecological design practices, to include how consumers perceive and understand products (including factors such as consumers' interaction with HEV and meanings of

HEV adoption to consumers). Furthermore, HEV consumers' preferences should be integrated not only in the design phase, but also in the ideation phase and throughout the creation of the entire value chain.

The rest of this dissertation document is composed of 8 chapters. The first is an introduction chapter devoted to addressing the need behind the research. The next chapter is a literature review, while the chapter after that is one that sets a general theme for the analysis part of the dissertation, consisting of 3 analysis chapters. The last is a limitation and next research chapter.

# 2. INTRODUCTION

## 2.1 Oil: Limited Supply, Growing Demand

The global fuel consumption is growing. Oil producing countries have the responsibility to meet this increasing global energy demand. According to the Energy Information Administration (EIA), the international oil supply relies on Organization of the Petroleum Exporting Countries (OPEC) to meet the global demand, placing the highest expectation on Saudi Arabia and Iraq (US Energy Information Administration, 2014). Given the current situation in Iraq, this expectation is primarily upon Saudi Arabia. However, Saudi Arabia itself is suffering from a progressive domestic consumption. In Saudi Arabia, the consumption increment between the years of 2012 and 2013 is 3.1% compared to 2.2% for the Middle East (BP, 2014). Saudi Arabia in fact is the largest petroleum consumer in the Middle East, especially for power generation and transportation sectors (US Energy Information Administration, 2014). According to the 2014 British Petroleum Statistical Review of World Energy, Saudi Arabia in 2013 was the 12$^{th}$ largest total primary energy consumer, consuming almost 3 million barrels per day, almost doubling the consumption in 2000. The national oil company, Saudi Aramco, through spokesperson, explicitly said that crude export will be short by 3 million barrels per day by 2028 given the current domestic demand continuation

(Stevens, 2011). Saudi Aramco's CEO said that "domestic liquids demand was on pace to reach more than 8 million bbl./d of oil equivalent by 2030 if there were no improvements in energy efficiency" (US Energy Information Administration, 2014). Less optimistic views are forecasting that, if Saudi Arabia's rate of consumption continues as usual, the country's export will stop and the production will not meet the domestic need by the year of 2038 (Stevens, 2011).

There is another point of view worth mentioning here, which is an economical one. Saudi Arabia's CIA fact book state that "The petroleum sector accounts for roughly 80% of budget revenues, 45% of GDP, and 90% of export earnings" ("The World Factbook: Saudi Arabia," 2013). A conservative fuel consumption will help the Saudi economy by freeing up more oil previously set for domestic consumption to be exported (US Energy Information Administration, 2014). Therefore, there is a need for moving faster toward efficient use of energy in many sectors, one of which is transportation.

## 2.2 Why Encourage HEV Adoption?

Many reasons reported drive the effort to encourage efficient vehicles adoption, like HEV. These reasons include, but are not limited to, reducing Greenhouse and $CO_2$ emission, pollution and global warming, reducing foreign oil dependence (Belzowski & McManus, 2010), and possible oil shortage (Bhunnoo, Oogarah-Hanuman, & Ramsaran-Fowdar, 2011) (Sioshansi, Fagiani, & Marano, 2010) (Y. Tanaka & Shigeta, 2007).

The United Nations Environment Program has recently announced that, in several global atmosphere watch stations, $CO_2$ concentrations hit 400 part per million, higher than the safe level of 350 part per million, (NASA, 2016). Saudi Arabia 2012 $CO_2$ emissions estimate as a result of energy consumption is 582.7 million metric tons (The-World-Factbook, 2016). The International Organization of Motor Vehicle Manufacturers (OICA) has revealed that 15.9% of the man-made

$CO_2$ emissions are caused by cars, trucks and buses (Hong, Khan, & Abdullah, 2013). Unfortunately, this is set for a much worse scenario as global passenger vehicle sales are expected to increase by more than double by 2050 (Hao, Geng, & Sarkis, 2016). In Japan, for example, the transportation sector is the second largest source of $CO_2$ emissions after the industrial sector, with 20% increase rate between 1990 and 2004, and around 90% of the transportation sector is made up by passenger cars (Y. Tanaka & Shigeta, 2007). If this happens in Japan[1] where fuel prices are high and advanced metro system exists, it is logical to think that these numbers would be much worse in different parts of the world where cheaper oil price exists and there is poor or no public transportation system in place, which resembles the current state in Saudi Arabia.

From local perspective, the environment in Saudi Arabia faces different challenges that cry for actions to achieve the aspirations of millions of Saudis citizens. Poor air quality negatively affects health and productivity, which lead to national economic loss (Environment, 2015). The air pollution in Saudi Arabia is caused variably by transportation systems, greenhouse emissions and other sources, while there are no institutional capabilities to govern air quality and therefore pollution ("Turn Down the Heat in the Arab World," 2015). $CO_2$ emission in metric tons per capita for Saudi Arabia – a country with an economy based almost entirely on oil - is comparable to the United States level. Vehicles in Saudi Arabia are a major air pollution source, causing almost 66% of CO, 50% of NO and hydrocarbons pollution in the air (Environment, 2015).

United Nations reports say that the following factors can affect the quantities of transportation sector emissions: vehicle usage, vehicle age and technology, vehicle maintenance, appropriate fuels availability, and climatological, atmospheric and topological conditions (Gorham, 2002). Unfortunately, in Saudi Arabia, all the above factors exist, making transportation

[1] Average fuel price in Japan is 1.05 US$/liter

emissions worse. Internal Combustion Engine (ICE) is almost the only vehicle engine technology being used and gasoline is the dominating fuel with limited presence of diesel.

International corporations and local ones should have another reason for encouraging HEV. Corporation's environmental performance can enable companies to have a competitive advantage. Some researcher used HEV Prius as an example of how Toyota improved its performance relative to other automakers using its success with the Prius. "This article illustrates a typology of benefits from leading organizations that demonstrate how improvement to environmental performance enables competitive advantage" (Finster & Hernke, 2014, p. 652).

## 2.3 The Saudi Auto Market

In 2013, Saudi Arabia's motorization rate (number of vehicles per each 1000 of the population) was 241 with a 4% increase from the previous year. More than 2 million vehicles over 20 years old are currently on the roads, representing 25% of the total vehicles in the entire country (Alharbi, 2015), contributing negatively to the low transportation efficiency and high emissions levels. New vehicle sales in Saudi Arabia are well positioned to reach 1 million vehicles per year very soon (OICA, 2013), as shown in Figure 1.

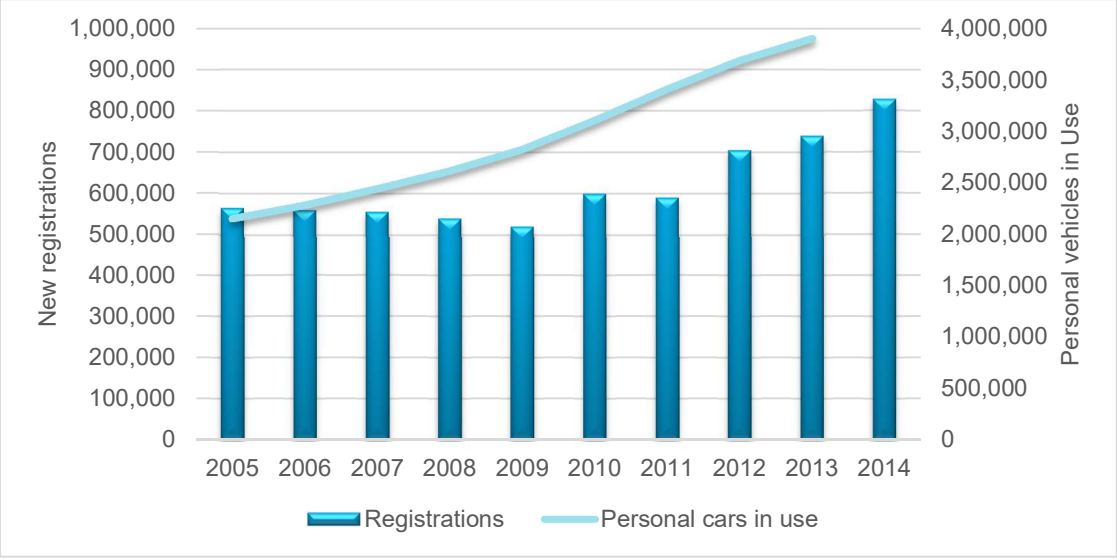


**FIGURE 1 NEW SALES REGISTRATION AND VEHICLES IN USE IN SAUDI ARABIA**

The level of vehicles imports makes Saudi Arabia the biggest importing country in the Middle East. In 2011 alone, Ford sales increased by 60%. The following year, 2012, Chrysler sales increased by 80% (USSABC).

It is very important to keep in mind that, up until now, there is no domestic vehicle manufacturing facilities, which makes this market very attractive for global vehicle manufacturers. It is so attractive in a way that global manufacturing companies are considering establishing production lines locally. For example, Isuzu plant in the east part of the country is now capable of assembling 600 vehicles a year with the aim to be able produce -not just assemble - 23000 light and heavy trucks of by the year of 2017. June 2014, The Chinese giant BYD Auto released that they are in the feasibility study stage examining a joint venture to start manufacturing vehicles locally. Jaguar /Land Rover has already signed a letter of intent with National Industrial Clusters Development Program to establish a production line for its luxurious vehicles with the aim to produce 50,000 Land Rovers a year by 2017 (2015).

The general projections about the Saudi auto market is favorable for the long term due to "demographic factors, likely economic and financial stability, high levels of disposable income and low import tariffs and fuel prices." (2015). All these movements and investments are calling for more research about the auto industry, adding more reasons for devoting my PhD dissertation research to this region.

## 2.4 Policies in Face of Challenges

The government of Saudi Arabia has made some efforts to address the increasing fuel consumption and emissions levels. In January 2001, the government introduced the unleaded gasoline for the sake of reducing vehicle exhaust pollution (Dincer, Hussain, & Al-Zaharnah, 2004). In 2009, a policy was enacted that would not allow for used vehicles older than five years

to be imported to the country. They also formed the National Energy Efficiency Program (NEEP), for "promoting a variety of supply- and demand-side energy efficiency and conservation measures, targeted at domestic consumers, as well as at commerce and industry" (Alyousef & Varnham, 2010). In November 2010, NEEP formed the Saudi Energy Efficiency Center (SEEC) to look after energy conservation in three sectors, namely construction, industry, and road transport ("Road Transport," 2013). Since 2013, the SEEC has required vehicle manufacturers and distributers to report fuel economy data, and each new vehicle for sale to have fuel economy information labels attached to those vehicles at showrooms. The SEEC also seeks to standardize the fleet economy to achieve a goal of increasing the fuel efficiency by 4% annually. They also develop regulations related to the resistance of heavy-duty vehicle tires that eventually will lead to 6-8% better fuel efficiencies. When achieving SEEC project goals, an equivalent of 210,000 barrels per day would be saved by the year 2030 (Alharbi, 2015).

In short, fuel consumption is increasing, and hence emission. Therefore, fuel-efficient technologies must be adopted in the transportation sector. These efforts are more important for those countries that are sources for the global energy need. HEV represents a winning weapon for reducing transportation emission and fuel consumption in Saudi Arabia.

# 3. LITERATURE REVIEW

## 3.1. HEV Purchase Motivations Studies

Vehicles are complex symbolic objects, used by people not just for transportation, but to express themselves as well (Bremson, Meier, Lin, & Ogden, 2013; Plötz, Schneider, Globisch, & Dütschke, 2014). Becerril Arreola (2013) suggested that HEVs are associated with clean energy, technological advancement, environmental consciousness, and also considered as a wealth display sign. Moreover, HEV is not only about reducing petrol consumption or saving on fuel, but also

about expressing driving practices and making a statement of being part of a green community (Ozaki, Shaw, & Dodgson, 2013). Since HEV adoption behavior is complex, different policies have been enacted to motivate people to adopt HEV. It can be driven by a variety of reasons, some of which are related to identity, personal values, social pressure and demographic factors, and response to financial incentives – to name a few. Below is an elaboration on HEV adoption motivations found in the literature.

### 3.1.1. SOCIAL MOTIVATIONS

Consumers' preference is a critical factor in the dissemination of HEVs (Chorus, Koetse, & Hoen, 2013), therefore it must be studied. Consumers are affected by seeing other people buying HEVs (Belgiawan, Schmöcker, & Fujii, 2013) as a result of social norms and social pressures exerted by adopting communities (Goody, 2014; Hori, Kondo, Nogata, & Ben, 2013). Rai and Nath (2014) reported that word of mouth (or generally social influences) increased the value of pure Plug-in Electric Vehicle (PEV) in the eyes of their adopters. Chan, Miranda-Moreno, Patterson, and Barla (2013) show that HEV consumers usually cluster in the same area, compelled to conform to cluster's values and norms. Hong et al. (2013) also asserted that compatibility with the society is positively related to purchasing not only HEV, but also biofuels and hydrogen powered cars. Gadenne, Sharma, Kerr, and Smith (2011) found that the factors influencing environmental behaviors include sense of social responsibility, ease of adoption and personal relevance. They also highlighted that consumers are positively influenced by the opinions and actions of family members, friends and associates. Belgiawan et al. (2013) confirmed the importance of peer influence in Indonesia and recommended promoting the message that driving HEV is normal and is not out of the ordinary. In the United States, Keith (2012b) explained why Prius sales are not uniformly geographically distributed (mostly in the West, East Coast and

Washington, D.C.). He discussed how consumers' social networks exacerbated heterogeneous adoption thresholds.

HEV purchase motivations, as discussed above, are complex. Moreover, they are associated with many factors, some which are least expected. In the United Kingdom, for example, the value of comfort, style and fashion, and the size of the vehicle were all reported as reasons for buying a Prius. That is, consumers are buying a Prius not just because of economic and lifestyle reasons, but also because of other features Prius can offer such as a quiet ride, which is expected only from luxury vehicles (Ozaki & Sevastyanova, 2011).

### 3.1.2. FINANCIALS MOTIVATIONS

There is a large volume of published studies suggesting that financial gains were quite often more important than environment related benefits. For instance, Krupa et al. (2014) found that the environmental benefits gained from Plug-in Hybrid Electric Vehicle (PHEV) adoption were ranked less important than financial gains or battery factors. Sullivan and Sivak (2012) suggested that a lower carbon emission alone might be an insufficient incentive unless some financial benefits can be attained along the way. Another study by Tran, Banister, Bishop, and McCulloch (2013) revealed that financial benefit has the largest influence on early adoption (rather than pro-environmental behavior), thus suggesting that HEV marketing should emphasize economic benefits, along with pro-environmental behavior motivations. Their study also found that "HEV adopters while being more financially savvy might still reflect general consumer behavior by placing greater emphasis on short-term financial savings at the pump, rather than longer-term savings from improved fuel economy" (Tran et al., 2013 p. 872). Fortunately, there are HEV buyers who are driven only by their desire to preserve the environment (Russell-Verma, 2013).

## 3.2. Saudis Purchase Behavior Studies

HEV is not yet available in the Saudi market. At the same time, related consumers' behavior research on Saudi Arabia is limited, so is the literature in Arabic language (spoken in Saudi Arabia). Traditional diesel vehicles, despite being in the market for a long time, have not been discussed and no studies have examined how diesel engine vehicles are diffused within Saudi society. It is helpful, though, to briefly review Saudis' consumer behavior research in the next paragraphs to pave the way for a better understanding.

The spread of consumerism in Saudi Arabia is a result of many local and global reasons, for example: the internet, proliferating shopping centers, the national government subsidies, absence of taxes, liberal import policies (Assad, 2008). In his recent field study, El-Omari (2014) stated that 68% of Saudis put more weight on the desire to purchase rather than on financial ability. The study also reports that 70% of Saudis place heavier emphasis on "influence of elements, other than income, on their overall desire to purchase", with males doing so more than females. These elements included items like price, access to information, complexity of the production, country of origin, perceived risk, level of satisfaction, family size, economic conditions, level of education, current job and future job expectation, product attitude, and others. Out of these, the size of the family, access to information, and attitude toward a product seem to have the highest importance.

Opoku (2012 P. 178) reported that "informational influence on publicly consumed luxuries would be greater in terms of peer influence than privately consumed necessities among young adults". He found that, among young Saudi adults, the effect of peer influence on public's consumption of luxuries is greater than private necessities, like television.

In a typical household in Saudi Arabia, the husband in a household is dominant when making a vehicle purchase decision, more specifically on what and how much to pay for a given

vehicle. The wife, however, has a greater influence on exerting the need for the vehicle (Yavas, Babakus, & Delener, 1994). It is also shown that the wife's influence on the purchase decision, including automobile purchases, is a function of the education level. Another study has reported that Saudi girls are less likely to give attention to vehicle commercials than Saudi boys (Yavas & Abdul-Gader, 1993).

Saudis are likely to consume more durable goods when compared to other people in industrial societies. For example, a study by Assad (2008) indicates that Saudis replace their vehicles more frequently. The study also points out that each Saudi family tends to own more than one car and employs a full-time chauffeur for the family.

Each society perceives HEV differently, resulting in a different pattern of HEV's diffusion, which in turn calls for certain types of polices for each society. Thus, there is an obvious need to study more communities, cultures, and countries. Additionally, the literature on Saudi Arabia vehicle consumers' behavior is limited. This dissertation is an attempt to fill the gap by providing a better understanding about vehicle purchase behavior and motivations in Saudi Arabia. Then, in light of this understanding, recommend appropriate policies to promote HEV diffusion in the country.

## 3.3.HEV Consumer Discrete Choice Modeling Studies

Consumer choice modelling is one of the heavily employed techniques to study HEV preference. It is an application of advanced logistic regressions to model how subjects make choice between different options. The process basically estimates model coefficients, which then can be used to evaluate scenarios of market share for each of the vehicle types under consideration. Consumer heterogeneity and the design specifics play a role in determining the consumer discrete choice model. The model can be multinomial logit (MNL) model (Ewing & Sarigöllü, 1998)

(Horne, Jaccard, & Tiedemann, 2005) (Mau, Eyzaguirre, Jaccard, Collins-Dodd, & Tiedemann, 2008), nested logit models, (NMNL) (Bunch, Bradley, Golob, Kitamura, & Occhiuzzo, 1993) (Potoglou & Kanaroglou, 2007), or mixed logit models (Batley, Toner, & Knight, 2004) (Train, 2008). When there is no order between options, and when seeking simplicity (Mau et al., 2008), MNL can be used. MNL dictates that MNL estimated coefficient be identical for every respondent, usually refered to as the independence of irrelevant alternatives (IID) assumption. NMNL, on the other hand, allow for violations of the (IID) assumption.

Some researchers determined how demand for clean-fuel vehicles varies as a function of vehicle's attributes that change between ICE and other vehicle forms. These attributes include price, fuel cost, driving range, fuel availability, whether the vehicle has multi-fuel capability or dedicated fuel, and emissions. For instance, around 700 Californians participated in the survey of vehicles and fuel type preference. Using nested multinomial logit model (NMNL), for vehicle choice and binomial logit model for fuel choice, the researchers found that driving range is essential attribute for fuel and vehicle choice, and fuel cost is most critical for fuel. (Bunch et al., 1993)

In another study, Alternative Fuel Vehicles, (AFV) consumers' stated choice was modeled using a mixed logit model, (ML) to show that AFV still has a large negative preference, predominantly because of limited driving range and fuel times. AFV Preference was found to be increasing with range, fuel availability and fueling time enhancements. Generally, AFV preferences were found highly heterogeneous, and the most important factor that determines heterogeneity in preferences is the annual mileage in a way that when it increases, a substantial reduction in preference for EV and fuel cell vehicles is noticed (Hoen & Koetse, 2014).

Multiple discrete-continuous choice approach was used to forecast household ownership and use of alternative fuel vehicles in South Korea (Ahn, Jeong, & Kim, 2008). In designing the choice cards, authors used fuel type (gasoline, diesel, CNG, LPG and Hybrid), body type (ordinary and multipurpose), maintenance cost, engine displacement, fuel efficiency and fuel price (except fuel and body type, all are set at four levels). They used fractional factorial design to get twelve alternatives divided by 3 cards (with four in each). This study is weak from the following perspectives: (1) they only considered households that own one vehicle and thus, their analysis did not capture a large portion of immediate potential buyers; (2) it only considered two auto body types, which can make a huge difference when demand pattern is considered and does not really reflect the wide range of body types available in the market; and (3) they did not consider the purchase price as one of the attributes and thus, each choice set/card assumes all alternatives are equally priced, which is far from truth as HEV is always priced with premium.

The list of vehicle's attributes that potential buyers consider when making a purchase decision can be very long. Therefore, researchers must be very careful in including very relevant attributes during the design of stated preference study. Among methods that can help researchers assess whither a product attributes are key to customers or not: focus group and direct observations (Chen, Hoyle, & Wassenaar, 2012).

Table 1 below presents a literature review of several AFV discrete preference modeling studies. The table shows what type of choice model was used, some of the attributes that have been considered, and in which country each study was conducted.

**TABLE 1 CONSUMER CHOICE MODELING STUDIES**

| Publication | Price | Fuel cost | Emissions | O&M cost | Incentives | Fuel type | Model | Country |
|---|---|---|---|---|---|---|---|---|
| **Beggs, Cardell, and Hausman (1981)** | x | x | | | | | Ranked Logit | USA |
| **Bunch et al. (1993)** | x | x | x | | | | Nested Logit (NMNL) | USA(CA) |
| **Ewing and Sarigöllü (1998)** | x | | x | x | | | MNL | Canada |
| **Batley et al. (2004)** | x | x | x | x | | | Mixed Logit Model | UK |
| **Horne et al. (2005)** | x | x | x | | x | | MNL | Canada |
| **Hess, Train, and Polak (2006)** | x | x | | x | | | Mixed Logit Model | USA(CA) |
| **Potoglou and Kanaroglou (2007)** | x | x | x | x | x | x | Nested Logit (NMNL) | Canada (Hamilton) |
| **Ahn et al. (2008)** | | x | | x | | | Mult. Disc. Cont. Ext. Value | S.K.(Seoul) |
| **Train (2008)** | x | x | | | | | Mixed logit model | USA (CA) |
| **Mau et al. (2008)** | x | x | | | | | MNL | Canada |
| **Dagsvik and Liu (2009)** | x | x | | | | | Generalized extreme value random utility model | Shanghai |
| **Caulfield, Farrell, and McMahon (2010)** | | x | x | | x | | MNL, and (NMNL) | Ireland |
| **Beck, Rose, and Hensher (2011)** | x | x | x | | | | MNL | Australia |
| **Hidrue, Parsons, Kempton, and Gardner (2011)** | x | x | x | | | | MNL, Latent Class model | USA |
| **Mabit and Fosgerau (2011)** | x | x | | x | | | Mixed logit model | Denmark |
| **Zhang, Gensler, and Garcia (2011)** | x | x | | | | | MNL | USA |
| **Maness and Cirillo (2012)** | x | x | x | | | | MNL | USA |
| **Ziegler (2012)** | x | x | x | | | | Multinomial Probit Model | Germany |
| **Ko and Hahn (2013)** | x | | | | x | | Mixed Logit Model | South Korea |
| **Chorus et al. (2013)** | x | x | | x | x | | Mixed Logit Model | Netherlands |
| **Neerkaje (2013)** | | | | | | | NMNL | India |

## 3.4.HEV Diffusion Simulation Studies

Simulation science has served HEV diffusion in many forms. I focus on two types of simulation modeling, Systems Dynamics Modeling (SD) and Agent Based Modeling (ABM). ABM is a fairly new simulation technique in which an individual or an agent is the unit of analysis. Each of these agents' behavior is governed by a few rules. These agents interact to present global consequences that ultimately emerge as a complex, nonlinear behavior. Agents' interactions reveal the collective behavior, (for example, the diffusion of HEV), thus, a deeper understanding of HEV purchase motivations is required (Daire McCoy & Seán Lyons, 2014; Daire McCoy & Sean Lyons, 2014; Tran, 2012a; Wolf, Nuss, Schröder, & de Haan, 2012; Wolf, Schroeder, Neumann, & de Haan, 2014). SD, on the other hand, deepens on causal relationships between system elements in form of stocks and flows. The unit of SD analysis is called feedback loop (reinforcing feedback or goal-seeking one). The outcome is a pattern of complex behavior driven by the system structure under consideration. SD is ideal when the phenomenon being investigated is associated with long lead times as SD is considered an aggregate tool. For example, changing the consumption level of the national Saudi fleet may take many years. Also, SD –and ABM for that matter as well- is excellent for their policy testing capabilities, creating a safe and cheap policy testing environment (assuming a robust model in place). Opposite to ABM's ability to accommodate heterogeneity, SD deals with all entities – say vehicle potential buyers - as if they were all the same (in other words, SD does not support heterogeneity).

A new emerging type of simulation is a combination of ABM and SD and is usually referred to as Multi-method modelling or hybrid modeling. Hybrid modeling is not applied to HEV as heavy as SD and/or ABM, and thus, the following two subsections are reviewing some HEV studies that employed SD or ABM.

### 3.4.1. AGENT BASED MODELING

Daire McCoy and Seán Lyons (2014) tried to provide more understanding of electric vehicle (EV) consumers' behavior and created a safe policy testing environment (simulation modeling) for Ireland, using HEV preference understanding as a proxy to understand EV.

Another study done by Wolf et al. (2014) Wolf et al. suggested that research and development, (e.g. battery technology), is critical, but not enough to achieve EV diffusion goals. For the diffusion to be achieved, demand side challenges need to be addressed as well. This was the driver for Wolf et al. to develop an ABM model for consumers' perceptions and decisions toward innovation's adoption in sustainable transport.

Tran et al. (2014), pointed out to United Kingdom consumers' sensitivity to: fuel economy, $CO_2$ emissions, improved fuel economy financial gains, government policy benefits, and environmental appeal when considering a HEV purchase (Tran, Brand, & Banister, 2014). Also, in the United Kingdom, Tran (2012) developed technology- behavioral testing scenarios to reveal how consumers with different preferences might respond to changes in technological performance (Tran, 2012b). The same was done also in two other publications to study the EV diffusion in Berlin, Germany (Wolf et al., 2012) (Hirte & Tscharaktschiew, 2013).

Haan, Mueller, and Scholz (2009) simulated auto market to explore the effects of "feebate" (efficient vehicles receive a cash incentive (rebate), while inefficient vehicles pay fee) using ABM. In their model, consumers have different price sensitivities and different behavior in response to feebates. They found out that incentives of €2000 for very efficient vehicles resulted in reducing $CO_2$ emission between 3.4% - 4.3%, and that the rebound effects risk is low.

Zhang et al. (2011) used ABM to investigate the diffusion of HEV, after capturing the heterogeneous consumer preferences through choice-based conjoint analysis. Their simulation

results support that market pull, (word of mouth) positively impacts HEV diffusion and "increases the social good by decreasing the preference for fuel inefficient vehicles". They also suggest that word of mouth results in more willingness to pay for HEV, manufacturer focused governmental push (like fuel economy mandates) can result in a decrease in air pollution improvement as a results of an increasing inefficient market share.

### 3.4.2. SYSTEMS DYNAMICS MODELING

T. BenDor and Ford (2006) used SD simulation to study financial incentive's effects on diffusion of green vehicles. They studied a "feebate" concept that combined the rebates and fees to promote the sales and subsequent use among vehicles fueled by compressed natural gas, CNG, electricity, alcohol and gasoline. They showed that, -based on discrete choice demand models - feebates proved effective in attaining important, but graduate reductions in vehicles' emissions. They also showed that scrappage payments resulted in faster emission reduction as well. They showed that a sustainable emission reduction can be achieved using both feebate and scrappage payment incentive through recommending a designated fund, which is financed by fees applied on new high emission vehicle sales.

Struben and Sterman (2008), developed an SD model of the diffusion of and competition among AFV. They focused on consumer awareness to demonstrate that there exists a critical threshold for sustained AFV adoption. They showed that this threshold is dependent on behavioral and economic parameters. They also showed that non AFV adopters' word of mouth is important for AFV diffusion. They finally suggested that AFV subsidies along with marketing programs must continue for long time to achieve self-sustaining diffusion.

Keith (2012a), using an SD model, examined the innovation diffusion of Prius while there exist supply constraints (long waiting times when Prius introduced as a result of a limited

production capacity, where he showed that “the failure to model supply constraints can bias diffusion model parameter estimates”. He then explored the possibility of HEV bridging the gap to large scale EV adoption, to find that a smooth “transition from HEVs to EVs is possible but not assured, identifying public policy and firm strategy decisions that have the potential to accelerate this transition.”

T. K. BenDor (2012) analyzed the US automobile gasoline consumption dynamics since 1975. After reviewing the fuel economy and energy policies literature, he created an SD model to study effects of potential gas tax changes to fuel economy standards. He concludes, “When increases in mandated fuel economy are not conducted in an environment with rising fuel costs, fuel economy improvements may be directly counteracted by shifting tastes of consumers towards larger automobiles with lower fuel economy”.

Neerkaje (2013), in his MS degree thesis at MIT, used SD simulation to explore India’s AFV adoption dynamics. He showed that, it takes more than incentivizing demand for AFV introduction success. Sufficient refueling infrastructure is necessary for AFV diffusion. He also showed that PHEV, -when effective policies are in place- has the potential to dominantly diffuse in India.

# 4. RESEARCH THEME, METHODOLOGY AND DATA COLLECTION

The literature review presented earlier shows that consumer behavior literature pertinent to Middle East countries is very limited. Existing studies get even sparser when looking at Saudi vehicle consumers' behavior. Therefore, the research of this dissertation is going to follow a pyramid shaped research steps as shown in Figure 2 below. The ultimate goal of this research is to be able to inform an effective policy to encourage the diffusion of efficient vehicles. Such policy should be designed based on deep knowledge of purchase determinants and vehicles' purchase decision making. As mentioned earlier, there is no solid base of literature on vehicle purchase determinants in Saud Arabia. Thus, I needed to build a broader understanding of consumer purchase decision and motivations to serve as the foundation upon which the rest of the research structure stands. Then, after ensuring that the foundation has been in place, an assessment of the intention to adopt HEV[2] in Saudi Arabia is performed. Then, the last stage of the research is to assessing who might be the early HEV adopters. Outcomes of these stages will certainly provide key inputs to designing the right policy, or at least, to provide the right parameters to test for in a policy testing simulation environment. It is important to state the above mentioned steps might not be sufficient to design and enact the right policy. The right policy, however, would depend on the outcomes of the aforementioned steps. This was captured in the research schematic plan presented in Figure 2, below represented by the gap between the last step and the policy step.

[2] While HEV might have a different meaning, in this research, I am only considering HEV that uses, besides regular fuel, an electric drivetrain, by means of battery that does NOT require plug-in charging.

These three levels of the pyramid involve many sub steps. To make reading this dissertation easier, the major steps of the research were mentioned beside each pyramid level in figure 2. In the following chapters of the dissertation, details for all the analyses are presented.

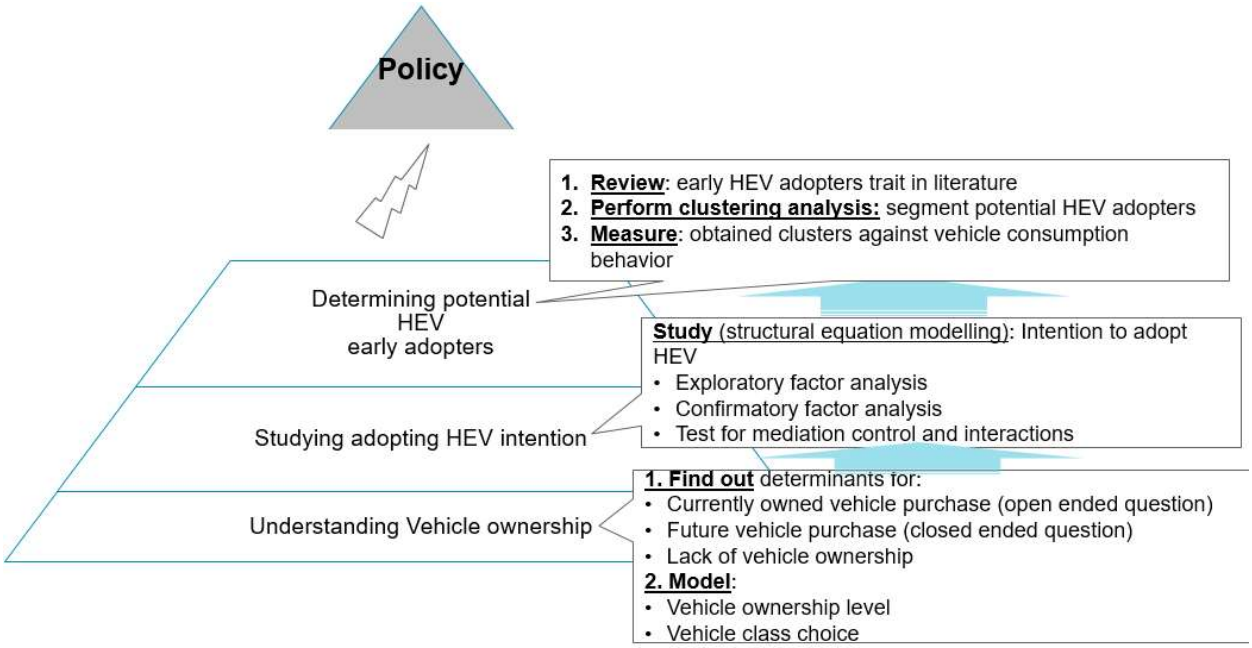


**FIGURE 2 GENERAL RESEARCH THEME AND STEPS**

The data needed to conduct all the above research steps is not readily available, therefore, I created an online questionnaire as a mean of getting the data (see appendix A for WPI Institutional Review Board approval, and appendix B for the whole questionnaire). Several relevant studies have used the questionnaire approach such as (Hong et al., 2013; Nordlund & Garvill, 2003; Ozaki & Sevastyanova, 2011; Ozaki, Shaw, & Dodgson, 2012). Other studies have employed other forms of surveys such as phone interviews (Sangkapichai & Saphores, 2008). A number of studies surveyed a convenient subset of the Saudi population in pursuing different research objectives using a self-reported questionnaire (Al-Ghamdi, Sohail, & Al-Khaldi, 2007; Alotaibi & Al-Matari, 2015; Alqahtani, 2014; Khan, Abdo, & Al-Ghabban, 2015; Musaiger &

Zagzoog, 2013). In particular, Quraeshi, Luqmani, and Yavas (1991) explored the purchasing and spending behavior by surveying university students in Saudi Arabia. In fact, surveying university personnel for studying HEV purchase decisions in other parts of the world is not uncommon, as many studies have applied that exactly (Egbue & Long, 2012; Potoglou & Kanaroglou, 2007).

Collecting data using the internet is regarded as less expensive, with much shorter response time and an automatic data saving and coding mechanism. However, an online questionnaire is criticized for its limited access by the targeted population. While this issue can be serious in some countries, Saudi Arabia (member of the G20) has an internet penetration rate of 65.9%, which makes such a concern insignificant (Internet-World-Stats, 2015). Another issue with an online questionnaire is the lack of control compared to other forms of surveys. To lower the effect of such issue, multiple rounds of questionnaire testing were piloted, and the feedback was integrated to make necessary changes to questionnaire design and syntax.

In this research, I considered a subset of the Saudi population for completing the survey, using a combination of email lists (from a public university-Albaha University- a small college - Albaha Technical College-, and private firms –Sharq Eastern Petrochemical Company), social media (Twitter, Facebook and LinkedIn), and messaging (namely WhatsApp). The data were collected using a self-administered online questionnaire, targeting respondents from Saudi Arabia of 18 years old or older. Because of the convenience sampling method, it is not possible to indicate a response rate, and further indicate non-response bias. The original survey instrument was written in English. However, since the survey was conducted in an Arabic speaking country, there was a need for Arabic version too. Therefore, to make sure the meaning is properly conveyed during the translation, the back translation method was used from English to Arabic and back from Arabic to

English (Douglas & Craig, 1983). Qualtrics was used to conduct the online questionnaire, collecting the data from August to October 2015. Respondents who finished the whole survey were entered into a raffle to win one of five $50 gift cards, or one of the five $27 prepaid phone services with a choice of a local telecom operator.

A total of 1600 responses were returned, but not all of them were useful due to missing values and incomplete responses. For the main elements in the questionnaire, only complete responses were kept. For the control items, however, the median is used to replace the missing values for categorical data types and the mean for continuous data types. Also, since participating in the survey involved a potential reward, some reward seeking respondents may not be serious about answering all the questions (that is, choosing one choice for all questions). Consequently, the responses with very low standard deviations were removed. Outliers were not a concern for this study as I have all the answers coded and in a drop down list. After a final cleaning of the data, there were:

- 460 valid responses for exploring current vehicle purchase determinants in chapter (5.2.1)
- 460 valid responses for exploring future vehicle purchase determinants in chapter (5.2.2)
- 847 valid responses for modeling Theory of Reasoned Action in chapter 6

All relevant statistics for each sample is presented in its associated chapter. The relatively low completion rate is possibly caused by the length of the survey, which took, on average, around 30 minutes to finish. Also, looking at samples for each of the analyses conduced in the subsequent chapters, the data might seems over representing younger population. It is in fact reflecting the true case about the Saudi population. Saudi Arabia is a young nation, with 19.11% of the Saudi population between the ages of 15 and 24, 54.9% between the ages of 25 and 54 (The-World-

Factbook, 2016). The sample underestimated female population, however, the Saudi society is male dominated society and thus, a lower female response rate is expected, in addition to the fact that generally females are less curious about vehicles than males.

# 5. ANALYSIS OF VEHICLE CONSUMPTION IN SAUDI ARABIA

## 5.1. Background

Vehicle ownership happens for far more reasons than moving from point A to point B. Vehicle ownership is a complex phenomenon that reflects identity, status and cultural meaning too (Dittmar, 1992). Thus, auto market decision makers and policy makers cannot assume simplicity of vehicle ownership. The lack of research about vehicle ownership in Saudi Arabia, unfortunately, highlights that some are still holding to this assumption. On the other hand, for other part of the world, many publications have explored vehicle ownership to discover factors behind ownership patterns. For example: Republic of Ireland (Eakins, 2013), Spain (Matas & Raymond, 2008), United Kingdom (Stephen D. Clark, 2007), Belgium (Van Acker & Witlox, 2010), Netherlands (Oakil, Ettema, Arentze, & Timmermans, 2013), Canada (Potoglou & Kanaroglou, 2008) and many studies in the United States. Some studies compared vehicle ownership between different countries, for instance, Giuliano and Dargay (2006) compared the level of vehicle ownership between the United States and the United Kingdom. Medlock III and Soligo (2002) investigated and compared the relationship between economic development and vehicle ownership for 28 countries, but none was from the Middle East except Turkey.

## 5.2. Exploration of Vehicle Ownership Determinants in Saudi Arabia

This chapter is an attempt to shed some light on reasons behind vehicle ownership in Saudi Arabia. Thus, the questionnaire contained two sections for this sole purpose. I realize that reasons for purchasing current vehicle might be different from reasons behind purchasing one's next

vehicle. I also realize that when people are asked to explain, in their own words, the reason for owning a given vehicle, might result in different answers from the case in which respondents are asked to choose among a group of reasons presented to them. Therefore, a combination of these ways of extracting respondent's answers were employed. The first is an open ended question that aimed to capture the determinants that were behind the purchase of respondent current vehicle, while the second is a closed ended question (importance ranking exercise) that aimed to assess future vehicle purchase determinants, through ranking 14 reasons behind vehicle ownership reported in literature.

The ranking question was placed after the open ended question so to not affect respondents open ended answers. These two questions and their associated analyses are presented in the below sections.

### 5.2.1. CURRENT VEHICLE PURCHASE DETERMINANTS: AN OPEN-ENDED QUESTION

In order to base the open ended question on the right foundation, a group of questions was presented first to collect respondents' current vehicle ownership data. These questions were about the number of vehicles owned, whether the vehicle most used was bought new or used, the annual distance driven, etc. After presenting these questions to respondents, the open-ended question is presented, which was phrased as: "In your own words, what is the main reason you (or your household) chose to buy/lease your current [……] (please specify)?" (Ozaki & Sevastyanova, 2011 p. 2226). As the current vehicle ownership status was collected prior to presenting the question to the respondent, the brackets in the question wording above would be filled automatically by the current vehicle the respondent owns, to the make and model level. This will take care of the respondents who currently own vehicles. For those respondents who don't own

vehicle, Qualtrics will present them with a different question asking about the reason why they don't own a vehicle yet. The lack of ownership is analyzed and presented in section 5.5 of this dissertation.

It is important to notice here that the open ended question was phrased to highlight the **main** reason for choosing to own the current vehicle (or the vehicle most used if the respondent owned more than one). Most respondents answered the question by providing one reason, however, some reported more. In such a case, all reasons mentioned after the first one were dropped. Then, all reasons were manually coded, resulting in a list of 45 reasons behind vehicle ownership, presented in Figure 3. Please note that these are a number of overlapping determinants stated by respondents. To make these overlapping determinants easier to spot in Figure 3, a color coding was applied only for overlapping determinants, while the default color for the rest of determinants is dashed blue and white.

Not surprisingly, price was found to be the most important determinant behind the current vehicle owned. Almost 18% of respondents stated that price is the main reason for owning their vehicles. Though this factor was coded as price, it probably means the price that fits the respective respondent budget.

Next, 13% of respondents stated that vehicle passenger capacity is the main determinant for vehicle ownership. Passenger capacity's second position in the ranking can reasonably be attributed to the typical large household size in Saudi Arabia. The survey upon which this analysis was carried out collected household size of respondents and the data showed that 62.7% lived in a household size of five or more people. It is important to notice the different "family" meaning in Saudi Arabia, which include not just the spouse and children, but also parents, even if they live in

a different house. Additionally, 35th capacity (0.4%) and 38th family friendly (0.2%) were mentioned, though later in the rank, light blue color coded. If added to the second category, passenger capacity, it would add up to almost 14%. Though not as important, the cargo capacity as opposed to passenger capacity has emerged as one of the determinants, ranked as 30th with 0.7% of respondents.

The grand scheme of the following three green coded determinants is economy:

- 7th : economical
- 12th : fuel efficiency
- 16th : efficiency

If green coded determinants were added up, it would have represented 7.2% of respondents, and it would have been ranked the 5th determinant, following comfort.

Almost 11% indicated that vehicle quality was the main reason to buy their current vehicle. Quality has a broad meaning, which might include: comfort, luxury, durability, brand's reputation, country of origin, reliability, and value, all of which were determinants explicitly stated in the analysis. Even though these determinants are related, they are not coded with the same color, just to reinforce the fact the quality can mean different things. To clarify this further, consider that almost 8% of respondents stated that comfort is the main reason behind their purchase for their current vehicles, ranked right after quality. Comfort for some people, is embedded in the meaning of vehicle quality. If these two categories were to be merged, they together would constitute 18.5%, even more important than the price.

5.22% of respondents were interested in owning a powerful vehicle, given a purple color code, along with the following closely related determinants to vehicle performance:

- 19th: 4X4/4WD (1.3%)
- 34th: performance (0.4%)
- 37th: speed (0.2%).

The rank position relative to the remaining determinants, even if all purple determinants were added together, would not change. It is important to notice here that powerful engine and performance were ranked way before fuel economy.

Determinants that are centered about "me" showed up more frequently. These determinants are yellow coded in Figure 3. These are: 9th Personal choice (2.6%), 20th Fits where I drive (1.3%), and 41st Fits my personal circumstances (0.2%). Adding up all yellow coded determinants would position the new emerging determinant as 6th, representing 4.1% of respondents, and tie with the determinant that highlighted consumers who looked for practical and multiuse aspects of owning a vehicle (6th determinant, with 4.1% of respondents).

"Past experience" (0.7%) and "trusted seller and important person advice" (0.4%), both show the trust aspect of owning a particular vehicle: either trusting the seller, or trusting the vehicle's brand as a result of prior experience.

Maintenance cost and frequency (1.7%) and spare parts availability (1.3%) are clearly related, thus coded with the same color: black. While the former is reasonable, the latter is surprising to be the main reason for some people to buy a certain vehicle over another. This might be one of the determinants that, to the best of my knowledge, is not reported in the literature.

Brand and reputation (1.7%) and country of origin (0.9%) were coded the same color, dark red. These categories signify those who place a heavy weight on the sign on the vehicle's hood.

If I stop looking at the determinants axis at the efficiency determinant, ranked 16th, I would be capturing 80% of consumers' vehicle purchase determinants in the Saudi auto market. All determinants past 31st were mentioned by only one or two respondents. This group contained almost 4% of respondents all together. Vehicle technical attributes like speed and automatic transmission showed up more frequently in the low ranked determinants rather than high ranked ones.

Finally, though representing only one respondent, environment friendliness emerged as a vehicle ownership determinant. This respondent is a MS degree holder, who owned a 2015 Impala, and he stated "GM Environmental Efforts" were behind owning this vehicle.

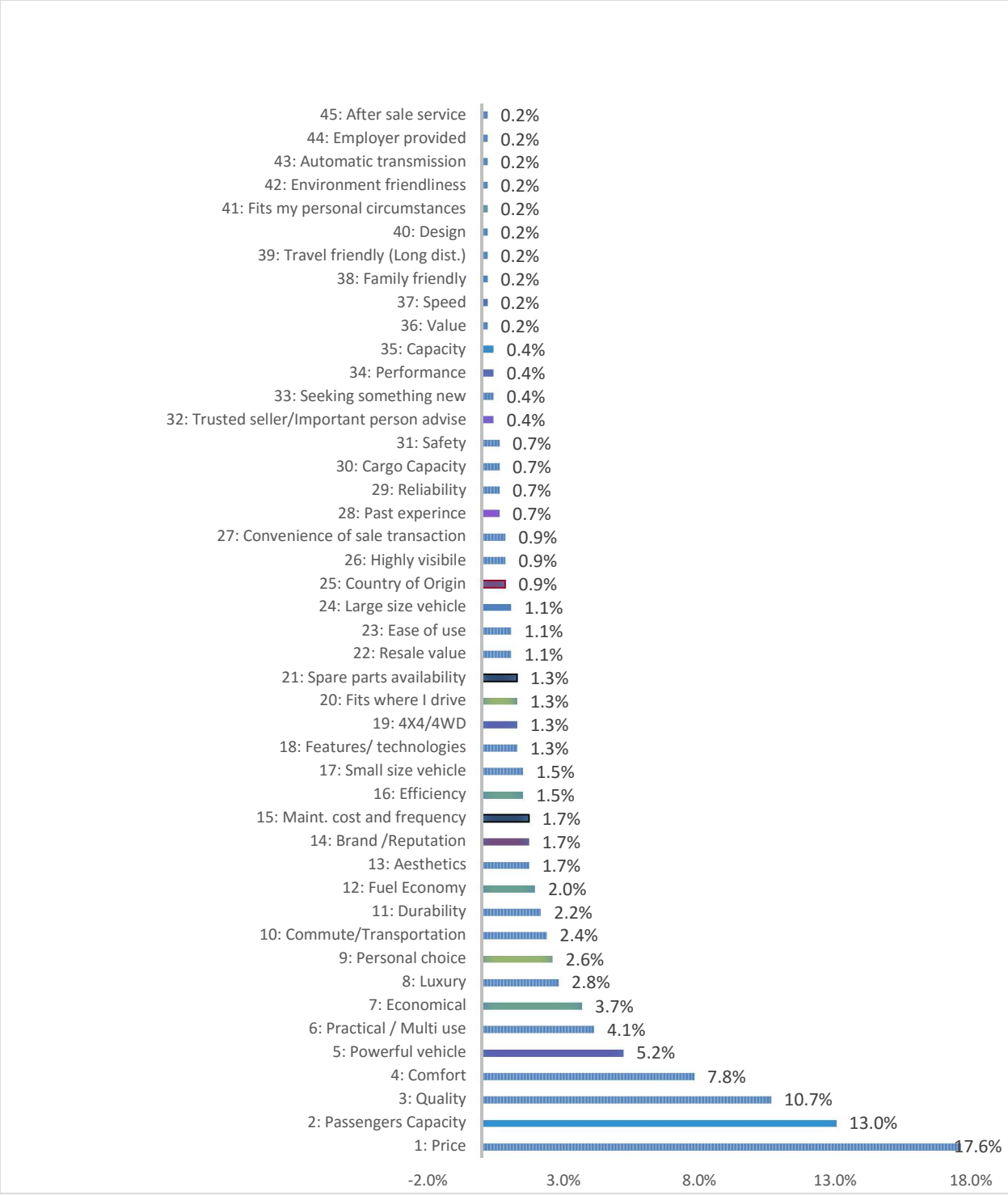


**FIGURE 3 CURRENT VEHICLE PURCHASE DETERMINANTS (OPEN ENDED QUESTION)**

### 5.2.2. FUTURE VEHICLE PURCHASE DETERMINANTS: A CLOSE-ENDED QUESTION

Respondents were asked to rank 14 vehicle purchase determinants from the most important to the least. The question was phrased as "Considering your next vehicle purchase or lease, can you rank the following factors from the most important in influencing your purchase or lease decision to the least?" These 14 determinants are: reputation of manufacturer, price, luxury amenities and or special features, seating capacity, cargo space/truck bed space, the ability to see the road, performance of engine, fuel economy, operating and maintenance cost, favorable financing, safety rating, towing capacity, appearance and finally services offered by the near dealer. Presenting all these 14 determinants in the same order to all respondents, would create an order bias. To remove this bias, a randomization mechanism is embedded in this question so that the order of these 14 factors is changed for each respondent.

Responses to this ranking exercise were analyzed using a Condorcet method that is extensively used in election science. It simply looks at candidates in pairwise comparison, and whichever candidate wins in all comparisons, that candidate is considered the winner and referred to as the Condorcet winner (Black, Newing, McLean, McMillan, & Monroe, 1958). In applying Condorcet method to this analysis, I used Professor Morris (2003) Excel template[3]. The template allows for determining the number of winners, however, I choose to run the analysis looking for 13 winners (the total number of determinants in the question) as I was most interested in the order of importance. The output of Condorcet ranking is presented in Table 2, which has two main columns. The first column contains Condorcet ranking output, while the second contains the open

[3] The VBA and excel workbook is electronically attached in appendix C. It can also be found at: http://faculty.winthrop.edu/morrisr/KerleyVotingMethod.htm

ended question ranking (section 5.2.1) to facilitate comparing the two analyses. The comparison here should be dealt with care as it is not fair comparison. This is due to the fact that we are evaluating past purchase to a future one using two distinct ways of getting the data.

Not surprisingly, and confirming the outcome of the open ended question analysis, consumers in Saudi Arabia are concerned about vehicle price. In fact, if I was only looking to find one Condorcet winner, price would satisfy the Condorcet criterion. This means that if each respondent was asked to choose between price and each one of the 13 remaining determinants on one to one comparisons, none of respondents would choose anything else over price.

**TABLE 2 CURRENT VS. FUTURE VEHICLE PURCHASE DETERMINANTS**

| | Future vehicle purchase determinants: Importance rank (Condorcet method) | Current vehicle purchase determinants: The open ended question (%) |
|---|---|---|
| 1 | Price | 1st (17.6%) |
| 2 | Reputation of manufacturer | 14th (1.7%), 25th (0.9%) |
| 3 | Safety rating | 31st (0.7%) |
| 4 | Performance of engine | 5th (5.2%), 19th (1.3%) |
| 5 | Luxury amenities and/or special features | 8th (2.8%), 18th (1.3%) |
| 6 | Operating and maintenance costs | 15th (1.7%) |
| 7 | Appearance | 9th (2.6%), 13th (1.7%) |
| 8 | Seating capacity | 2nd, (13%) |
| 9 | Services offered by the nearby dealer | 45th, (0.2%) |
| 10 | Fuel economy (kilometer per liter) | 7th (3.7%), 12th (2%), 16th (1.5%) |
| 11 | Cargo space / truck bed space | 30th (0.7%) |
| 12 | Favorable financing | Closest, but far: 27th (0.9%) |
| 13 | Ability to see the road (ride height) | |
| 14 | Towing capacity (e.g., for boats or trailers) | |

The second Condorcet winner, and more surprising, is the “Reputation of the manufacturer”. It is even more important than safety, and operating and maintenance costs. Being

ranked the second shows how word of mouth drives the dynamics of the auto market in Saudi Arabia. This might also have something to do with the country of origin too, and thus, the next section (5.3), I will address this in a more detailed fashion.

Luxury amenities and/or special features was ranked 5th in the ranking exercise for the future purchase, while "Luxury" as an independent determinant in previous vehicle owned was ranked 8th (in the open ended analysis). Also notice that, "features and technologies" emerged as a determinant, ranked 18th in the open ended analysis.

Appearance was the 7th winner in the ranking exercise, compared to the 13th: aesthetics (1.7%) and, less related, 9th: personal choice (2.6%) in the open ended analysis. Appearance is another example of the discrepancy between the types of the analyses conducted. Not only in appearance ranking, but also for its relative rank to important determinants. For example, appearance was ranked right before the seating capacity in the ranking exercise, while, in the open ended analysis, was 9th, way after seating capacity.

Seating capacity was ranked the 8th. Probably unique to Saudi Arabia and neighboring countries, perhaps contradicting the case for North America and Europe, passenger capacity beat fuel economy for every respondents, as clearly evident in both analyses. Seating capacity importance seems to change dramatically between buying the current vehicle and buying the future vehicle as evident by the order difference between the two analyses (second in the open ended analysis –previous purchase-, vs. 8th in the closed ended analysis –future purchase-). As reported in other parts of the world, (Ozaki & Sevastyanova, 2011) and observed within Saudi Arabia, (Assad, 2008), some households opt for multi vehicles mode, in which one of the vehicles has far more passengers' capacity than the other.

Services offered by the nearby dealer was ranked 9th in the closed ended analysis, while it showed up in the open ended analysis as "after sale service", among the least frequent, representing only 0.2% of the respondents. This reflects the low expectations of a typical Saudi from dealerships. More clearly, in the open ended question analysis, spare parts availability was the main reason for 1.3% of respondents to choose their current vehicles, highlighting how low the expectations are from dealerships. I can confidently say that most Saudis only use the dealership services for the free service sessions that come with the sale of a new vehicle. Even if, during one of those free visits to the service, something wrong is diagnosed with the vehicle, if not covered by the warranty, most vehicle owners would not fix their vehicles at the dealership service centers. This is probably due to a larger problem related to illegal foreigner services that offers such services at a much cheaper price.

Fuel economy was ranked 10th, beating four determinants in the Condorcet matchings, two of which are for specialty vehicles: Cargo space / truck bed space and Towing capacity (e.g., for boats or trailers). The other two are: favorable financing and the ability to see the road (ride height). All of these four determinants are low ranked determinants in both analyses, which, again, shows that fuel economy is only better than the least important determinants.

The full matrix for the one on one comparison between all the 14 determinants is presented in appendix D. Two of the Condorcet ranking determinant, did not have equivalent in the open ended analysis: The ability to see the road (ride height), and towing capacity (e.g., for boats or trailers). Luckily I added the open ended question to the online questionnaire as it brought up 27 determinants into the picture of Saudis vehicle purchase decision making.

## 5.3. Vehicle Makers and Ownership Determinants

Saudi society seem to have cultural connotation with vehicle country of origin. This was clear in ranking manufacturer reputation in the 2nd place in Condorcet ranking exercise. Luxury is generally associated with German vehicles, while durability and quality with Japanese vehicles and finally comfort is attributed to American vehicles. These connotations are not set in stone, they are changing over time. Korean vehicles, for example, once perceived as lower quality vehicles are now shaking Toyota empire in the Saudi market, claiming the second largest market share in just few years. To assess these assumptions and possibly discover some other insights, further explorations are presented below.

Respondents' vehicle ownership data, including vehicle year, make and model were captured. Table 3 shows the make distribution for owners respondents who choose to reveal these data. The oldest vehicle was made in 1984, while the newest was 2016. Ownership data were cross tabulated against the results of the first seven highly repeated open ended question purchase motivations: price, passenger capacity, quality, comfort, luxury, economical and efficiency.

**TABLE 3 RESPONDENTS CURRENT VEHICLES MAKERS**

| MAKE | FREQUENCY | % | CUMULATIVE % |
|---|---|---|---|
| TOYOTA | 221 | 35.0% | 35.0% |
| FORD | 76 | 12.0% | 47.1% |
| CHEVROLET | 61 | 9.7% | 56.7% |
| GMC | 48 | 7.6% | 64.3% |
| LEXUS | 34 | 5.4% | 69.7% |
| HYUNDAI | 33 | 5.2% | 75.0% |
| HONDA | 29 | 4.6% | 79.6% |
| NISSAN | 28 | 4.4% | 84.0% |
| MERCURY | 26 | 4.1% | 88.1% |
| MERCEDES | 13 | 2.1% | 90.2% |
| OTHERS | 62 | 9.8% | 100.0% |

The condense outcome of this cross tabulation exercise is presented in Figure 4 below. Price was mentioned most frequently among all brands, which again, signify this determinant value across brands, even for some luxury brands like Lexus.

Toyota gained the superior positions for three determinants: price, economical and quality. Consumers distinguished Toyota by perceiving it as the most economical brand, six times more than the next highest brand, Hyundai. Toyota is also perceived as a quality brand, at least more times more than the next brand: Honda. Honda and Toyota shared the same first place for efficiency.

Passenger seating capacity was the place for GMC, followed by Toyota, Chevrolets, and Ford respectively. This resonates well with the most common models of large vehicles on the Saudi roads, Yukon for GMC, V(or G)XR for Toyota, Tahoe or Suburban for Chevrolet and Excursion, Expedition and Explorer for Ford.

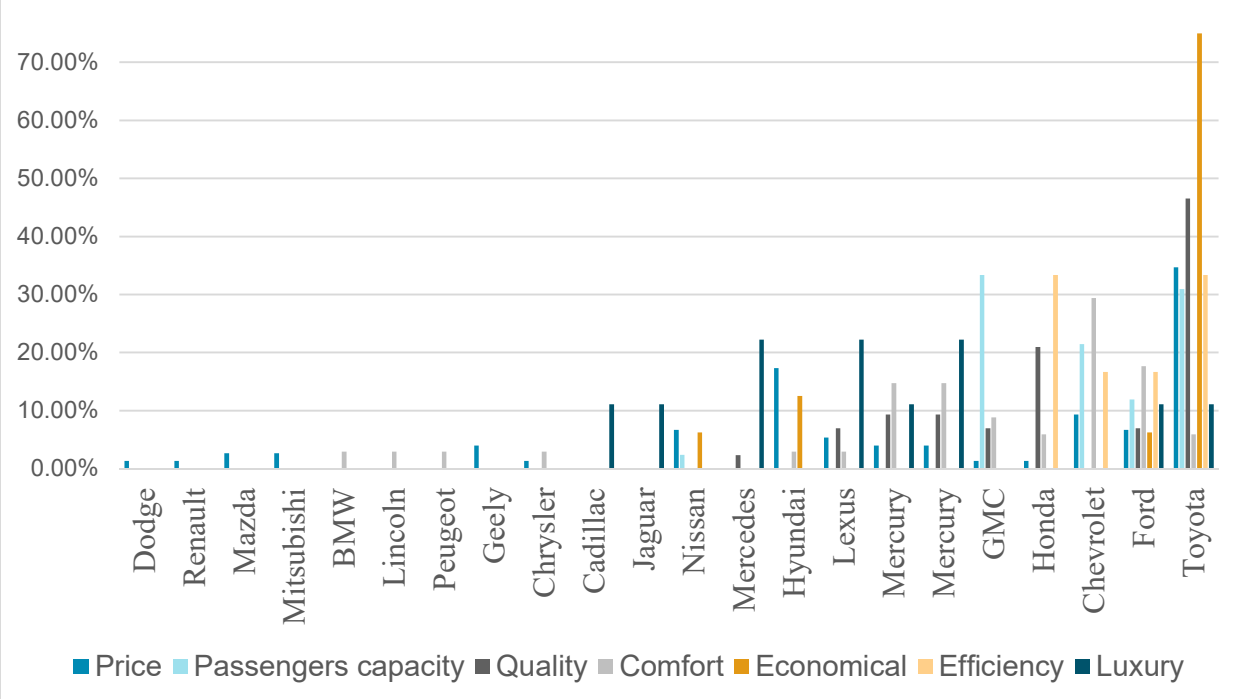


**FIGURE 4 MAKES AND HIGHELY MENTIONED 7 DETERMINANTS**

## 5.4. Vehicle's Ownership Level and Vehicle's Class Determinants

Many entities need to develop vehicle ownership predictive models for a variety of reasons. Vehicle manufacturers use such models to capture consumers' preferences for vehicles' attributes so then be able produce a selling vehicle. Oil companies want to predict transportation fuel demand. Traffic and environment departments use these models to forecast transport demand, emission and energy consumption levels (De Jong, Fox, Daly, Pieters, & Smit, 2004).

The purpose of this chapter is exploratory in nature and thus, general socioeconomic variables are studied in order to see its effects on vehicles consumption. A literature review for: income, age, gender, education level and household size is presented in the following section.

Higher income is directly associated to more spending, and therefore directly related to vehicle ownership (Cirillo, 2010). Whelan (2007) suggests that income determines the number of vehicles owned by individuals. Spissu, Pinjari, Pendyala, and Bhat (2009) found out that high income is positively associated with buying large sedans, coupes, SUVs, and vans and negatively with buying pick-ups.

Age changes purchasing behavior for many products. When it comes to purchasing vehicles, younger people (less than 35 years) tend to buy compact vehicles, while middle aged group (older than 36, but younger than 55 years) tend to buy coupes and vans (Spissu et al., 2009).

In 2010, TrueCar did a study for the previous two years to explore the effect of gender on vehicle consumption looking at the gender printed on vehicles registration. Their data showed 64% registrations were for males , while 36% for females, even though males make up 49% of the United States' population at that time (TrueCar, 2010). Consumer Reports National Research Center performed a more recent study on more than one million vehicles' owners. The study

showed that women want a safe, reliable, and fuel-efficient vehicles while men want powerful vehicles. The study also showed that Hybrid Electric Vehicles (HEVs) are common with female more than with male drivers (Consumer reports, 2015). In Austria, gender was found to be statistically significant determinant of not only vehicle ownership, but also vehicle use (Borgoni, Ewert, & Prskawetz, 2002).

Household size impacts the level of vehicle ownership as well as vehicle class (Karlaftis & Golias, 2002). Naturally, as the number of the household members increases, the need for transport increases too. Whelan (2007) suggest that the number of employed people in a household is an important determinant of vehicle ownership level. Spissu et al. (2009), stated that larger household size is associated with buying vans. They also suggest that, generally, having children in the household is associated with buying large sedans, SUVs, and vans. On the other hand, having seniors in the household is associated with buying large sedans, vans, and is associated with a lower likelihood to buy SUVs.

Income is generally a function of education level. Also, as some vehicle classes are more environment friendly than others, education is expected to increase preference for efficient vehicles. Therefore, studying education level effect on vehicle on vehicle consumption behavior is advised. Ozaki and Sevastyanova (2011) found out that, some Prius drivers expect that, owning a HEV speaks not only about their education level and that they are part of green society, but also speaks about their ability to educate others about this type of vehicle technology.

Based on the available data, and the literature review presented earlier, I explored gender, age, education level, household size and income effects vehicle on vehicle's ownership level and vehicle's class, in the following two subsections.

### 5.4.1. VEHICLE OWNERSHIP LEVEL: A POISSON REGRESSION MODEL

Vehicle ownership level is defined as the number of vehicles owned by a given respondents. The analysis idea is to regress the vehicle class (the dependent variables here) on respondents' age, gender, education level, income, household size. Figure 5 shows the dependent variable.

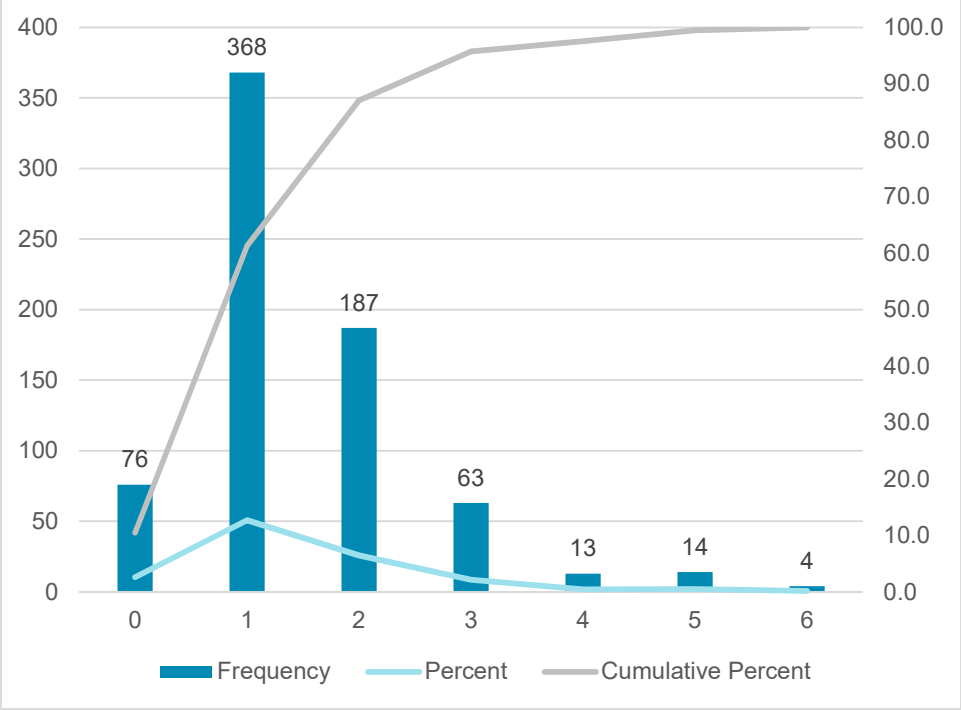


**FIGURE 5 NUMBER OF OWNED VEHICLES**

725 valid responses were are used in performing this analysis. Table 4 shows some statistics about respondents.

**TABLE 4 OWNERSHIP LEVEL POISSON REGRESSION MODEL VARIABLES**

| *Variable* | *Explanation* | | *Mean* | *Std. Dev.* |
|---|---|---|---|---|
| *Age* | Age between 18–24: | 12% | 34.88 | 9.27 |
| | Age between: 25–34: | 44.4% | | |
| | Age between: 35–49: | 37.2% | | |
| | Age between: 50–64: | 6.3% | | |

| | | | |
|---|---|---|---|
| | Age between: 65 & over: 0% | | |
| *Household size* | 1: 2.6%<br>2: 7.3%<br>3: 12.4%<br>4: 15.0%<br>5: 25.1%<br>6: 11.6%<br>7: 12.3%<br>>7: 13.7% | 5.05 | 1.89 |
| *Gender* | 0: Female (17.9%)<br>1: Male (82.1%) | 0.82 | 0.384 |
| *Income* | (< 1200): 3.4%<br>(1201: 2800): 5.1%<br>(2801: 4000): 2.1%<br>(4001: 6000): 7%<br>(6001: 9000): 9%<br>(9001: 12000): 12.4 %<br>(12001: 15000): 24%<br>(15001: 18000): 10.1%<br>(18001: 21000): 8.1%<br>(21001: 24000): 5.7%<br>(24001: 27000): 3.3%<br>(27001: 30000): 2.5%<br>(>30000): 7.3% | 14149.66 | 8111.65 |
| *Education level* | 1: Did not complete high school: 0.7%<br>2: High school: 8.8%<br>3: Some college/associate: 11.9%<br>4: Bachelor's degree: 55.9%<br>5: Master's degree: 17.7%<br>6: Advanced graduate work or Ph.D.: 0.1% | 3.96 | 0.956 |

Two normality tests: Kolmogorov-Smirnova (statistic: 0.817, 725 df, and 0.000 significant) and Shapiro-Wilk (statistic: 0.292, 725 df, and 0.000 significant) have been performed on the dependent variable, both showing that this variable is significantly different from the normal

distribution. I also tried the LN and LOG transformations, but none allowed the vehicle ownership level to pass the normality test. The nature of the dependent variable dictates the type of the regression model. The dependent variable is a count data. Therefore, Poisson distribution regression present itself as the right type of regression model. Moreover, the dependent variable histogram presented earlier in Figure 5 shows how close that histogram to a Poisson distribution histogram.

A Poisson distribution regression model was obtained using IBM SPSS 22 Generalized Linear Models utility, with Poisson distribution and Log link function. A significant Omnibus test with 75.066 Likelihood Ratio Chi-Square and 5 df indicated a good fit for the model.

Poisson distribution regression models assumes equidispersion, a case happen when the variance equals the mean. Deviating from this assumption results in either overdiseprsion (variance is greater than the mean) or underdispersion (variance is less than the mean). In most cases, deviating from the equidispersion assumption is expected. In practice, most studies seem to be more concerned with the case of overdispersion (Berk & MacDonald, 2008). The obtained model, on the other hand, seems to experience a mild underdispersion issue, as evident by the deviance value/df = 0.64 and Pearson Chi-Square/df = 0.67. It is important to notice that underdispersion places its strongest effects only on standard errors; and has quite minor effects on the regression coefficients (Winkelmann, Signorino, & King, 1993). Since the underdiserson figures above are closer to one than to zero, I decided to continue assessing this Poisson distribution based regression model.

Poisson regression coefficient can be interpreted: as the predictor variable changed by one unit, the logs of the expected number of vehicles is expected to change by the respective regression

coefficient, given all the other model variables held constant. This interpretation is not intuitive, so the exponent values of the coefficient is calculated and added to the model output presented in Table 5. Consistent with the expectations, gender, age, and income were all found to be positively significant in determining vehicle ownership level.

Gender is the only categorical variable used in this model. Its coefficient estimate compared females to males, given the other model variables are held constant. The difference in the logs of expected number of owned vehicles is expected to be 0.258 units higher for females compared to males, while holding the other model variables constant. More intuitively, using exponent of the log of the number of vehicles owned, males are 29.38% more likely to own vehicles than females.

Contradicting the expectations, both education level and household size were found to be statistically insignificant in determining vehicle ownership level, therefore, their respective coefficients are not going to be interpreted.

The exponent of age parameter estimate of Poisson regression coefficient suggested that, for each year increment of the respondent's age, there is 1.75% more chance to own more vehicles, given the other model variables are held constant. For 30 years old man, he is 17.5% more likely to have more vehicles than 20 years old man, given they both have the same amount of income, education level and household size.

The exponent of the income parameter estimate of Poisson regression coefficient indicated that, for each Saudi Riyal increment of the subject income, there is 0.0011% more chance to own more vehicles, given the other model variables are held constant. In other words, for each 1000 SAR increment in the monthly salary, the chance to own more vehicles is 11% more. This kind of

interpretation for income, and age should be evaluated with care, as both variables are only assumed to be continues variables, while in fact, age is the average of age categories, and income is the average of income groups.

**TABLE 5 VEHICLE OWNERSHIP LEVEL POISSON DIST. REGRESSION MODEL**

| Parameter | B | Std. Error | 95% Wald Confidence Interval | | Hypothesis Test | | | Exp(B) | Exp(B) 95% Wald Confidence Interval | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lower | Upper | Wald Chi-Sqre | df | Sig. | | Lower | Upper |
| **(Intercept)** | -0.711 | 0.194 | -1.091 | -0.331 | 13.444 | 1 | 0.000246 | 0.49107 | 0.336 | 0.718 |
| **Gender (Male:1)** | 0.258 | 0.0959 | 0.07 | 0.445 | 7.215 | 1 | 0.00723 | 1.29375 | 1.072 | 1.561 |
| **Age** | 0.017 | 0.0034 | 0.011 | 0.024 | 25.721 | 1 | 0 | 1.0175 | 1.011 | 1.024 |
| **Education level** | 0.002 | 0.0337 | -0.064 | 0.068 | 0.002 | 1 | 0.963685 | 1.00153 | 0.938 | 1.07 |
| **Household size** | 0.018 | 0.0172 | -0.015 | 0.052 | 1.127 | 1 | 0.288461 | 1.0184 | 0.985 | 1.053 |
| **Income** | 1.12E-05 | 4.06E-06 | 3.21E-06 | 1.91E-05 | 7.56 | 1 | 0.005969 | 1.00001 | 1 | 1 |

### 5.4.2. VEHICLE CLASS: A MULTINOMIAL LOGISTIC REGRESSION MODEL

In this section, a try to discover what drives the adoption of a certain vehicle class over others. This is achieved through collecting respondents' current vehicle ownership data, (year, made and model of the respondent's vehicle), then performing a regressing on age, household size, gender, income and education level, all presented in Table 6 below.

**TABLE 6 VEHICLE'S CLASS MULTINOMIAL LOGISTIC REGRESSION MODEL VARIABLES**

| *Variable* | *Explanation* | *Mean* | *Std. Dev.* |
|---|---|---|---|
| *Age* | Age between 18–24: 9.8%<br>Age between: 25–34: 44.1%<br>Age between: 35–49: 39.7%<br>Age between: 50–64: 6.4%<br>Age between: 65 & over: 0% | 35.4 | 9.11 |
| *Household size* | 1: 2.3%<br>2: 7.9%<br>3: 13.1%<br>4: 16.2% | 4.97 | 1.87 |

| | | | |
|---|---|---|---|
| | 5: 25%<br>6: 11.2%<br>7: 11.6%<br>>7: 12.7% | | |
| *Gender* | 0: Female (10.4%)<br>1: Male (89.6%) | 0.9 | 0.31 |
| *Income* | (< 1200): 2.6%<br>(1201: 2800): 3.8%<br>(2801: 4000): 1.7%<br>(4001: 6000): 6.3%<br>(6001: 9000): 8.4%<br>(9001: 12000): 13.7 %<br>(12001: 15000): 24%<br>(15001: 18000): 10.7%<br>(18001: 21000): 6.3%<br>(21001: 24000): 5.6%<br>(24001: 27000): 3.3%<br>(27001: 30000): 3%<br>(>30000): 7.4% | 14689.3 | 7925.11 |
| *Education level* | 1: Did not complete high school: 0.5%<br>2: High school: 6.9%<br>3: Some college/associate: 12.6%<br>4: Bachelor's degree: 54.9%<br>5: Master's degree: 19.3%<br>6: Advanced graduate work or Ph.D.: 5.8% | 4.03 | 0.934 |

Given the nature of the dependent variable: vehicle class, a multinomial logistic regression was obtained using IBM SPSS 22. Useful data were a result of 605 valid responses. Owned vehicles were categorized into one of four categories:

- Subcompact and compact
- Full size sedan
- Pickup, truck or similar
- SUV, VAN and similar.

It is important to note here that vehicle class definitions differs from one geography to another. For instance, compact vehicle here in the US might be considered subcompact in the Arabian Gulf area. The same vehicle might be considered full-size sedan in Europe. Because of this variation in the definition of vehicle class, prior observation of the local market in Saudi Arabia and several discussions with interested people were conducted. These investigations lead to forming the above four categories as close as possible to most understood meaning of vehicle classes.

Table 7 shows the distribution of respondents' number of currently owned vehicles across the aforementioned categories. Since the pickup, truck and similar vehicles class was the smallest sample size (34), and since subcompact and compact category sample size was not large too (85), I decided to add these two categories together, and refer to them as "Others". The total of "Others" is 119, representing 19.7% of the total sample.

**TABLE 7 RESPONDENTS OWNED VEHCILES' CLASSES**

| Vehicle class | Frequency | % | Cumulative % |
|---|---|---|---|
| **Pick up or truck** | 34 | 5.6 | 5.6 |
| **Subcompact or compact** | 85 | 14 | 19.7 |
| **SUV , Van or similar** | 224 | 37 | 56.7 |
| **Full size sedan** | 262 | 43.3 | 100 |
| **Total** | 605 | 100 | |

This model was customized in SPSS, forcing all variables enter the model for obtaining the main effects estimates. Then all two-ways interaction terms for all the variables were entered to the model on a stepwise fashion, using SPSS "forward entry" utility.

The final model is a significant model, with chi-square of 141.065, 12 degrees of freedom and 0.000 significant level. The model has achieved an acceptable goodness of fit as evident by Pearson test (Chi-Square: 705.957, df: 696, Sig. 0.388) and Deviance test (Chi-Square: 659.415,

df: 696, Sig. 0.837). The model Pseudo R-Square readings were: 0.208, 0.237, 0.111 for Cox and Snell, Nagelkerke and McFadden respectively. The second step in obtaining the model (when the model has all variables and the interaction terms too) is associated with a significantly different model from the model of the first step (the model with all the variables, but without interaction terms), with Chi-Square: 9.243, 2 df and significant level of 0.010.

One of the ways to judge the usefulness of this model is to examine the model predictability, presented in Table 8. The overall vehicle class predictability of the model is 56%. The highest predictability power in the model is for full size sedan category, being able to classify correctly 66.4% of the cases. This probably reflects the large sample size for full size sedan class (43.3% of the data). Not far from full size sedan, SUV, VAN and similar vehicle (37% of the data) correctly classified 63.4% of the cases. The least correctly classified vehicle class was "others". "Others", contained many other vehicle classes, thus, not really helpful to consider, even if it has better classification %.

**TABLE 8 MULTINOMIAL LOGSISTIC REGRESSION CLASSIFICATION MATRIX**

| Observed | Predicted | | | |
|---|---|---|---|---|
| | Others | Full size sedan | SUV, VAN and similar | Percent Correct |
| **Others** | 23 | 58 | 38 | 19.30% |
| **Full size sedan** | 18 | 174 | 70 | 66.40% |
| **SUV, VAN and similar** | 6 | 76 | 142 | 63.40% |
| **Overall Percentage** | 7.80% | 50.90% | 41.30% | 56.00% |

The regression output is presented in Table 9 below. For the full-size sedan, age, educational level and income are statistically significant determinants of vehicle class. Age, educational level and income are positively related to the vehicle class. For example, for two men having the same levels of: age, income, and household size, the one with a higher education has 278% more chances of adopting full size sedan than "other" classes. On the other hand, statistically

significant but negativity related to vehicle class are household size and the interaction between age and education Level.

For SUV the VAN and similar vehicles, income, education level age and the interaction between age and education level where all found to be statistically significant in determining this vehicle class.

The biggest surprise so far for vehicle's class regression model is that household size is not significant in determining for SUV, VAN and similar vehicles class.

**TABLE 9 VEHICLE CLASS MULTINOMIAL REGRESSION MODEL**

| | Parameter | B | Std. Error | Wald | df | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower Bound | Upper Bound |
| **Full size sedan** | Intercept | -3.49 | 1.929 | 3.272 | 1 | .0704640 | | | |
| | Income | 0 | 0 | 6.564 | 1 | .0104082 | 1.0000435 | 1 | 1 |
| | Education level | 1.332 | 0.483 | 7.603 | 1 | .0058286 | 3.7885212 | 1.47 | 9.765 |
| | Gender (Female) | 0.05 | 0.378 | 0.017 | 1 | .8956602 | 1.0508866 | 0.501 | 2.207 |
| | Gender (male) | 0[b] | . | . | 0 | | | . | . |
| | Age | 0.149 | 0.055 | 7.217 | 1 | .0072233 | 1.1602743 | 1.041 | 1.293 |
| | Household size | -0.3 | 0.064 | 22.456 | 1 | .0000022 | .7392966 | 0.652 | 0.838 |
| | Age * Education level | -0.04 | 0.014 | 7.281 | 1 | .0069705 | .9630441 | 0.937 | 0.99 |
| **SUV, VAN and similar** | Intercept | -9.1 | 2.353 | 14.937 | 1 | .0001111 | | | |
| | Income | 0 | 0 | 10.311 | 1 | .0013222 | 1.0000560 | 1 | 1 |
| | Education level | 1.63 | 0.564 | 8.345 | 1 | .0038672 | 5.1053087 | 1.689 | 15.431 |
| | Gender (Female) | 0.59 | 0.399 | 2.188 | 1 | .1390520 | 1.8036284 | 0.826 | 3.94 |
| | Gender (male) | 0[b] | . | . | 0 | | | . | . |
| | Age | 0.251 | 0.062 | 16.611 | 1 | .0000459 | 1.2851219 | 1.139 | 1.45 |
| | Household size | -0.11 | 0.07 | 2.273 | 1 | .1316873 | .8999031 | 0.785 | 1.032 |
| | Age * Education level | -0.04 | 0.015 | 7.97 | 1 | .0047547 | .9586227 | 0.931 | 0.987 |

For both classes: full size sedan and SUV, VAN and similar, the interaction between age and education level was found to be statistically significant. Both education level and age were significantly and positively effecting vehicle class (for their main effects) in both SUV, VAN and

similar and full size sedan. The interpretation of the interaction term between age and education level is tricky, therefore, Figure 6 was obtained to assess this relationship: as the age increase, the relationship between education level and the likelihood of owning full size and SUV, VAN and similar vehicles increases.

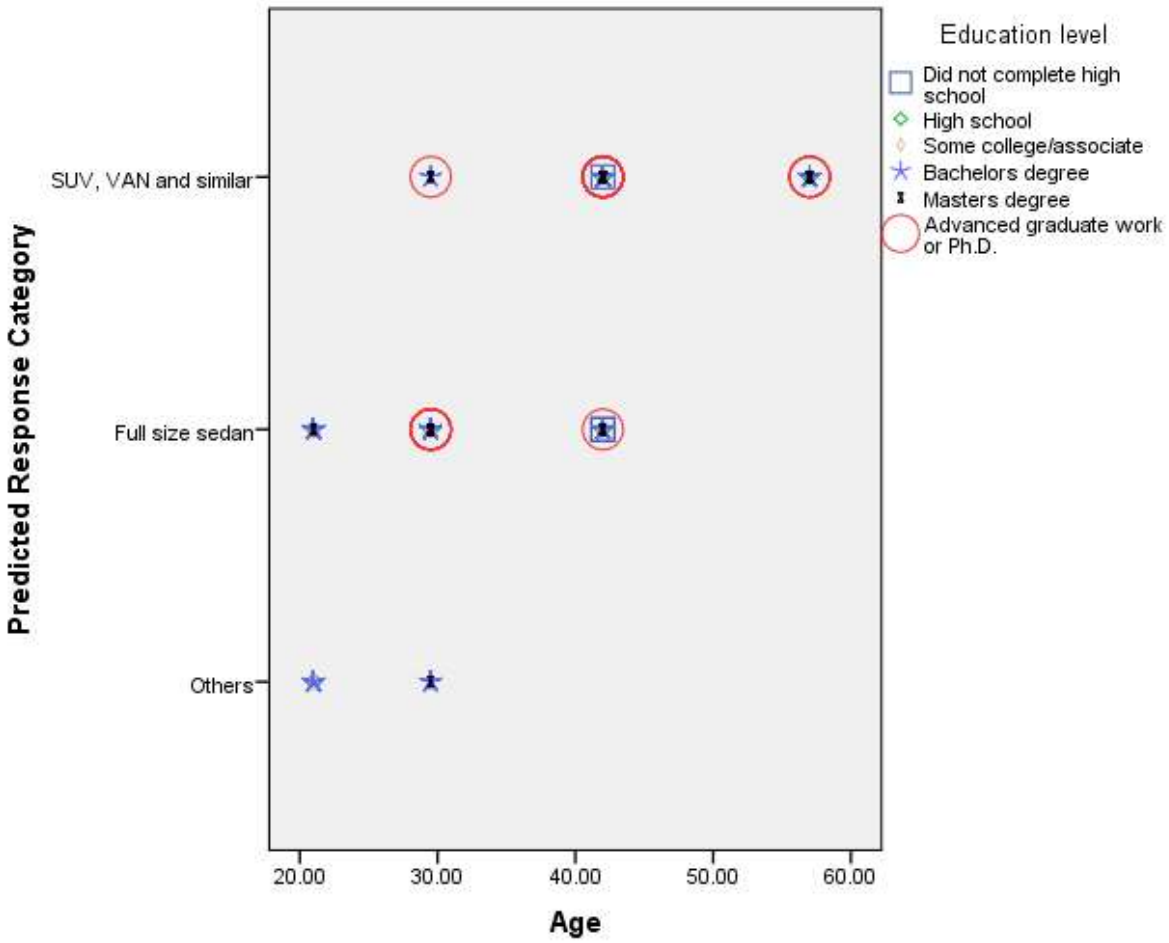


**FIGURE 6 RELATIONSHIPS BETWEEN EDUCATION LEVEL AND AGE AGAINST PREDICTED VEHICLE CLASS**

All variables, except gender were found to be statistically significant in determining the vehicle class. More surprisingly, household size is not statistically significant in determining wither a consumers is a SUV, VAN or similar relative to be "Other" vehicle class consumer.

The older respondents tend to be more likely to adopt SUV, Van and similar vehicles, than to adopt other vehicle classes. It is important to keep in mind that the comparison here is between

SUV, VAN and similar vehicles versus all other vehicle classes except full size sedan. In other words, it is SUV, VAN and similar vehicle versus subcompact and compact, pickups or trucks. Older respondents are 16% more likely to adopt full size sedan than other vehicle classes except SUV, VAN and similar. Also, older respondents are 29% more likely to adopt full size sedan than other vehicle classes except SUV, VAN and similar.

Individuals from a larger household size was found, not surprisingly, around 4% less likely to own full size sedan. What is surprising is that household size is insignificant for determining SUV, Van and similar class.

## 5.5.Lack of Vehicle Ownership

The questionnaire is designed to collect the number of vehicles owned by the respondents, from a drop down list, starting from zero (a case where the person does not own a vehicle yet). Whoever indicated that she or he does not own a vehicle (chose zero), were asked: "Can you please explain why you don't own/lease any vehicle?"

76 respondents indicated that they don't own any vehicle, the majority (75%) of which, were females. Figure 7 shows different reasons behind lack of vehicle ownership. In Saudi Arabia, women are not allowed to drive, and therefore some women would be discouraged to own vehicles (31% of non-owners). Additionally, slightly different category emerged –who are probably more convinced by the social norm of allowing only men to drive- 12% of respondent indicated being female is behind the lack of vehicle ownership.

Affordability was the 2$^{nd}$ highest reported reason for lack of vehicle ownership, with 24% of respondents. This category is different than the 9% category members who indicated that being a student or having no income is the reason for lack of ownership. The difference between these

two categories is that, the first group has income, but not enough to be able to afford buying a vehicle, while the latter has no income.

3.5% of the females group reported that they don't own a vehicle because their employers provided one or there is no need for the vehicle, compared to 21% of the males. Also, 3.5% of the females group reported that they are students and therefore they don't own vehicles, compared to 21% in the males group. 17.5% females group indicated the affordability is behind lack of vehicle ownership compared 42% of males. 5.3% of the females group reported that their spouses owned a vehicle and thus, they don't need to own one.

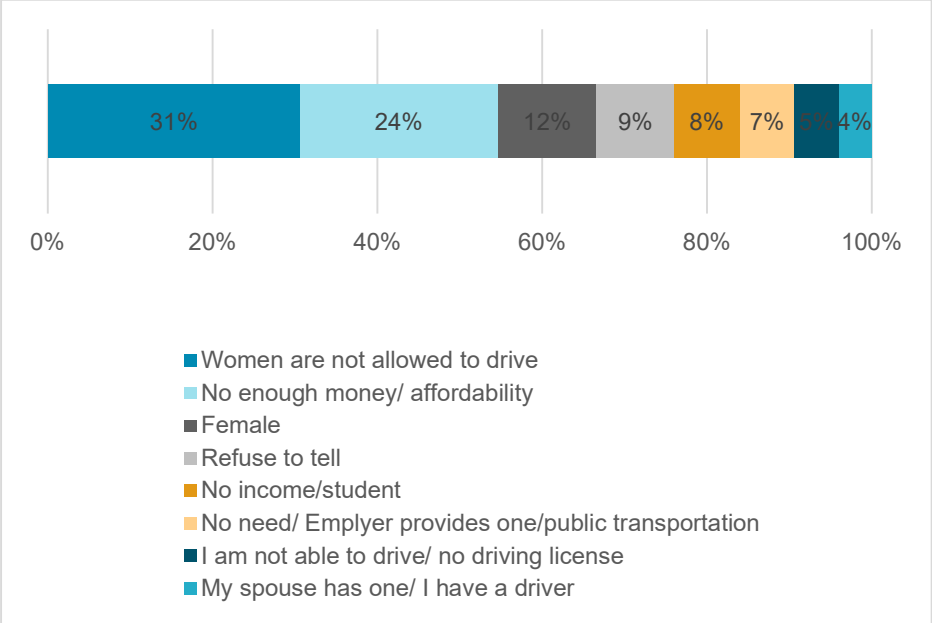


**FIGURE 7 REASONS FOR LACK OF OWNERSHIOP**

## 5.6.First Perspective Concluding Remarks

Despite Saudi Arabia being a high income country, price is found to be the most important determinant for a typical Saudi vehicle consumer, as confirmed by findings of both analyses. This is conforming to the vast majority of the literature that studied the same phenomenon in other parts of the world. Therefore, this must not be overlooked when establishing policies that aim to reduce

the nation's level of vehicle fuel consumption, and reduce passenger vehicles emissions, through encouraging more efficient vehicles' sales. Not only policy makers who should not overlook the importance of consumers' sensitivity for vehicle's price, but also local dealerships and distributers. If local distributers would like to comply with the rapidly changing fleet efficiency standards, required by the government in Saudi Arabia, then they must evaluate their pricing strategy to help develop a better product mix and therefore achieve fleet fuel efficiency targets.

Price being the first determinant of vehicle ownership might not be unique about the Saudi consumers, however, passenger capacity being second to price might. A wider vehicle represents the need for a large portion of vehicles' consumers. Relevant parties must realize this seating capacity needs. Hence, copying the United States scenario of introducing Prius and similar vehicles first in the Saudi market might not succeed as it does not solve the seating capacity need for vehicle consumers. Additionally, the fact that engine's performance was highly ranked (among top 5) in both analyses adds to the fear of not realizing HEV full potential if it started with compacts and subcompacts vehicles in the Saudi market. In fact, introducing small HEVs first to the Saudi market might have a negative impact on the overall HEV diffusion, if the first impression consumers have about HEV vehicle is being small or having inferior performance.

Men are almost 30% more likely to own vehicles in Saudi Arabia than women. However, gender was not found to be statistically significant in determining owners of full size Sedan and SUV, VAN or similar vehicles. This points to the need for further research in this regard, especially after knowing that the government seems to be soon relaxing "only men allowed to drive", which might be an amazing opportunity for diffusion HEV rapidly.

Education level and age, (in order of importance), were the most influential factors behind wider vehicle choices (strong positive relationship with adopting a vehicle with more seating capacity). This piece of information should be utilized by many entities, including government agencies and private sector decision makers. They also should know that, while seating capacity is very important for vehicle consumers in Saudi Arabia, household size is not the driver for purchasing larger vehicles. In the Saudi community, seating capacity seem to be defined in an unintuitive way: the space that I might be needed, not really the space needed. To put this in perspective, consider this personal situation: if my mother would be visiting me for a week in a whole year, then my vehicle should be enough for my family, my mother, and here made too.

# 6. APPLYING THEORY OF REASONED ACTION TO CONSUMERS' INTENTION TO ADOPT HEV IN SAUDI ARABIA

This chapter is assessing the intention of the people in Saudi Arabia to adopt HEV. The chapter starts with a theory, hypotheses and measure section, followed by section describing the methodology. After that, the analysis section is presented, followed by a concluding remarks.

## 6.1. Theories, Hypotheses and Measures

Ajzen and Fishbein (1980) in their theory of reasoned action (TRA) asserted that, given the right measures, the intention is the best determinant for a behavior under consideration. Since then, many studies have used intention as a measure for different technology adoption behaviors (e.g. Davis, Bagozzi, & Warshaw, 1989; S. Wang, Fan, Zhao, Yang, & Fu, 2014). TRA has been extensively used to study many types of behavior, such as unethical behavior, (Chang, 1998), renewable energy adoption behavior (Bang, Ellinger, Hadjimarcou, & Traichal, 2000), HEV adoption behavior (S. Wang et al., 2014), and recycling behavior (Goldenhar & Connell, 1993).

Ajzen (1985) extended TRA by adding a perceived behavioral control construct, making TRA to be become the Theory of Planned Behavior, (TPB) (Ajzen, 1985). I have chosen to use TRA over TPB in this chapter for many reasons. First, this work is the first that attempts to understand the intention to adoption HEV in Saudi Arabia, thus a simpler theory fits the purpose better. Second, some authors questioned the practical significance of the difference between TPB and TRA (Rossi & Armstrong, 1999). Currently, since HEV is not yet available in Saudi Arabia, there is no way to measure the behavior of adopting HEV, except for using behavior intention as the only determinant for the adoption behavior. Finally, TRA is generalizable to explain any human behavior (Icek & Fishbein, 1980), and is capable of holding its explanatory power across

different cultures (Park & Levine, 1999). Therefore, for all the above reasons, it is appropriate to apply TRA to studying the intention to adopt HEV in the context of Saudi Arabia.

An individual's attitude toward adopting HEV is a function of his or her beliefs (**b**), about the adoption consequences, and the evaluation (**e**) that an individual places on performing the HEV adoption. Subjective norm (**SN**) is a function of an individual's normative beliefs (**nb**) and the motivation to comply (**mc**) with those nb. Attitude, abbreviated by **A**, is assessed using four 5-points' semantic differential scale items: A1…A4. Subjective norm, abbreviated by **SN**, is assessed using four 5-points Likert scale items: SN1...SN4. **A**dopting **HEV I**ntention, abbreviated by AHEVI, is assessed using three 5-points Likert scale items: AHEVI1...AHEVI3. Then, TRA is expressed mathematically as below:

$$AHEVI = A + SN$$

$$A = \sum b_i \cdot e_i$$

$$SN = \sum nb_i \cdot mc_i$$

S. Wang et al. (2014) gathered the relevant survey constructs from many sources such as (Bagozzi, Dholakia, & Basuroy, 2003; Jakovcevic & Steg, 2013; Nordlund & Garvill, 2003) and then modified them to fit the adoption of HEV behavior. In this study, the wording of all the items of TRA items are taken directly from the work of S. Wang et al. (2014) due to the similarities in research topic and goal. A schematic representation of the model is given in Figure 8, showing, in light of the above theoretical discussion, the following research hypotheses about the intention to adopt HEV in Saudi Arabia:

- H1: Attitude about adopting HEV is positively related to adopting HEV's intention

- H2: Subjective norm about adopting HEV is positively related to adopting HEV's intention

In HEV adoption motivation literature, it has been reported that environmental consciousness sometimes drives HEV adoption. Plötz et al. (2014), for example, suggested that HEV buyers are motivated by HEVs' environmental advantages. Krupa et al. (2014) found that people who are concerned with the environment find that Plug-in HEVs' environmental benefits are a higher purchase motivator than financial benefits. They also found that participants who were most concerned with climate were 44.4 times more likely to purchase PHEV than those least concerned. This finding fits the overarching objective of this research, which is to test the environment concern (EC) effect on TRA constructs. EC is assessed using four 5-point Likert scale items that are taken directly from S. Wang et al. (2014) work mentioned earlier. In light of the above EC discussion, the following set of hypotheses emerges:

- H3: Environmental concern is positively related to attitude about adopting HEV
- H4: Environmental concern is positively related to subjective norm about adopting HEV

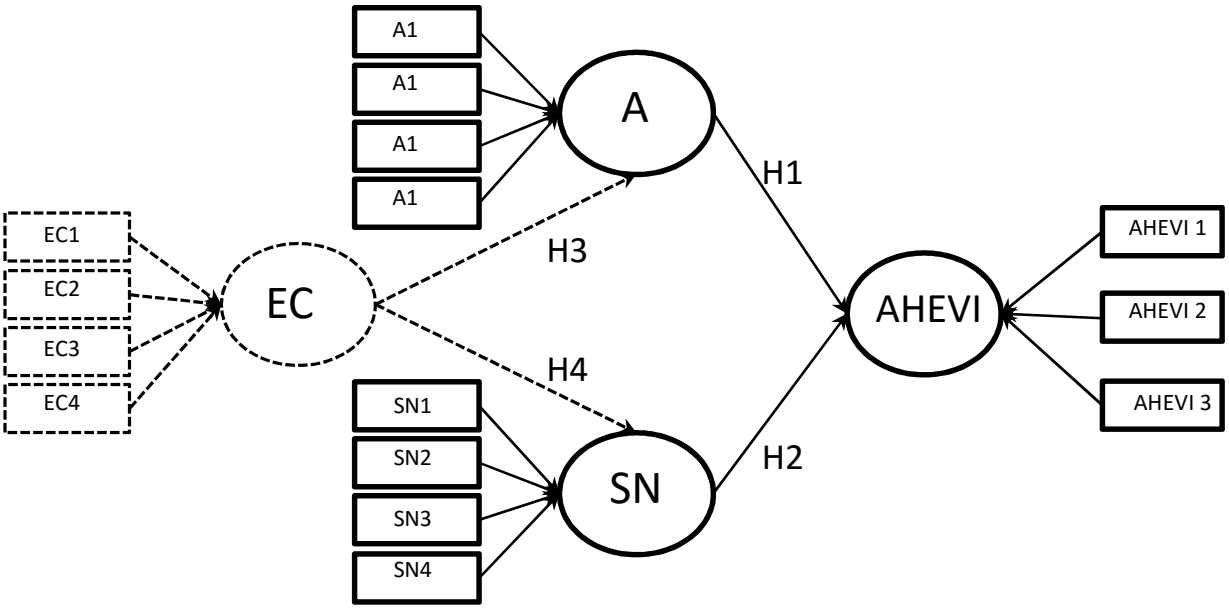


**FIGURE 8 SCHEMATIC DESCRIPTION OF THE PROPOSED EXTENDED TRA MODEL**

After a final cleaning of the data, there were 847 valid responses that account for about a 53% completion rate. The relatively low completion rate is possibly caused by the length of the survey, which took, on average, around 30 minutes to finish.

**TABLE 10 FIRST PERSPECTIVE RESPONDENTS DEMOGRAPHICS**

| *Variables* | *Frequency % (N = 847)* | |
|---|---|---|
| *Gender* | F:29.8% | M:70.2% |
| *Age* | 18–24: 10% | 35–49: 32% |
| | 25–34: 52% | 50–64: 5% |
| | >65: 0% | |
| *Education level* | Did not complete high school: 0.6% | BS: 62.2% |
| | High school: 7.6% | Master's degree (15.1%) |
| | Some college/associate:10.2% | Advanced grad. Work /PhD (4.4%) |
| *House structure* | Married (no children): 7.1% | Single parent (non-dependent children): 0.1% |
| | Married(dependent offspring): 71.7% | Single: living with family: 11% |
| | Married (non-dependent children): 4% | Single: living alone: 4.8% |
| | Single parent (dependent children): 0.2% | Other: 1.1% |
| *Household size* | 1: 2.2% | 5: 35.9% |
| | 2: 6.3% | 6:9.9% |
| | 3: 10.6% | 7:10.5% |

| | | |
|---|---|---|
| | 4:12.9% | >7: 11.7% |
| *Income (SAR)* | <1200: 3% | 15001 to 18000:8.6% |
| | 1201 to 2800: 4.4% | 18001 to 21000: 7% |
| | 2801 to 4000: 1.8% | 21001 to 24000 (4.8%) |
| | 4001 to 6000: 6% | 24001 to 27000 (2.8%) |
| | 6001 to 9000: 7.7% | 27001 to 30000 (2.1%) |
| | 9001 to 12000: 10.6% | > 30000 (6.3%) |
| | 12001 to 15000: 34.9% | |
| *Nationality* | Saudis: 96.1% | Others: 3.9% |

## 6.2. Analysis and Results

Several studies have reported different rules for determining a sufficient sample size for conducting Structural Equation Modeling (SEM). For example, J. S. Tanaka (1987), suggests 20 observations for each 1 free parameter ratio. Less restricted recommendation is to consider a ration as low as 5 to 1 (Bentler & Chou, 1987). Kenny (2015) suggests a sample size of 200 as a goal for SEM. For this study, the sample size of 847 is sufficient (using the aforementioned rules) and thus, it is safe to proceed to perform all the steps leading to estimating model parameters. However, since this research is based on a survey, there is potential for common method bias. A Harmen's one factor test was conducted, showing that one factor is not responsible for the majority of the variance explained, and hence, there is no concern for such bias (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003).

The rest of the analysis was conducted over 3 stages: exploratory factor analysis (EFA) using IBM SPSS, measurement model testing, and finally testing the structural model both using AMOS Graphics. Each of these stages is explained in the following sections.

### 6.2.1. Exploratory Factor Analysis (EFA)

An EFA was carried out using the Maximum Likelihood extraction method with Promax rotation and Kaiser Normalization in SPSS. The first solution obtained had Kaiser-Meyer-Olkin

measure of sampling adequacy of 0.869 (significant approximate chi-square test, Bartlett's test of sphericity of 6361.557, with 105 degrees of freedom). The cumulative variance explained 59.107%, however, items EC3 and EC4 had low extractions: 0.296 and 0.353, and low loadings on EC construct: 0.529 and 0.599 respectively. Therefore, EC3 and EC4 were deleted. Also, A1 was found to be highly correlated with A2 (significant 2-tailed 0.01 Pearson correlation: 0.771), therefore, A1 was deleted too, resulting in a solution with Kaiser-Meyer-Olkin measure of sampling adequacy of 0.847 (significant approximate chi-square test, Bartlett's test of sphericity of 5027.604, with 66 df). All the constructs of the TRA: A, SN and AHEVI, along with EC construct emerged from the solution, explaining 63.185% of the total variance. All items loaded on their respective factors nicely and the average of items loading on their respective factors was at least 0.7 (Gaskin, 2013). There was no cross loading for any of the items within a difference of 0.2, (see Table 12). Therefore, I conclude that the model has obtained an acceptable level of convergent and discriminant validity. Additionally, Cronbach's alpha reliability measures for all the factors were obtained, indicating all factors, but EC, are at the acceptable scale of internal consistency level of 0.7. EC construct Cronbach's alpha is 0.65, close to the threshold mentioned above. It is known that Cronbach's alpha is sensitive to the number of items within the construct under consideration, the more the items, the larger alpha gets (Cronbach, 1951). In this case, EC has only 2 items, the minimum possible, therefore, EC reliability level is accepted. The solution factor loadings, reliabilities info and others are presented in Table 12 below.

### 6.2.2. CONFIRMATORY FACTOR ANALYSIS

A confirmatory factor analysis (CFA) is then performed to examine the measurement model validity. For a CFA model with sample size up to 200, the chi-square test is a reasonable fit

measure, however, for larger sample size model, like the one in this study, chi-square test is likely to be statistically significant (Kenny, 2015). Therefore, the model fit is evaluated using the following alternative measures: chi-square/df (CMIN/df), goodness-of-fit Index (GFI), adjusted goodness-of-fit index (AGFI), bender's comparative fit index (CFI), standardized root mean squared residual (SRMR), and probability of close-fit (PCLOSE). Measures and their respective thresholds are presented in Table 11 (Hu & Bentler, 1999). The CFA model fit readings are presented in Table 12. Although the model fit readings are all at the acceptable thresholds, the modification indices were examined, which indicates that no valuable gain would be realized from any changes in the initial CFA model.

**TABLE 11 CFA MODEL FIT READINGS AND THRESHOLDS**

| Measure | Threshold | Extended TRA |
|---|---|---|
| **CMIN/DF** | < 3 | 2.485 |
| **GFI** | > 0.95 | 0.977 |
| **AGFI** | > 0.8 | 0.963 |
| **CFI** | > 0.95 | 0.986 |
| **SRMR** | < 0.05 | 0.0275 |
| **PCLOSE** | > 0.05 | 0.918 |

The composite reliability (CR) for EC is 0.655, as seen in Table 12, and is just below the traditional acceptable level of 0.7. Also, the more conservative AVE measure of EC is 0.488, less than the suggested threshold of 0.5. Therefore, the EC construct convergent validity is questionable, because the error explains more than 50% of the variance (Fornell & Larcker, 1981). Other than EC construct limitation that was accepted because of the small deviation from the established thresholds, there was no validity issue with the CFA model as evident by the rest of CR, average variance extracted (AVE), maximum shared variance (MSV), and average shared variance (ASV) presented in Table 12. Therefore, the analysis is ready to proceed to perform SEM

using AMOS Graphics software. Before that, however, since AMOS is capable of only dealing with linear relationships among SEM model, linearity has to be checked. After performing curve estimations for all the relationships in the CFA model were obtained, it was determined that all the relationships in the model are definitely linear. Multicollinearity for EC, SN and A (predicting AHEVI) were checked using variance inflation factors (VIF) and proved that there is no such concern as all VIFs were below 3.3 (Lowry & Gaskin, 2014), thus it is safe to use AMOS covariance based SEM algorithm.

### 6.2.3. STRUCTURAL MODEL

The initial SEM fit (CMIN/df: 4.071, GFI: 0.963, AGFI: 0.942, CFI: 0.969, SRMR: 0.0965 and PCLOSE: 0.024), was improved upon checking the modification indices. it was found that if the analysis is repeated while treating the covariance between A and SN error terms, the model fit will get to, and exceed, the acceptable model fit thresholds (CMIN/df: 2.452, GFI: 0.977, AGFI: 0.964, CFI: 0.986, SRMR: 0.0284 and PCLOSE: 0.932). This change led to a valid SEM that has a squared multiple correlation of 0.52, which represents the amount of variance the model explains in AHEVI. Both regression lines from SN and A are significant (at 0.001 level): 0.19 between A and AHEVI, and more than 3 times as much, 0.63 between SN and AHEVI.

**TABLE 12 EFA AND CFA RESULTS**

| Constructs | Items | Loading | CR | α | AVE | MSV | ASV | AHEVI | A | SN | EC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Adopting HEV intention (AHEVI)** | AHEVI1 | 0.73 | 0.91 | 0.91 | 0.76 | 0.48 | 0.23 | 0.874 | | | |
| | AHEVI2 | 0.96 | | | | | | | | | |
| | AHEVI3 | 0.87 | | | | | | | | | |
| **Attitude (A)** | A2 | 0.82 | 0.89 | 0.89 | 0.73 | 0.18 | 0.12 | 0.429 | 0.86 | | |
| | A3 | 0.89 | | | | | | | | | |
| | A4 | 0.86 | | | | | | | | | |
| | SN1 | 0.63 | 0.81 | 0.80 | 0.52 | 0.48 | 0.22 | 0.692 | 0.38 | 0.7 | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Subjective norms (SN)** | SN2 | 0.77 | | | | | | | | | | |
| | SN3 | 0.62 | | | | | | | | | | |
| | SN4 | 0.76 | | | | | | | | | | |
| **Environmental Concern (EC)** | EC 1 | 0.81 | 0.66 | 0.65 | 0.49 | 0.03 | 0.03 | 0.172 | 0.17 | 0.2 | 0.7 | |
| | EC 2 | 0.60 | | | | | | | | | | |

CR: Composite reliability, AVE: Average variance extracted, MSV: Maximum shared variance, ASV: Average shared variance

### 6.2.4. ENVIRONMENTAL CONCERN'S MEDIATION EFFECT

Mediation effect analysis was conducted as suggested by Baron and Kenny (1986), following 3 phases as presented in Figure 9 below. First, the unmediated path between EC and AHEVI was inspected and showed a significant β of 0.169. Next, the relationships between EC and both A and SN were checked and proved to be significant (EC to A had a significant β of 0.174 and for EC to SN had a significant β of 0.177). Finally, the direct path between EC and AHEVI was checked in which it became nonsignificant when looked at in conjunction with mediator relationships; (readings are bolded and italics in Figure 9). Therefore, it is concluded that A and SN fully mediates EC and AHEVI.

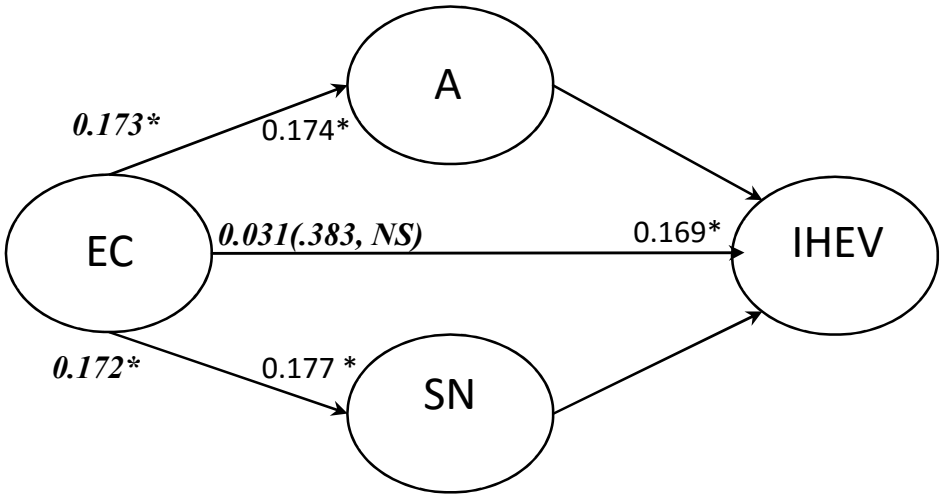


**FIGURE 9 MEDIATION EFFECTS (*: SIGNIFICANT AT LEVEL OF .001, NS: NOT SIGNIFICANT)**

### 6.2.5. TEST OF CONTROL VARIABLES AND INTERACTIONS

Family size, age, gender, and occupation often play important roles in forming consumption desire and patterns (El-Omari, 2014). Keith (2012b) found that HEV adoption is effected by social-economic and demographic factors. For example, HEV buyers in Switzerland and United Kingdom were found to have more than the average income and education levels (Plötz et al., 2014). A household with multiple vehicles is found to have a higher likelihood of adopting electric vehicles (Zubaryeva, Thiel, Barbone, & Mercier, 2012). In the Saudi context, many factors have the potential to affect AHEVI as well. Not only are the control variables important, but the interaction between them is useful to discover how they affect AHEVI. For example, I suspect that there is a correlation between age and education level that might affect AHEVI. I also suspect that the relationship between level of education and expected income exists. For these and other socioeconomic factors' interactions, it is imperative to explore any effect they might have on AHEVI. To do so and to ensure no multicollinearity issues, I first normalized all control variables under consideration, and then computed the following interaction terms: (Age X Education level), (Income X Education level), (Income X Household size), (Age X Household size), (Gender X Income), (Number of vehicles X Education level), (Number of vehicles X Household size), and (Number of vehicles X Age), see Table 13 below.

**TABLE 13 STANDARDIZED REG. WEIGHTS AND SIGNIFICANT LEVELS FOR CONTROL AND INTERACTIONS**

| Relationships | | | Estimate | S.E. | C.R. | P |
|---|---|---|---|---|---|---|
| AHEVI | <--- | Household size | 0.023 | 0.016 | 0.775 | 0.438 |
| AHEVI | <--- | Income | -0.027 | 0.012 | -0.817 | 0.414 |
| AHEVI | <--- | Education level | -0.056 | 0.032 | -1.825 | *** |
| AHEVI | <--- | Gender | 0.003 | 0.067 | 0.093 | 0.926 |
| AHEVI | <--- | Age | 0.012 | 0.044 | 0.350 | 0.727 |
| AHEVI | <--- | Current vehicle owner? | -0.115 | 0.107 | -3.146 | ** |
| AHEVI | <--- | Number of vehicles | 0.064 | 0.030 | 1.906 | *** |

| Relationships | | | Estimate | S.E. | C.R. | P |
|---|---|---|---|---|---|---|
| AHEVI | <--- | Age X Education level | 0.000 | 0.027 | -0.013 | 0.989 |
| AHEVI | <--- | Income X Education level | -0.030 | 0.026 | -0.994 | 0.320 |
| AHEVI | <--- | Income X Household size | 0.006 | 0.026 | 0.210 | 0.834 |
| AHEVI | <--- | Age X Household size | 0.114 | 0.027 | 3.454 | * |
| AHEVI | <--- | Gender X Income | -0.005 | 0.037 | -0.167 | 0.868 |
| AHEVI | <--- | Number of vehicles owned X Education level | 0.003 | 0.033 | 0.085 | 0.933 |
| AHEVI | <--- | Number of vehicles owned X Household Size | -0.010 | 0.027 | -0.339 | 0.735 |
| AHEVI | <--- | Number of vehicles owned X Age | -0.014 | 0.026 | -0.478 | 0.633 |

*: Significant at level of 0.001, **: Significant at level of 0.05, ***: Significant at level of 0.1

Despite prior evidence, income (Diamond, 2009; Erdem, Şentürk, & Şimşek, 2010; Gallagher & Muehlegger, 2011; S. Wang et al., 2014), gender (Erdem et al., 2010) and age (Gallagher & Muehlegger, 2011) were found to have no statistical significance. The finding that the household size is statistically insignificant is consistent with the result from the study by Erdem et al. (2010). Education level, however, was found to have a statistically significant effect, but surprisingly a negative one. This finding is in contrary to other studies such as (Erdem et al., 2010; Potoglou & Kanaroglou, 2007). Current status of vehicle ownership (defined as whether the person has a vehicle or not) was found to be negatively significant, however. Moreover, the number of vehicles owned was found to be positively significant. The latter is in line with findings in Zubaryeva et al. (2012). Among all the interactions that were tested, the interaction between age and household size was significant. Figure 10 shows that age changes the relationship between household size and AHEVI from a negative relation with younger population to a positive relation with older population.

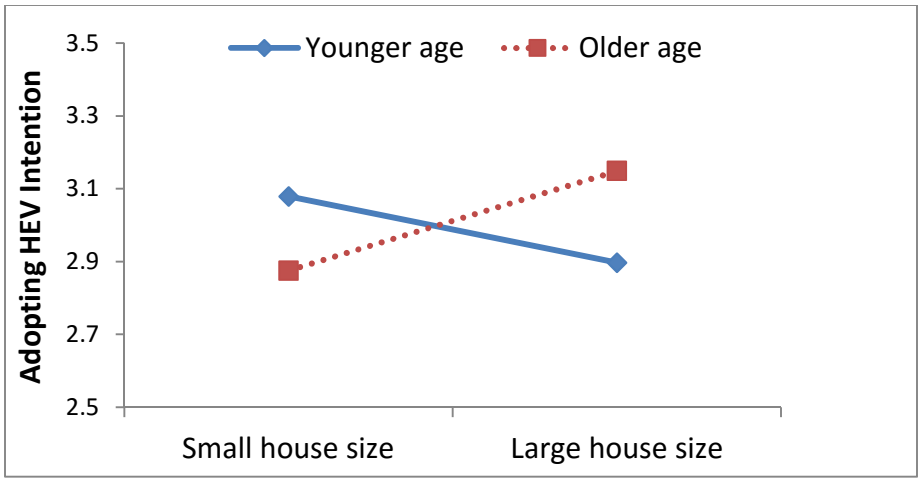


**FIGURE 10 INTERACTION EFFECT OF AGE AND HOUSEHOLD SIZE ON AHEVI**

## 6.3.Second Perspective Concluding Remarks

This chapter presented an application of the theory of reasoned action to model the intention of the consumers in Saudi Arabia to adopt Hybrid Electric Vehicles (HEV). The empirical results showed that, in Saudi Arabia, subjective norms and attitude, to a lesser degree, significantly affect HEV adoption intention. Furthermore, I explored the effects of environmental concern on attitude and subjective norms pertaining to the HEV adoption's intention. I found that attitude and social norm fully mediate the effect of consumers' environmental concern on their intention to adopt HEV.

To the best of my knowledge, this research is the first that investigates HEV adoption's intention in Saudi Arabia. Thus, I argue that the findings not only add theoretical contribution to the literature, but also provide insights that have global and local implications. Global implications can be observed in two avenues. The first has to do with saved fuel – any amount of saved fuel in Saudi Arabia (giving its local unprecedentedly growing consumption) will help the country to meet the growing global energy demand. The second is the benefit for relevant industries; that is, the

international auto industry players, which can utilize this research findings to meet the potential demand for efficient vehicles, HEV in particular, in the Middle East's largest market.

The implication of this research in the context of Saudi Arabia is to provide the government and the policy makers with such relevant insights on, for example, the design and update of the Saudi Corporate Average Fuel Economy (CAFE) standards, which are still in its infancy. The research findings can also help auto distributers and dealers in Saudi Arabia to better assess the potential market for HEV in the country.

The modeling effort in this chapter have shown that subjective norm has a greater effect on the intention to adopt HEV than attitude. This is in contrary to what Trafimow and Fishbein (1994) suggested that attitude tends to predict behavior intention better than the subjective norm. A study by Park (2000) also suggests that collectivistic culture members' score on subjective norms tend to be higher than attitude. The Saudi society, in general, places a heavy weight on what others might think or say when exhibiting a behavior such as adopting HEV. This finding is consistent with those in the study by S. Wang et al. (2014), which asserts that HEV consumer's adoption intention in China is more sensitive to subjective norm than attitude as a result of being a collective society. Accordingly, HEV advertising messages should emphasize that adopting HEV is in line with what influential people such as family members as well as celebrities and think tanks would prefer. Such individuals have a strong effect - as evidenced by the analysis - to create positive norms, which then can create favorable HEV adoption intention to ultimately get people to buy and drive HEVs.

Although attitude was not a strong factor as subjective norm was, it was found to significantly affect the intention to adopt HEV. This finding speaks to policy makers concerned

with HEV diffusion in Saudi Arabia that they should focus on positively altering peoples' attitudes toward adopting HEV. This might be done through not only influencing the societal beliefs about the attributes of HEV, but also by creating new perceptions; for example, disseminate the message that HEV can have the same, if not better, performance than traditional gasoline vehicles (performance was among the best 5 determinants in both analyses).

It is important to recognize that, even though the theory of reasoned action suggests that intention precedes the behavior (attitude affect the intention which then affect HEV adoption behavior), making HEV test drives available at local dealerships can create a positive attitude, which can then create a favorable HEV purchase decisions.

Whether a person currently owns a vehicle or not was found to negatively affect the intention. In other words, those who currently own a vehicle have a lower intention to adopt HEV than those who don't. Interestingly, it was further found that the larger the number of vehicles owned by a person, the higher the possibility that he or she intends to buy a HEV. It is common in Saudi Arabia –as in other parts of the world - that some households have multiple vehicles, and these families sometimes opt for multi-vehicle mode due to economic reasons (to prevent the more luxurious and/or family-friendly vehicle from the wear and tear of the daily commute if it was the only vehicle owned by the household). This has been found true in other studies; for example, Zubaryeva et al. (2012) pointed out that a household owning more vehicles has a higher likelihood to adopt electric vehicles (the second vehicle is usually used for short commutes, while the first is often saved for different types of journey). Other researchers reported a similar pattern where in a multi-vehicle mode, shorter-range trips are serviced by battery electric vehicles, and the longer-range PHEV are for longer-distance trips (Tran, Banister, Bishop, & McCulloch, 2012)

While the effect of gender on the intention to adopt HEV was investigated and turned out to be insignificant, it is important to keep in mind that, for this study, more than 40% of those that indicated lack of vehicle ownership were females, who are not allowed to drive in Saudi Arabia, therefore, interpreting the this insignificant should be dealt with carefully. This aspect can be researched further, with more in-depth and focused instruments.

Household size was found to be insignificant, consistent with a study by Erdem et al. (2010). This finding, at the beginning of the dissertation research, was not expected, as families in Saudi Arabia tend to be larger than a typical European or North American family and thus I expected it to have a significant effect. However, one of the outcomes of chapter 5 is closely related to this finding, which stated that household size is not significant in determining SUV, VAN and similar vehicles owners. Such a finding might be explained as follows, if purchasing a vehicle is based on a need for space, all other factors that might have been considered under other circumstances would not be as important. In other words, passenger capacity would be the most important (if not the only) factor in determining next purchase intention. This explanation is in line with the observed phenomenon of quick SUV class proliferation compared to other vehicle classes in Saudi Arabia.

The analysis also shows that the interaction between age and household size is significant (household size is defined as the number of members in a given household). Young Saudis who happen to be members of a small household size tend to have more intention to adopt HEV than those who are part of a larger household size. These young people might be newly married couples or couples with a few years of marriage, and tend to be more conscious about their spending than older people, due to their limited income (younger age generally associated with less employment

time, possibly less education, both contributing to the limited household income). Young Saudis who happen to be members of a larger household size tend to have less intention to adopt HEV than those who are part of a small household size. Most probably, these individuals are not the heads of their households but are adult dependents (18 years old or older, eligibility to participate in the survey). In Saudi culture, children live with their families, even after getting to adulthood, until they either get married, or find a job in another city.

On the other hand, older people who happen to be part of a smaller household size have less intention to adopt HEV than those who happen to be part of a larger household size. This is possibly due to spending consciousness resulting from more financial responsibility as the household size increase.

Finally, education level was unfortunately found to be statistically significant, but negatively. as the education level increased , the intention to adopt HEV is decreased. This might have different meanings, but I tend to think that education, nation wise, focus too little on the importance of preserving the environment. Education level, at the same time, is associated with more income, which would decrease fuel sensitivity, and would sophisticate vehicle taste, say toward performance, which is, by definition against HEV. Thus, educational institutes should exercise more effort to make environment courses part of curriculum. Luckily, It would be much easier to convince an educated individual with HEV benefits that to convince not education one.

# 7. POTENTIAL HYBRID ELECTRIC VEHICLES EARLY ADOPTERS IN SAUDI ARABIA

The aim of this chapter is to identify the potential early HEV adopters. This will help design the most effective way of targeting them to encourage the overall HEV diffusion. This was achieved over 3 main stages: studying HEV early adopters' traits, clustering consumers searching for similar traits, and finally assessing the obtained clusters against some vehicle consumption behavior. Before diving into the analysis through, it is important to provide some background, presented below.

## 7.1. Data Mining and Transportation's Applications

Data mining has attracted the attention of many researchers in different fields. Stephen D Clark (2009) suggested that mobility choice research using data mining falls into 3 categories. The first category related to accident occurrence. The second category is research that predicted individuals' transportation related behavior, for example, individual's transportation mode choice (bus vs. train). The third category is research that predicted transport systems performance.

Data mining has a broad meaning, and it encompasses a large collection of techniques and algorithms. Classification or clustering analysis is among the widely used data mining tools. Researchers sometimes use classification analysis in tandem with the well-established multinomial logistic model to compare the predictability of different models (Wets, Vanhoof, Arentze, & Timmermans, 2000). In some occasions, a classification algorithm proved to be more accurate in predicting traveling choice than multinomial logistic models (Xie, Lu, & Parkany, 2003). Additionally, classification algorithm have an advantage over regression models because it does not require any prior assumption about data distribution and nature (Stephen D Clark, 2009).

Clustering analysis using classification algorithm would help achieve the overarching objective of this research by allowing a look at survey respondents and how some of them cluster around each other to form a homogenous group. At the same time, how can that group be heterogeneous compared to other groups, in a way that conveys a better understanding. This analysis will allow for isolating the profile most similar to early HEV adopters reported in literature. Classification or sometimes referred to as clustering analysis, can help achieve this objective.

Literature that used classification to segment HEV early adopters is limited. Campbell, Ryley, and Thring (2012) utilized cluster analysis on United Kingdom census data to identify potential Alternative Fuel Vehicle (AFV) buyers in Birmingham city, using many variables including age and income. Rorke and Inbakaran (2009) segmented potential HEV consumers using age, education and income in Victoria, Australia.

## 7.2. Stage 1: HEV Early Adopters' Traits: A Literature Review

It has been reported that early HEV adopters share a number of characteristics (Campbell et al., 2012). Table 14 shows a literature review about early HEV adopters' traits and characteristics. The observer to Table 14, notices that they come from different continents, from North America, to Australia, to Asia and Europe. The location diversity highlights the consistency and persistency of such characteristics across cultures. This consistency seem to be stable over time as studies presented are spanning a diversified time frame, of more than 15 years. Earliest studies in Table 14 are published in 2000, which is the same year Toyota Prius started selling internationally, while the latest is published in 2016. Neither time nor location seems to change the observation that early HEV adopters exhibit a unique profile. Therefore, the analysis will

proceed examining the formation of a similar profile for the potential HEV early adopters in Saudi Arabia.

**TABLE 14 LITERATURE REVIEW FOR HEV EARLY ADOPTERS TRAITS**

| Attribute | Literature | Where? |
|---|---|---|
| Older age than the average* | • Ong and Haselhoff (2005)<br>• W. Wang and Namgung (2007)<br>• Rorke and Inbakaran (2009)<br>• Erdem et al. (2010)<br>• Ozaki and Sevastyanova (2011)<br>• Campbell et al. (2012)<br>• Power (2008) | • USA<br>• South Korea<br>• Australia<br>• Turkey<br>• UK<br>• UK<br>• USA |
| More education level than the average* | • Brownstone, Bunch, and Train (2000)<br>• Haan, Peters, and Mueller (2006)<br>• W. Wang and Namgung (2007)<br>• Klein (2007)<br>• Power (2008)<br>• Rorke and Inbakaran (2009)<br>• Hidrue et al. (2011)<br>• Plötz et al. (2014)<br>• S. Wang, Fan, Zhao, Yang, and Fu (2016) | • USA<br>• Switzerland<br>• South Korea<br>• USA<br>• USA<br>• Australia<br>• USA<br>• UK/Switzerland<br>• China |
| More income than the average* | • W. Wang and Namgung (2007)<br>• Power (2008)<br>• Rorke and Inbakaran (2009)<br>• Erdem et al. (2010)<br>• Hidrue et al. (2011)<br>• Campbell et al. (2012)<br>• (Plötz et al., 2014) | • South Korea<br>• USA<br>• Australia<br>• Turkey<br>• USA<br>• UK<br>• UK/Switzerland |
| Larger Household size than the average* | • W. Wang and Namgung (2007)<br>• Ozaki and Sevastyanova (2011) | • South Korea<br>• UK |
| More vehicles owned than the average* | • Ramjerdi and Rand (2000)<br>• W. Wang and Namgung (2007)<br>• Ozaki and Sevastyanova (2011)<br>• Campbell et al. (2012)<br>• Graham-Rowe et al. (2012) | • Norway<br>• South Korea<br>• UK<br>• UK<br>• UK |

*: The average for these studies mainly refer to the average of the respective population for location where the study was conducted. In my study, the average is the sample average for each variable.

## 7.3.Stage 2: Segmenting Potential HEV Adopters in Saudi Arabia

The same variables presented in Table 14 were considered for this clustering analysis, namely: age, education level, income, household size and number of vehicles owned. All these variables were captured in the online questionnaire, but measured in a different scales. For example, age is calculated in tens of years, while annual kilometers driven is measured in thousands of kilometers per year. Variables with large absolute values can distort cluster computations (Menasce, Almeida, Dowdy, & Dowdy, 2004). Hence, to overcome this possibility, all variables are first Z-score scaled, a technique aimed to have no single variable dominate the clustering algorithm.

Highly correlated variables would also negatively affect the clustering analysis, because if two variables are highly correlated, then considering one of them would be enough to capture the variability in both. Therefore, correlations between variables under consideration were checked, presented in Table 15 below. All correlations are reasonable for running the clustering analysis without the need to omit any variable.

**TABLE 15 VARIABLES CORRELATIONS**

| Variables | Income | Household size | Age | Education level | Number of Vehicles |
|---|---|---|---|---|---|
| Income | 1 | .186** | .315** | .263** | .253** |
| Household size | .186** | 1 | .189** | -.108** | .178** |
| Age | .315** | .189** | 1 | .122** | .335** |
| Education level | .263** | -.108** | .122** | 1 | .013 |
| Number of Vehicles | .253** | .178** | .335** | .013 | 1 |

**. Correlation is significant at the 0.01 level (2-tailed).

There are two main types of clustering analysis: hierarchical and non-hierarchical procedures. Each procedure has its advantages and disadvantages (Hair, Black, Babin, Anderson, & Tatham, 2006). A combination of the two procedures can result in combining the advantages of

both (Diamantopoulos & Siguaw, 2006). Hierarchical and non-hierarchical clustering analyses were conducted using IBM SPSS, and are presented in the following sections.

### 7.3.1. HIERARCHICAL CLUSTERING

There exists only subjective ways of determining the number of clusters, - referred to sometimes as the stopping rule - (Hair et al., 2006). Since non-hierarchical clustering analysis does require the researcher to determine the number of clusters, it is advisable to start with hierarchical analysis. The hierarchical clustering will help determine the number of clusters, which will be used in the next phase, non-hieratical analysis (Hair et al., 2006).Thus, I reverted to hierarchical clustering analysis first, for the purpose of specifying the starting point for number of clusters.

A hierarchical clustering was conducted using Between-Groups-Linkage clustering method (the default in SPSS), with squared Euclidean distance measure, shown in Figure 11. Examining this figure for the elbow point shows it is clearly close to the point 2. This point is considered a starting point for determining the appropriate number of clusters for the non-hierarchical clustering runs presented in the next section.

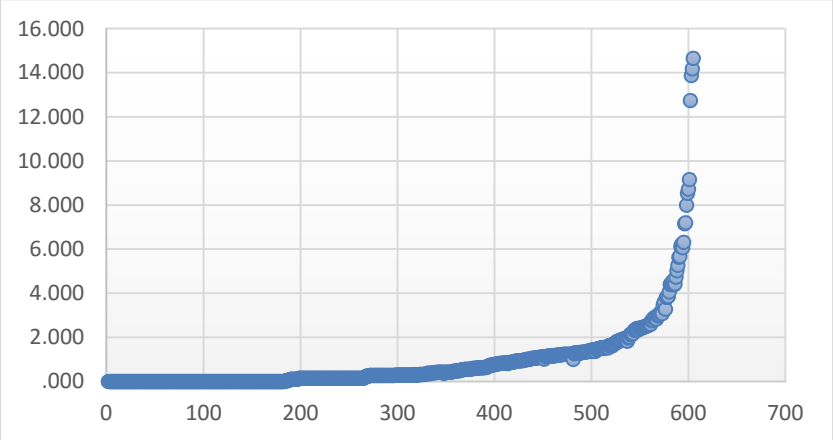


**FIGURE 11 HIERARICAL CLUSTERING**

### 7.3.2. NON-HIERARCHICAL CLUSTERING

K-means heuristic algorithm is one of the many non-hierarchical clustering methods (Shmueli, Patel, & Bruce, 2007). K in K-means refers to the number of clusters set by the researcher. The researcher first specifies the number of K, then, the cluster algorithm assigns each data point to the nearest cluster. After that, the cluster's mean is calculated using all the points in that cluster. All previous steps after specifying the K are repeated, until the solution converges, where the means of clusters don't differ anymore. The algorithm concludes by landing each data point in its final cluster, where means of clusters are calculated for the last time.

In the previous section, hierarchical clustering established the starting point for determining the cluster number, represented by the elbow point in Figure 11, when K=2. Therefore, K-Means clustering analysis was conducted starting from K=2. To find the most suitable solution, clustering analysis was also conducted for k=3, 4 and 5.

Table 16 shows different clustering runs with different cluster numbers (K), shown in the first column. In the second column, the size of each cluster is presented (number of respondents placed in that cluster). The third column presents the number of iterations it took SPSS until the cluster solution converged. The forth column is for variables included in the analysis, and finally, the last column is for the P-value indicating whether the associated variable was statistically significant in determining clusters.

For the case when K=2, two clusters were obtained, with the larger cluster containing 369, while the smaller containing 236 respondents (pf the total sample size of 605). The solution converged in the $9^{th}$ iteration, with all variables statistically significant in determining each one of the two clusters. K=2 solution was not considered in favor of other solution because it is too

simplistic for segmenting vehicles' consumers. When K=3, the solution converged in the 14th iteration, with all variables significant in determining each one of the three clusters. When K=4, SPSS reached the maximum number of iterations set by the researcher (15), without converging. K=4 solution is not viable because it did not convergence, indicating improper clustering. A step further, when K=5, the cluster solution converged in the 9th iteration, with all variables statistically significant in determining each cluster.

Different clustering runs presented in Figure 12, shows that HEV traits is persistent throughout runs, from k=2 to k=5. In Figure 12, these traits are represented by cluster 2 in K=2, cluster 3 in K=3, cluster 2 in K=4, cluster 4 in K=5. In fact, even the run when k=6 –not presented in figure - showed clear HEV early adopter traits, but the solution did not converge by the 15th iteration set in SPSS.

The solution for K=5 is chosen to be the best representation of vehicles consumers, because it passed the validation criteria: converging in the least number of iterations, and all variables statistically significant in determining all clusters. Part of the cluster solution validation is evaluating clusters relative sizes, which, in the k=5, was considered appropriate. Moreover, in his famous innovation diffusion model, Rogers (2010), showed that early innovation adopters make up 16% of the total potential adopters (if accounting for both innovator: 2.5% and early adopters: 13.5%). Interestingly, cluster number 4 in the K=5 cluster solution represents about 17% of the sample, very close to the value proposed by Rogers. Moreover, cluster number 4 in the K=5 cluster solution is in complete alignment with characteristics found in the literature presented in Table 14 for HEV early adopters. For the remaining parts of this analysis, I assumed that those variables

together is a good representation of the potential early HEV adopters in Saudi Arabia too. Campbell et al. (2012) utilized Rogers concept and made a similar number of clusters decision.

**TABLE 16 CLUSTERING RUNS**

| # Clusters | Cluster sizes | Convergence steps | Variables | Significance |
|---|---|---|---|---|
| **2** | 369 | 9 | Age | .000 |
| | | | Income | .000 |
| | | | Education level | .000 |
| | 236 | | House size | .000 |
| | | | Number of owned vehicles | .000 |
| **3** | 203 | 14 | Age | .000 |
| | | | Income | .000 |
| | 224 | | Education level | .000 |
| | | | House size | .000 |
| | 178 | | Number of owned vehicles | .000 |
| **4** | 255 | reached 15 iterations without convergence | Age | .000 |
| | | | Income | .000 |
| | 124 | | Education level | .000 |
| | | | House size | .000 |
| | 147 | | Number of owned vehicles | .000 |
| | 79 | | | |
| **5** | 75 | 9 | Age | .000 |
| | 138 | | Income | .000 |
| | 209 | | Education level | .000 |
| | 104 | | House size | .000 |
| | 79 | | Number of owned vehicles | .000 |

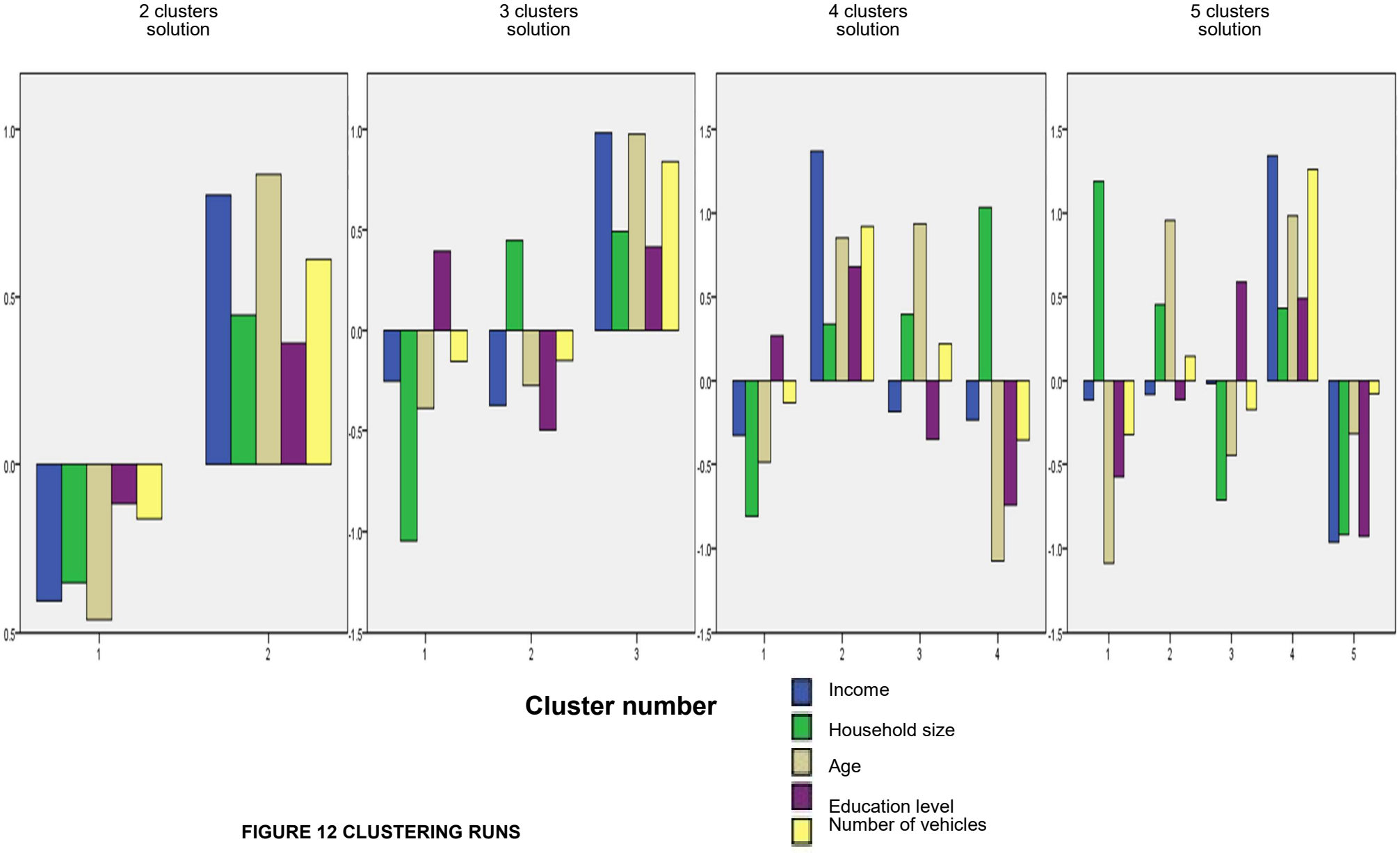


**FIGURE 12 CLUSTERING RUNS**

## 7.4. Stage 3: Vehicle Consumption Behaviors Against Clusters

After verifying that the traits of common HEV early adopters is present in the sample and therefore in Saudi Arabia, a need to obtain further insights about HEV diffusion in Saudi Arabia emerged. In order to discover new insights, I assessed vehicle consuming behaviors of members of the potential HEV adopters cluster for: currently owned vehicle class, fuel sensitivity, annual driven distance, HEV familiarity and environmental concern. Such assessments have the potential to provide impactful insights related to promoting HEV diffusion policies. Further details are in the sections below.

### 7.4.1. Environmental Concern and Potential Early HEV Adopters

Kahn (2007) found that environmentally conscious consumers tend to be more likely to adopt HEV than other people who might not be as conscious. The environmental concern is considered a determinant of individuals' behavior change toward a more environment-friendly behavior (Daziano & Bolduc, 2013). Such findings drove an interest to study how members of the potential early HEV adopters cluster perform on an environmental concern[4] 5-points Likert scale (S. Wang et al., 2016), compared to other clusters. Testing for internal meaning consistency of the environmental concern construct (4 items, EC1 to EC4) resulted in Cronbach's Alpha of 0.718, indicating a reliable construct. The priori is that the potential HEV early adopters would have a higher level of environmental concern than the rest of the clusters. Confirming the priori, Figure 13 shows that the majority members within the potential HEV early adopters cluster chose "strongly agree" in all environmental concern construct items. For the following two items, the

[4] Environmental concern is defined as the general awareness about environmental

potential HEV early adopters cluster was in fact the highest, compared to the rest of the clusters for "Strongly Agree" category:

- EC1: I think environmental problems are becoming more and more serious in recent years (more than 50% of respondents strongly agree).
- EC3: I think we are not doing enough to save scarce natural resource from being used up (more than 60% of the respondents strongly agree).

For the remaining two environmental concern items, namely:

- EC2: I think human beings should live in harmony with nature in order to achieve sustainable development.
- EC4: I think individuals have the responsibility to protect the environment

While the potential HEV early adopters cluster was not the highest of choosing "strongly agree", it is actually very close to the highest. The potential HEV early adopters cluster was the second for EC2, with only 1% difference (52% for the highest - cluster 1-, 51% for potential early HEV consumers cluster). For EC4, The potential early HEV consumers cluster got 54.8%, while the highest cluster (cluster 2) has 57.2% of respondents choosing "strongly agree", with only 2.4% difference.

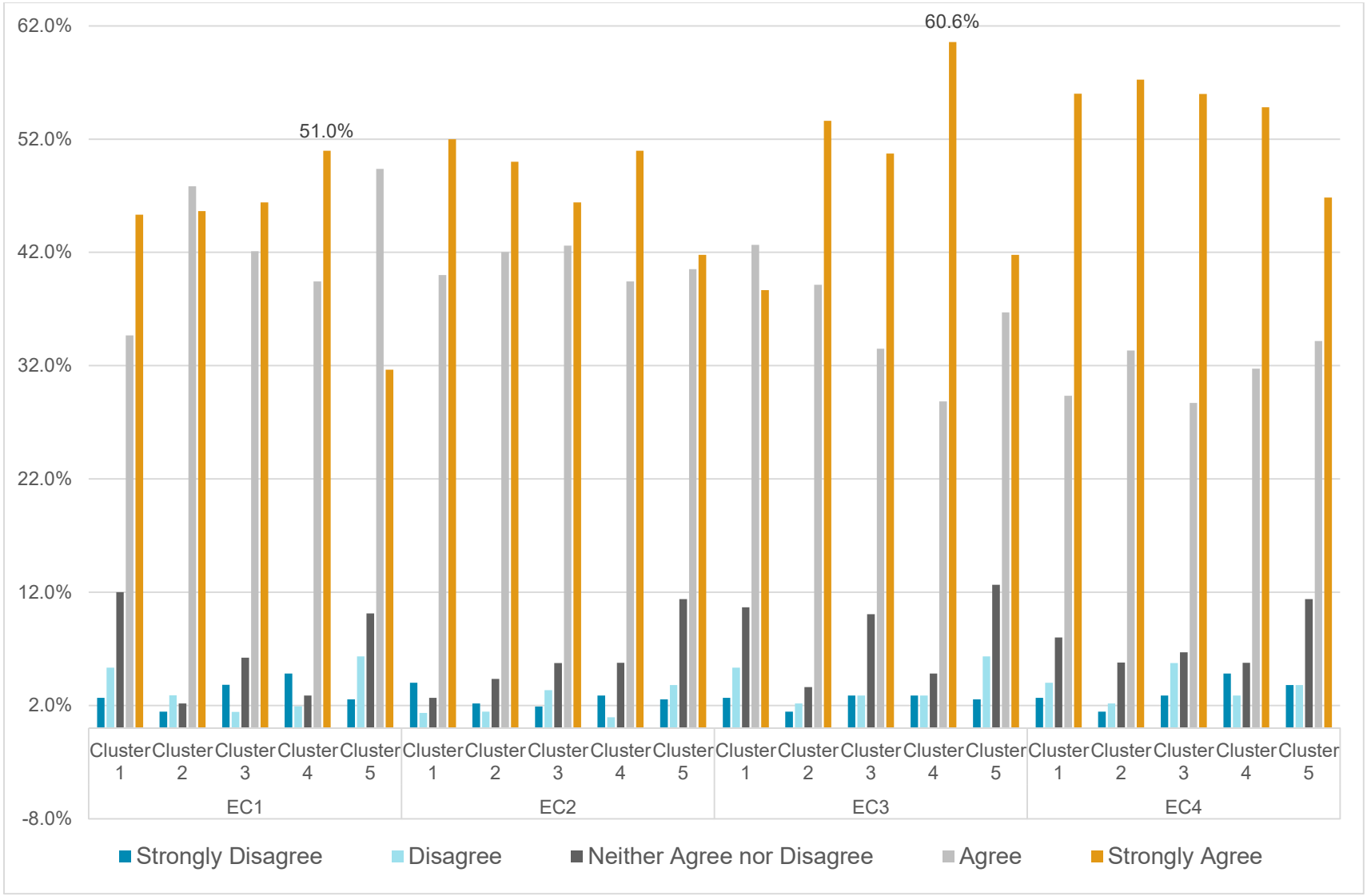


**FIGURE 13 ENVIRONMENT CONCERN AGAINST CLUSTERS**

### 7.4.2. HEV FAMILIARITY AND POTENTIAL HEV EARLY ADOPTERS

Product's familiarity drives its acceptance and use. Hence, it would be valuable to know how members of the potential HEV early adopters cluster are familiar with HEV. Familiarity construct is composed of three items of seven-point bipolar adjectives, meant to gauge respondents HEV's awareness. To make sure that these three items are internally consistent and measuring the familiarity scale, the Cronbach's alpha measure was obtained (0.908), indicating reliable construct. I had a priori that, potential HEV early adopters are more familiar with efficient vehicles than the rest of the clusters.

The level of HEV familiarity is investigated for all clusters as shown in Figure 14. Strikingly, members of the potential HEV early adopters cluster were found to be the least "extremely familiar" with HEV in two items out of the three familiarity construct items. For the third item, this cluster was the second least familiar after cluster 5. For the next point on the familiarity scale, "Quite familiar", the potential HEV early adopters cluster was found to be the highest only once (for item 3), the second highest for item 2, and least for item 1. Finally, for the "Slightly familiar" scale point, members of the potential HEV early adopters cluster were found to be the least familiar for item 1, second least for item 2 and third least familiar for item 3. In short, only 26.9% of the potential HEV early adopters cluster members indicated a level of familiarity with HEV (either slightly, quite or extremely familiar). It is worth mentioning that cluster 2 was highest for all three item for the category of "Extremely familiar".

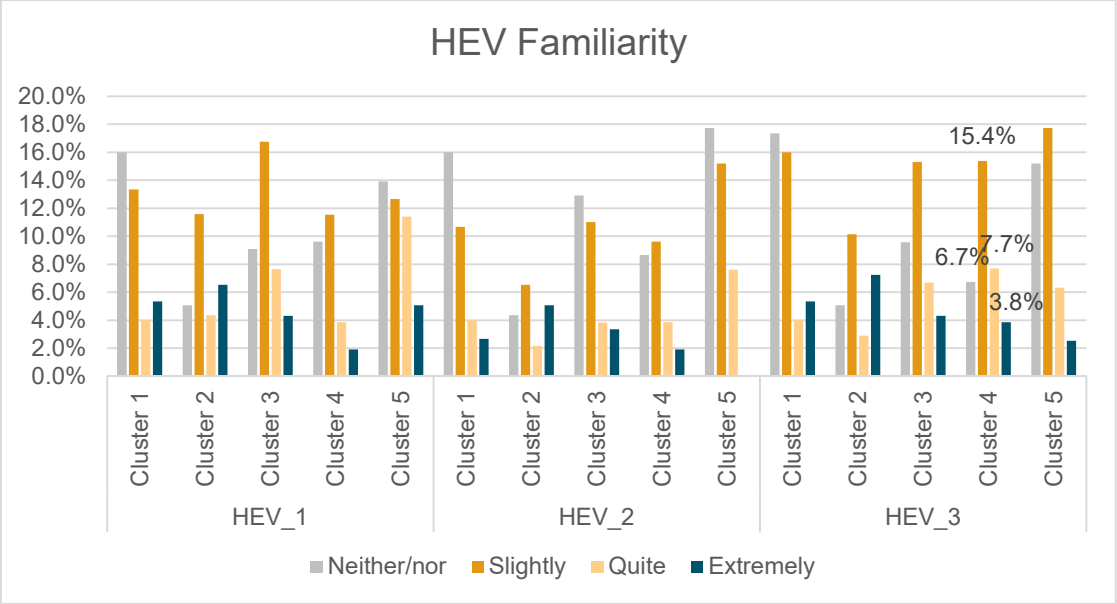


**FIGURE 14 HEV FAMILIARITY AGAINST CONSUMERS' CLUSTERS**

### 7.4.3. VEHICLE CLASS AND POTENTIAL EARLY HEV ADOPTERS

Respondents' current vehicle class data were captured in the online questionnaire, then coded into one of the following four categories:

- Subcompact and compact
- SUV , VAN and similar
- Pick up or truck
- Full size sedan

The largest category was for full size sedan, which represented 43.3%, while the smallest category was for pick up or truck for 5.6%. The second largest category was for SUV, VAN and similar vehicles for 37%. The next least category was for subcompact or compact class, for 14%.

Cross tabulation for all clusters with vehicle class is presented Table 17. Surprisingly, subcompact and compact category was the least owned class within the cluster of the potential HEV early adopters. This is surprising because of the general notion literature suggests that HEV early adopters are mostly thought of as Prius (compact) drivers. The vast majority of the members

of the potential HEV early adopter cluster owned SUV, VAN and similar vehicles. At first sight, in addition to being surprising, this might seem unfortunate, as compact and subcompact vehicles owners are the first to jump into mind when mentioning green drivers. The surprise here can be shrunk when the reader refers back to two main explanations. The first is the fact that the majority of Saudi population is young individuals (more dependents in Saudi family). Given the cultural definition of household, this makes the typical Saudi family large, requiring a larger passenger capacity vehicle (for example: SUV). Second, referring back to the analysis behind vehicle's ownership determinants in Saudi Arabia, presented in Table 2, section 5.2.2. It is clear that passenger capacity is very important determinant in vehicle's purchase. For environmentalist, and policy makers running after lowering fuel consumption and emission levels, this should be good news. Why one might ask? It is known that, generally, SUV consumes more fuel than smaller vehicles. Thus, any fuel consumption improvement in the most fuel consuming category, would result in the largest reduction in both fuel consumption and emission.

**TABLE 17 VEHICLE CLASS AGAINST CONSUMERS' CLUSTERS**

| **Vehicle class** | | **Cluster numbers / frequency** | | | | | **Total** |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **Full size sedan** | Count | 27 | 40 | 119 | 29 | 47 | 262 |
| | % within Cluster | 36% | 29% | 57% | 28% | 59% | 43% |
| **Pick up or truck** | Count | 11 | 12 | 4 | 5 | 2 | 34 |
| | % within Cluster | 15% | 9% | 2% | 5% | 3% | 6% |
| **Subcompact or compact** | Count | 26 | 13 | 29 | 6 | 11 | 85 |
| | % within Cluster | 35% | 9% | 14% | 6% | 14% | 14% |
| **SUV , Van or similar** | Count | 11 | 73 | 57 | 64 | 19 | 224 |
| | % within Cluster | 15% | 53% | 27% | 62% | 24% | 37% |
| | Total Count | 75 | 138 | 209 | 104 | 79 | 605 |

### 7.4.4. BRAND AND POTENTIAL EARLY HEV ADOPTERS

A large number of HEV diffusion studies focused on Toyota Prius (i.e. Keith, 2012b; Ozaki & Sevastyanova, 2011). I wondered if Toyota brand had any effects on these studies so I looked at this further, through examining brands owned by respondents against all clusters, presented in Table 18. GMC consumers were found to be largest portion of both the potential HEV early adopters cluster and cluster 2, 37% equally. Hyundai, the second largest market share holder in Saudi Arabia, was found to be the least owned brand among the potential HEV early adopters cluster members. In a sense, this is expected as it should be in light with the previous finding that most the potential HEV early adopters are SUV drivers. GMC claims a large share of SUV market in Saudi Arabia.

**TABLE 18 MAKES AGAINST CONSUMERS' CLUSTERS**

| Makes | Cluster1 | Cluster 2 | Cluster 3 | Cluster 4 | Cluster 5 |
|---|---|---|---|---|---|
| **Toyota** | 28 (13%) | 51 (24%) | 73 (34%) | 32 (15%) | 27 (12%) |
| **Ford** | 6 (08%) | 23 (31%) | 21 (28%) | 16 (21%) | 7 (09%) |
| **Chevrolet** | 6 (10%) | 17 (30%) | 19 (34%) | 8 (14%) | 5 (09%) |
| **GMC** | 1 (02%) | 18 (37%) | 7 (14%) | 18 (37%) | 4 (08%) |
| **Hyundai** | 14 (42%) | 2 (06%) | 9 (27%) | 1 (03%) | 7 (21%) |
| **Lexus** | 2 (06%) | 0 (0%) | 20 (64%) | 5 (16%) | 4 (12%) |
| **Honda** | 1 (03%) | 3 (10%) | 16 (57%) | 3 (10%) | 5 (17%) |
| **Nissan** | 8 (28%) | 5 (17%) | 7 (25%) | 4 (14%) | 4 (14%) |
| **Mercury** | 3 (12%) | 5 (.2%) | 8 (32%) | 2 (08%) | 7 (28%) |
| **Mercedes** | 1 (07%) | 4 (30%) | 3 (23%) | 4 (30%) | 1 (07%) |
| **Dodge** | 1 (11%) | 2 (22%) | 4 (44%) | 0 (0%) | 2 (22%) |

### 7.4.5. Fuel Price Sensitivity and Potential Early HEV Adopters

Fuel prices have been frequently reported in literature as one of the reasons behind HEV adoption (Ozaki & Sevastyanova, 2011). This ignited an interest to assess the potetnial HEV early adopters cluster's fuel sensititivty and how does this cluster compares to the rest of the clusters. The priori here is that, potential early adopters would be more sensitive to fuel pirces than those who might not be a member of this cluster.

Figure 15 showed, to the fullest surprise, that the members of the potential HEV early adopters cluster were the least fuel price sensitive, for the range of fuel price increament between 0.5 SR to almost 2 SR per liter (almost 300% increment). Increasing the fuel price from 2 to 2.5 SR per liter resulted in ranking the cluster of potential early HEV adopters the second least sensitive. Finally, increasing fuel price from 2.5 SR to the end of the scale in Figure 15, 5 SR per liter, resulted in ranking the potential HEV early adoperts cluster the third least sensititve among all clusters. If there is a fuel price change in Saudi Arabia, it is most likely to happen in the lower side of the X- axis, and the further right one goes on X-axis, the less likely the fuel increment would happen in that fuel price level. This finding, therefore, contradict the priori that the potential early HEV adopters cluster is a fuel sensititive cluster. It is worth mentioning here that, cluster 2 was the most fuel senstititve cluster among all clusters.

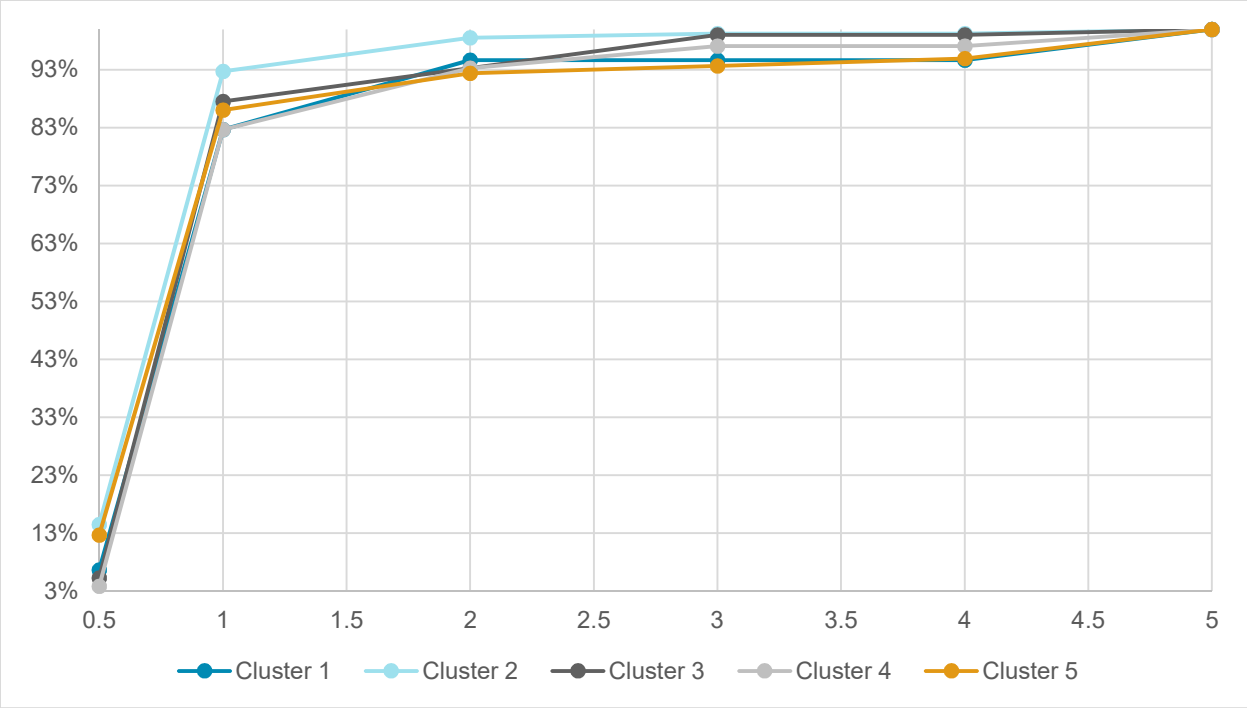


**FIGURE 15 GASOLINE FUEL SENSITIVITY FOR EACH CLUSTER**

### 7.4.6. ANNUAL DISTANCE DRIVEN AND POTENTIAL EARLY HEV ADOPTERS

Green drivers are expected to aviod driving whenever they can, which would reflect on a less number of kilormeters driven per year. To assess this, the online questionnaire captured respondents' distance driven per year, then the data were cross tabulated against the all clusters, as seen in Figure 16 below.

The majority members (56.7%) of potential HEV early adoperts cluster drove less than the median of 30000 kilometers per year. This puts the potential early HEV adoperts cluster in the first place for driving the least distance per year. Cluster 2 memebers were the second least distance drivers, with 51.4% driving below the median. If "green drivers" are defined as those who dive less than the average, then, the potential HEV early adopters cluster and cluster 2 are mostly composied of green drivers. For the rest of the clusters, the proportions for cluster members driving less than the median were 46.7%, 48.8% and 40.5% for clusters 1,3 and 5 respectively.

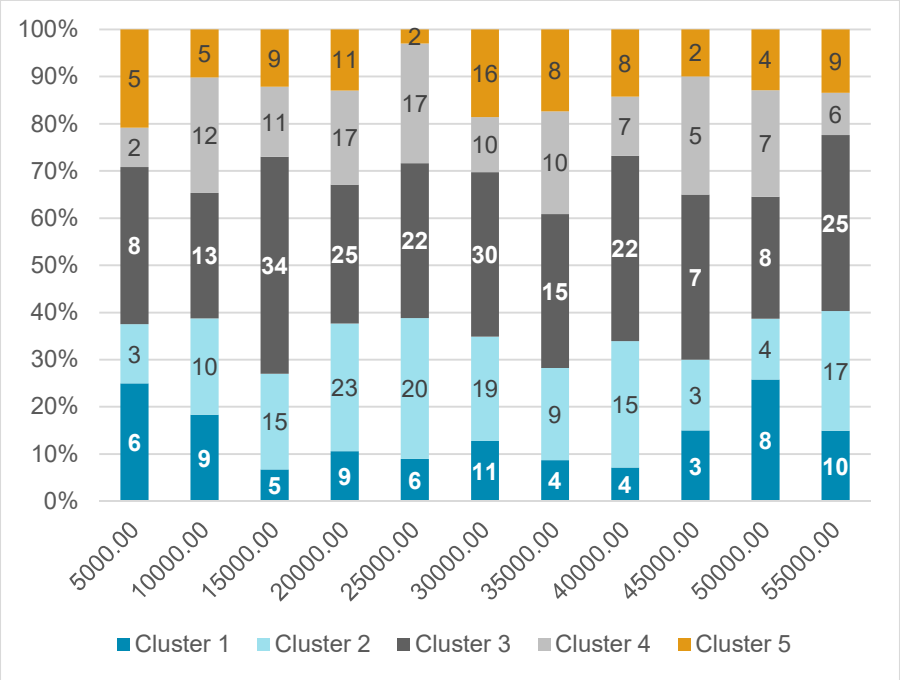


**FIGURE 16 ANNUAL DISTANCE DRIVEN FOR EACH CLUSTER**

## 7.5.Comments on Cluster 2: A Reflection upon Theory of Reasoned Action

Throughout the analysis above, attention was not paid only to the potential HEV early adopters cluster, but all clusters. This close observation, more than once, showed interesting behavior for cluster 2 particularly. These interesting observations are noticed in cluster member's environmental concern, HEV familiarity, fuel sensitivity, and annual distance driven.

Cluster 2 is, surprisingly, the most familiar cluster with HEV among all clusters (contained the most HEV familiar respondents' proportion). For the scale point "Extremely familiar", it was, in all 3 familiarity construct items, the highest. This cluster is at the opposite spectrum of familiarity scale when compared to cluster 4, the cluster that I referred to in previous sections as the potential HEV early adopters cluster. This might be related to the general enthusiasm about vehicles. Members of the potential HEV early adopters cluster might be those who are willing to buy HEV for any reason other than being enthusiastic about certain type of vehicles. On the other

hand, cluster 2 members, might be those who are enthusiast about vehicles and took an extra step of familiarizing themselves with HEV.

For fuel sensitivity, cluster 2 members were found to be the most sensitive among all clusters until the scale point of 3 SAR per liter, which is the scale point where almost all clusters start having the same sensitivity level. This level of sensitivity can be utilized to push for more HEV adoption, if the policy involved reducing fuel prices subsidy in Saudi Arabia. Because, elsewhere, HEV sales directly relates to the fuel prices (Diamond, 2009; Gallagher & Muehlegger, 2011) . Also, it has been reported frequently that fuel sensitivity or, in other words, saving at the pump, was among reasons behind HEV purchase.

Not as green as the potential HEV early adopter cluster, but 51.44% of cluster 2 members drove less than 30000 kilometers per year. The cluster majority drives less than the average, which is only true for clusters 4 and 2.

Cluster 2 members showed a high level of environmental concern. The cluster majority chose “Strongly Agree” for EC4 (I think individuals have the responsibility to protect the environment). In fact, Cluster 2 was the highest among all clusters for that particular item, which highlights the feeling of an individual responsibility to protect the environment through acting responsibly. Also, the majority members (53.6%) within Cluster 2 voted for “Strongly agree” for EC3 (I think we are not doing enough to save scarce natural resource from being used up).

Age, household size and number of owned vehicles were all above their respective averages, for both cluster 2 and 4. While age and household size were almost the same as in cluster 4, number of owned vehicles in cluster 2 is much lower. Also, cluster 2 has less income and education level than the average. S. Wang et al. (2016) showed that income is inversely associated

with the intention to adopt HEV in China. Cluster 2 limited education probably resulted in less income, which then effected the number of owned vehicles. Also, the limited income probably drove up the fuel sensitivity among cluster 2, putting it the most fuel price sensitive cluster as showed earlier in Figure 15.

All the above observations about cluster 2, supported the urge assess cluster 2 and all clusters for that matter, against a more theoretical grounded measure. Given the fact that HEV is not yet introduced in the Saudi market, there are no viable means for checking real consumers. Thus, intention to adopt HEV can fill the missing link, as the intention to perform a given behavior is the best determinant of actually performing that behavior (Ajzen & Fishbein, 1980). Intention - the backbone of the Theory of Reasoned Action (TRA) -, is luckily captured in the online questionnaire, using a 3 items 5-point Likert scale construct (S. Wang et al., 2016). Adopting HEV intention (AHEVI) for items AHEVI_1 to AHEV_3 were plotted against all clusters, shown in the Figure 17 below.

It is very clear that cluster 2 was consistently the most favorable, among all clusters, in terms of its members' intention to adopt HEV. Proportions of cluster 2 members who chose "strongly agree", were the highest compared to all clusters. 9% of cluster 2 members strongly agreed to AHEVI_2, while 14% of the members strongly agreed for AHEVI_1 and AHEV_3. Moreover, proportions of cluster 2 members who chose "Agree", were the highest among all other clusters. If the interest here is to know who agree (adding "Agree" and "Strongly Agree"), then cluster 2 is not only the highest among all clusters (% wise) , but also the majority within the cluster itself is favorable, 54%, 53% and 65% for AHEV_1, AHEVI_2 and AHEVI_3 respectively,

a case only true for cluster 2. Full tabulation for all TRA construct's items against all clusters are presented in appendix E.

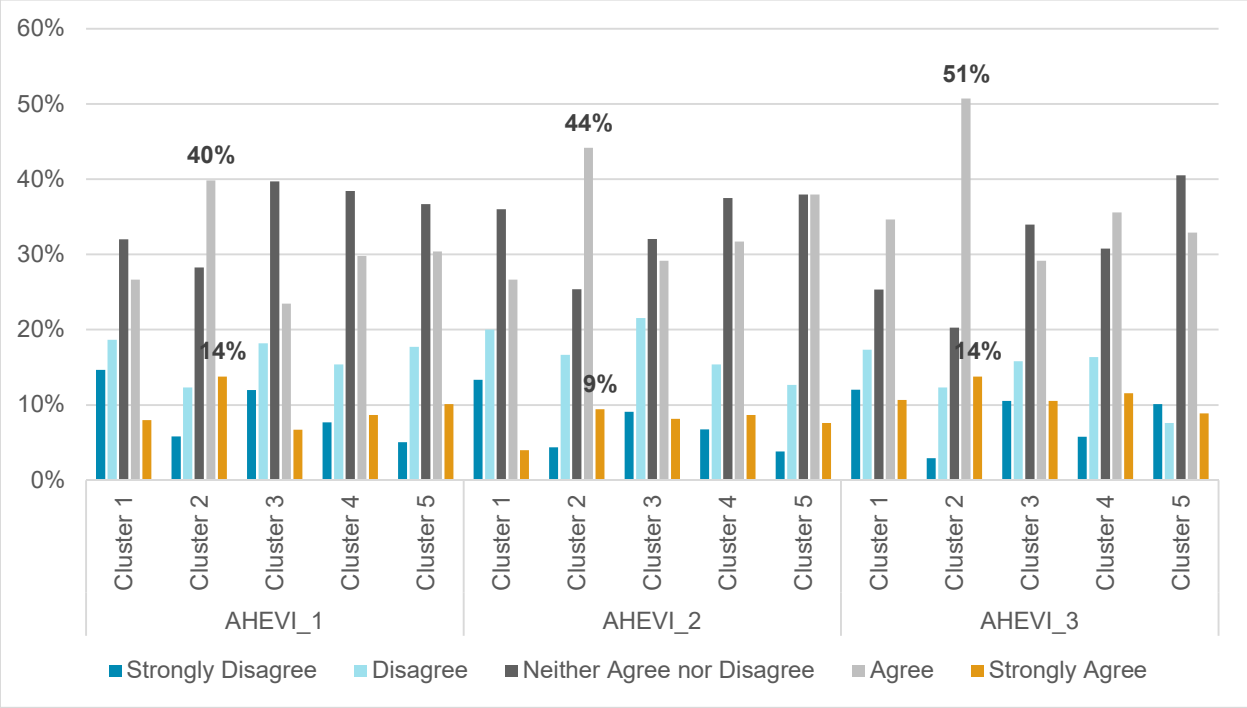


**FIGURE 17 INTENTION TO ADOPT HEV AGAINST CLUSTERS**

## 7.6.Attributes for Future Vehicle Purchase Against Obtained Clusters

There is a need for exploring these clusters of interest to better understand what the potential early HEV adopters' wants in their future vehicle purchase. The idea is to look at respondents answers to the ranking exercise, presented in section 5.2.2 and see how different clusters perform. Table 19 below presents the 14 attributes for the ranking exercise, along with the behavior of cluster 2 and 4 members.

Examining cargo space ranking for cluster 4 shows that it is the highest, (4%) among all clusters, (the next highest in other clusters are 1%). Keep in mind that, cluster 2 drivers mainly

own large vehicles, which in most cases, these vehicles have the ability to fold seats, increasing such vehicles cargo spaces.

Another observation is that cluster 4 members seemed paying much more attention to safety than other clusters. 23% of cluster 4 members ranked safety is highest attribute in their future vehicle purchase, while next highest is only 15%.

Additional observation is noticed about how both clusters 2 and 4 ranked the price as 1st attribute in the next vehicle purchase. They were the lowest: cluster 4: 20% while cluster 2: 21%, compared to 27%, 31% and 36% for clusters 5, 3 and 1 respectively.

Finally, the last interesting observation is about both clusters ranking for operating and maintenance cost. They were the highest proportion ranking it as 1st (8% and 5% for cluster 2 and 4 respectively, compared to 0%, 3% and 4% for clusters 1,3 and 5 respectively). The full tabulation, including clusters 1, 3 and 5 are presented in appendix F.

**TABLE 19 FUTURE VEHCILE PURCHASE AGAINST OBTAINED CLUSTERS**

| Attributes | Cluster | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | 10th | 11th | 12th | 13th | 14th |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Performance of engine** | 2 | 8% | 7% | 7% | 11% | 8% | 8% | 9% | 10% | 8% | 6% | 7% | 3% | 4% | 3% |
| | 4 | 6% | 13% | 6% | 4% | 13% | 8% | 6% | 10% | 8% | 8% | 2% | 6% | 6% | 3% |
| **Fuel economy** | 2 | 4% | 9% | 5% | 11% | 5% | 10% | 4% | 10% | 4% | 13% | 6% | 4% | 8% | 6% |
| | 4 | 2% | 9% | 5% | 8% | 9% | 9% | 8% | 12% | 8% | 11% | 6% | 4% | 4% | 4% |
| **Ability to see the road** | 2 | 1% | 1% | 1% | 3% | 4% | 3% | 5% | 10% | 7% | 11% | 8% | 16% | 18% | 12% |
| | 4 | 1% | 4% | 4% | 5% | 4% | 8% | 8% | 5% | 8% | 10% | 12% | 9% | 14% | 7% |
| **Seating capacity** | 2 | 10% | 10% | 10% | 10% | 10% | 7% | 6% | 8% | 7% | 8% | 4% | 4% | 1% | 3% |
| | 4 | 8% | 6% | 11% | 8% | 6% | 10% | 9% | 9% | 4% | 6% | 12% | 3% | 5% | 2% |
| **Cargo space** | 2 | 1% | 7% | 6% | 7% | 5% | 6% | 4% | 10% | 9% | 10% | 8% | 12% | 7% | 9% |
| | 4 | 4% | 4% | 7% | 5% | 9% | 1% | 7% | 7% | 6% | 3% | 5% | 16% | 14% | 11% |
| **Safety rating** | 2 | 13% | 7% | 9% | 9% | 9% | 8% | 8% | 9% | 4% | 4% | 7% | 6% | 1% | 5% |
| | 4 | 23% | 8% | 9% | 8% | 7% | 5% | 5% | 7% | 3% | 4% | 8% | 7% | 3% | 2% |
| **Price** | 2 | 21% | 13% | 13% | 5% | 9% | 7% | 13% | 1% | 4% | 2% | 1% | 4% | 2% | 2% |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 20% | 12% | 10% | 16% | 5% | 8% | 4% | 3% | 3% | 6% | 4% | 0% | 4% | 4% |
| **Favorable financing** | 2 | 5% | 9% | 8% | 7% | 3% | 5% | 1% | 6% | 5% | 4% | 8% | 13% | 13% | 13% |
| | 4 | 0% | 5% | 2% | 4% | 8% | 5% | 6% | 5% | 8% | 11% | 13% | 7% | 16% | 9% |
| **Reputation of manufacturer** | 2 | 15% | 5% | 10% | 7% | 7% | 8% | 9% | 9% | 9% | 7% | 4% | 1% | 4% | 4% |
| | 4 | 14% | 8% | 2% | 8% | 5% | 10% | 16% | 5% | 7% | 5% | 6% | 9% | 3% | 1% |
| **Services offered by the nearby dealer** | 2 | 4% | 9% | 9% | 11% | 9% | 6% | 8% | 5% | 8% | 4% | 7% | 5% | 9% | 6% |
| | 4 | 3% | 5% | 9% | 9% | 8% | 6% | 7% | 9% | 13% | 6% | 5% | 9% | 7% | 3% |
| **Appearance** | 2 | 4% | 4% | 7% | 6% | 12% | 6% | 8% | 10% | 14% | 6% | 7% | 6% | 7% | 3% |
| | 4 | 6% | 9% | 4% | 5% | 8% | 11% | 7% | 11% | 12% | 6% | 6% | 3% | 6% | 5% |
| **Luxury amenities** | 2 | 4% | 7% | 9% | 8% | 10% | 11% | 9% | 4% | 4% | 9% | 10% | 5% | 4% | 4% |
| | 4 | 7% | 9% | 9% | 7% | 6% | 5% | 10% | 8% | 7% | 8% | 7% | 10% | 2% | 4% |
| **Towing capacity** | 2 | 1% | 1% | 0% | 1% | 0% | 2% | 7% | 2% | 5% | 10% | 11% | 15% | 17% | 28% |
| | 4 | 0% | 0% | 2% | 1% | 2% | 3% | 4% | 2% | 6% | 8% | 6% | 11% | 15% | 39% |
| **Operating and maintenance costs** | 2 | 8% | 10% | 5% | 5% | 8% | 12% | 9% | 6% | 10% | 6% | 8% | 6% | 4% | 3% |
| | 4 | 5% | 7% | 19% | 11% | 9% | 10% | 2% | 6% | 6% | 7% | 7% | 5% | 0% | 5% |

## 7.7. Potential Early HEV Adopters' and Next Vehicle Purchase Source of Information

Before I conclude this chapter, I thought the next logical thing to do after segmenting the consumers and finding the most potential HEV early adopters, is to find out what is the best way to target them. In other words, what are the sources from which these potential consumers collect their information before placing their next vehicle purchase order, so we can make it a HEV purchase. To achieve this, respondents were asked to rank the important of the following sources of information, when making their next vehicle purchase, on a 7-points Likert scale, running from not at all important to extremely important:

- Dealership: talking to experts and going for a test drive.
- Magazines or other publications: reading consumers reports, automotive news, etc.
- Word of mouth: talking to your family, friends and acquaintances.
- Your own experience.

- Online reviews.

Before I present how clusters 2 and 4 performed, I thought it is helpful to share how the whole respondents' pool answered this question. If we add all "important" scale points: i.e.: Extremely important, Somewhat important and Very important, 86% of the respondents choose prior experience as an important source of information. This was followed by word of mouth, capturing 73% of respondents' "important" votes. Surprisingly, online review was the third, with 72%, while the dealership is fourth, with 71% of respondents' votes. Finally, magazines was the last with 65%.

Now, analyzing clusters of interest. If I add all important scale points as done above, there seem to be no different between cluster 2 and 4 from one side, and the whole respondents, from the other side, in terms of the order of importance for prior experience and word of mouth (89%, and 78% for cluster 2 and 88% and 74% for cluster 4 respectively). Opposite to the importance for prior experience and word of mouth, there is a clear lack of importance for dealership, online review and magazines, see Figure 18 below. For the rest of the source of information, cluster 2 had: 72% for magazines and online reviews, and 71% for dealership. Cluster 4, had 71% for dealership, 68% for online reviews and 64% for magazines. Figure 18 below offers a better way for comparing between the two clusters. For example, cluster 2 value dealership information clearly more than cluster 4, considering it extremely important (26% vs. 19% for clusters 2 and 4 respectively). Also, the same can be said for prior experience and word of mouth. In fact, cluster 2 consistently chose extremely important more than cluster 4 and cluster 4 chose "very important" consistently more than cluster 2 for all the sources of information presented. This show that cluster 2 members places more importance on all those sources of information, which might indicate that

there is a difference between these two clusters in the level of depth in seeking purchase information before placing a purchase.

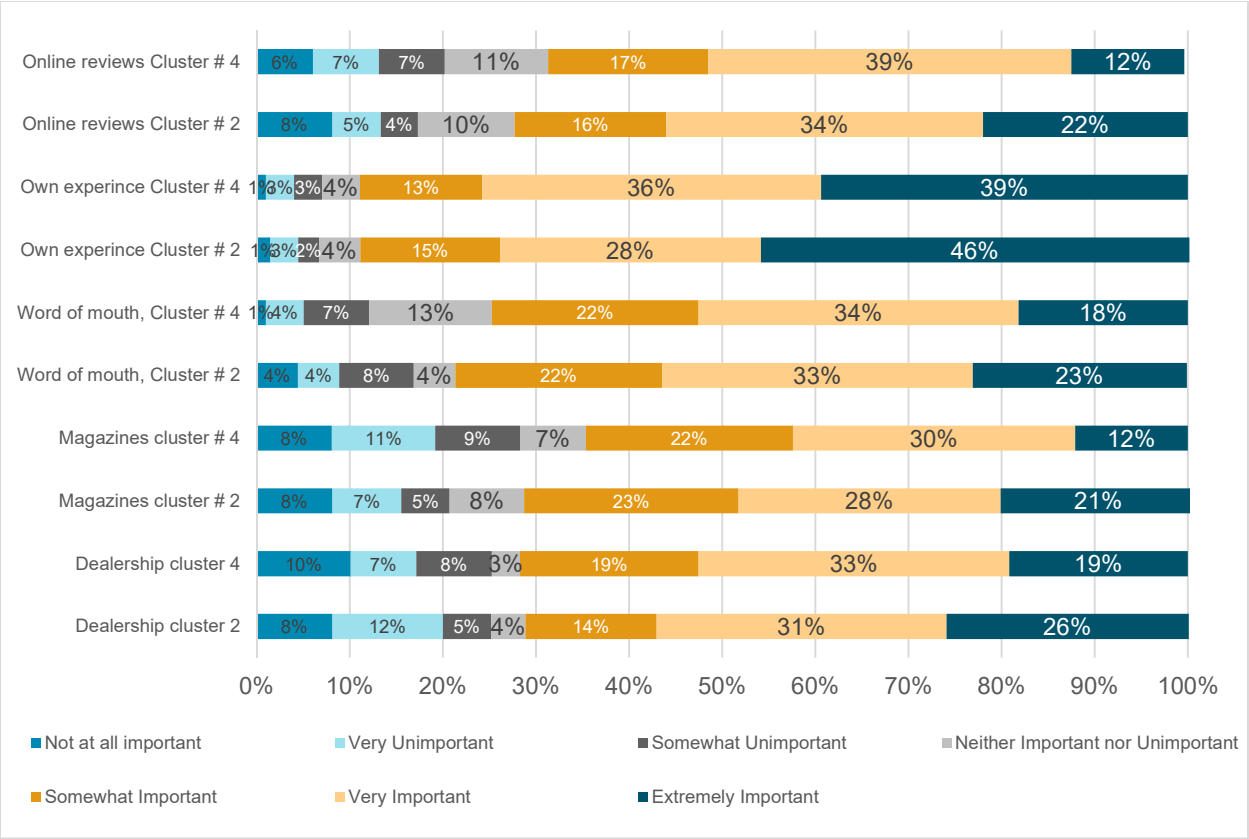


**FIGURE 18 SOURCE OF INFORMATION WHEN BUYING A VEHICLE**

## 7.8.Reflection on Variable Averages for Saudi Arabia

Age, income, education level, number of owned vehicles and household size were the five variables that were included in this clustering study. All these variables were based on the sample. For example, when I say: income for the potential early HEV adopters is more than the average, then I mean that it is more than the sample average. This reflects the general assumption that this sample is representative for the whole Saudi society. This, however, requires tying the findings to

the true population means for all the five variables to be truly able to provide recommendations. This is detailed in the following paragraphs.

The population in Saudi Arabia is mainly young as indicated earlier, in chapter 4, with the majority of the population is between 15 and 59 years old. The sample mean for age is 35 years, which is in between. Unfortunately, there is no more specific figure that can narrow this down to a more accurate figure, but would assume 35 years of age is good threshold.

The closest relevant info central department of statistics released is for the employment (15 years old and more) by education status, presented in Figure 19 below. It is important to notice here that this data includes ages of 15 to 18, which were excluded from our study. This make the difference between the sample proportion of bachelor degree holders (54.9% holds a bachelor degree) and the population (30%) smaller, and therefore, BSc. Degree is taken as the appropriate threshold for the potential early HEV adopters' population.

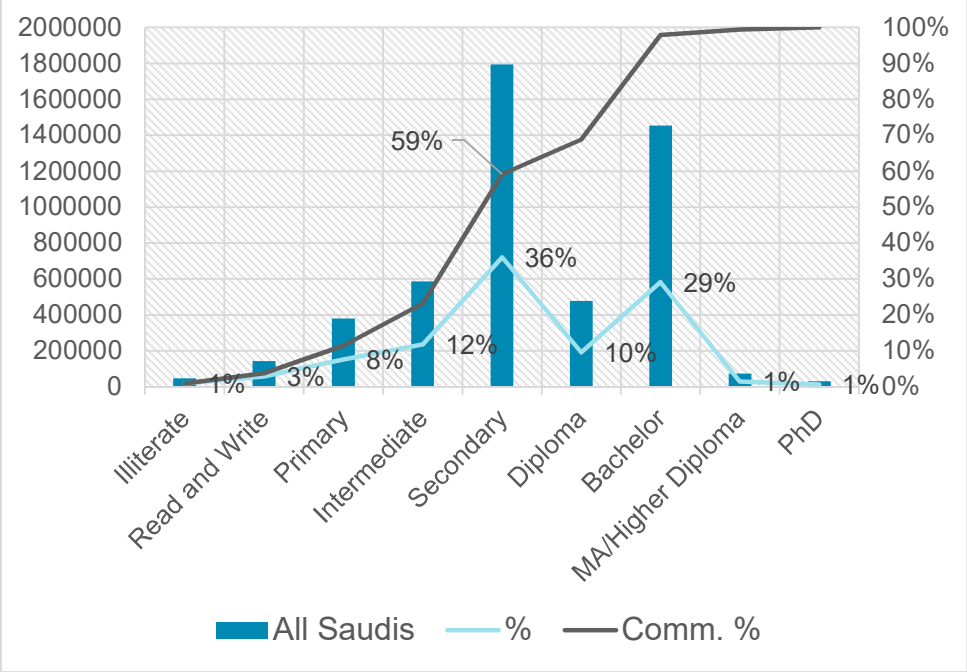


**FIGURE 19 EMPLOYMENT BY EDUCATION STATUS**

The typical Saudi household size remains high compared to the North America or European one. To give an example, consider the following statistics:

- Northern Borders (8.4)
- Hail and Jazan (7.4)
- Al Jouf (7.3)
- Al-Qaseem (7.1)
- Eastern Region (7.0)
- Al-Madina Al-Monawarah (6.1)
- Makkah Al-Mokarramah (5.5)

The average for all the above regions is 6.9, while Makkah has the smallest household size of the nation, (5.5 persons), showing how large the family size in Saudi Arabia. However, it is important to notice that, Saudi Arabia has a large portion of foreigners working in the country, not considered in the above statistics. Non Saudi households, on the other hand, remain small size (4.1 persons) in all the regions; ranging from the least (2.6) in Al Baha to (4.3) in: Makkah, Jazan and Eastern Region.

Based on the Saudi central department for stats, the national average income for the population is 10732 SAR, an equivalent of 2862 USD (Saudi and non-Saudi). However, it is important to distinguish, again, between the Saudi and non-Saudis populations, which would increase the figure to 13610 SAR an equivalent of 3629 USD for the Saudi population. Another statistics is provided by Bait.com, a large local recruitment agency of 3300 USD as the average for the private sector for both Saudi and non-Saudi. The sample has more than 90% Saudi

nationals. 3629 USD per month is closer to the sample income mean, and thus, is chosen to be the income threshold for the potential HEV early adopters.

Finally, for the number of vehicles owned, the sample has 59% of responses own 1 vehicle, but the average is 1.63. Thus the safest figure to pick is that, potential early HEV adopters are those who owns more than one vehicle. All variables sample means and chosen thresholds is presented in Table 20 below.

**TABLE 20 VARIABLES SAMPLE MEANS AND CHOSEN THRESHOLDS**

| Variables | Sample* average | National level |
|---|---|---|
| Age | 35.4025 | More than 35 |
| Education level | 4.0298 | Bachelor or more |
| Income | 14689 (3917 USD) | 3629 |
| Household size | 4.9719 | More than 6 |
| Number of vehicles owned | 1.6314 | More than 1 |

*The sample size is 604

## 7.9. Third Perspective Concluding Remarks

The objective of this chapter was to explore the potential HEV early adopters in Saudi Arabia. I first researched the literature that explored HEV potential adopters. Then, through an online questionnaire, relevant variables were captured. Clustering analysis was carried out for the relevant variables. Then, the obtained clusters were analyzed with respect to some vehicle consumption behaviors.

A similar profile to a HEV early adopter reported in literature was identified to be a person who enjoys more income, education level than the average, usually older the average, part of a larger household size, and finally owns more vehicles than the average population. It is important to remind the reader here that it was shown earlier in chapter 6, sections 6.3 and 6.4, that as age and household size increase, the intention to adopt HEV increases too.

Further analysis was conducted, in light of the application of the Theory Reasoned Action on the adoption of HEV in Saudi Arabia revealed an important cluster to consider, similar to the one mentioned above except that its members receive a lower income and education level than the average. It is also important to remind the reader here that, chapter 5, (section 5.4), finding suggested that education level is not statistically significant in determining the vehicle ownership level.

These findings can certainly help in designing effective messages to reach the potential HEV early adopters in Saudi Arabia. While these two clusters (2 and 4) are directionally different for two variables (education and income), a unified initial message can target those who are older than the average, and who are part of larger households. This segment of potential consumers is present in both of the clusters of interest almost identically, not only directionally, but also by the magnitude above the average, see Figure 12. Also, chapter 6 shown that consumers who are older than the average, and who are part of larger households have more intention to adopt HEV.

After the initial and more general massage discussed in the above paragraph, two other customized messages should target two other distinct consumers' segments. The first is for those who enjoy both more income and education level than the average. This message should show more focus on vehicle's safety and performance. The second message is for the consumers segment that is characterized by a less income and education level, which should focus on HEV favorable operating and maintenance cost, and possibly price.

Clusters 2 and 4, both are mainly large vehicle drivers. Targeting the potential HEV early adopters should make use of such observation, by designing effective marketing campaigns from the private sector and designing effective encouragement policies from the government sector. All

messages discussed in the previous paragraph, therefore, should positively highlight HEV seating capacity.

# 8. CONTRIBUTIONS, LIMITATIONS AND FUTURE RESEARCH

The research's contribution is observed in two aspects: the topic and methodology. The topic contribution is for the fact that it is the first research effort that discusses the potential of HEV in the largest oil producing country, Saudi Arabia, and the largest economy in the Middle East. This could have an impact not only on Saudi Arabia, but globally, because saved fuel can be used to meet the growing global fuel demand. Also, if transportation emissions were reduced in Saudi Arabia, and anywhere for that matter, it is for the benefits of the entire planet.

In addition, this research provides a contribution via methodology employed, specifically using clustering analysis to show the most potential HEV consumers in Saudi Arabia. I only found two articles that used similar approach, which were conducted on consumers in different contents for different vehicle technologies. This methodology can be easily utilized for further efficient transportation means, possibly with larger and random sample sizes for newer technologies like pure electric vehicles (EV), and driverless vehicles in Saudi Arabia and elsewhere.

The research implications cab be observed over many players in the Saudi transport sector, for example: vehicle manufacturers, consumers, and policy makers. This dissertation started with a preface that discusses the relevance between the need for such research and manufacturing engineering. The relevance lies in the fact that demand justify manufacturing, and demand is a function of consumers' preference. This dissertation showed that consumers in Saudi Arabia put more weight on certain vehicle attributes than others, uniquely to Saudi consumers. Manufacturers

have a better understanding about consumers wants and thus can meet consumers demand in a better way. Moreover, it certainly provide valuable inputs so manufacturers can plan, execute and hopefully achieve their environmental goals as well as meet CAFÉ and similar regulations and standards.

Policy makers can certainly use the outcomes obtained from these perspectives of HEV in Saudi Arabia. Other countries which enjoyed much more HEV diffusion research are still, up to this time yet to achieve their diffusion goals. Thus, this research will help put in place a better policy because it is going to be a policy that was based on real consumers' data, rather than mere speculations.

While I believe that the sample is sufficient to conduct various analyses, I acknowledge that a more random sample can help in generalizing the outcomes of this study reliably. Another general limitation stems from the research method. Since this study is conducted based on a self-administered online questionnaire, the caveat of social desirability bias should be kept in mind when utilizing the study results.

Chapter 5 that discussed vehicle purchase determinants for the case of the previous vehicle and the future vehicle purchase. However, this analysis skipped the distinction between the purchase of a new vehicle and a used one. The amount of money invested in a new vehicle is more -for a comparable vehicle- thus, not all the time the purchase determinant is the same. Also for the same chapter, the comparison between the two different determinant analyses should be approached carefully as the comparison is between an action that happened and an action that to happen. Also, the approach through data were extracted were different. Finally, post-purchase effect might have effects on the stated determinants for the currently owned vehicles. In other

words, for some respondents, reasons they stated might have not crossed their minds at the time of the purchase for their current vehicles.

Chapter 6 was based on the Theory of Reasoned Action (TRA), which sometimes is critiqued that there is a distinction between a goal intention of an ultimate accomplishment such as reducing the fuel consumption or reducing the level of emission and a behavioral intention (say buying HEV), which this theory fails to recognize. Thus, even if HEV becomes the dominating vehicle technology, this may not necessarily translate to a lower level of fuel consumption or emission for some vehicle drivers. Others say that, if it is more economic for drivers to operate an HEV (through reducing the fuel cost), they may drive more miles because of the savings on the fuel cost. Furthermore, for this same chapter, the environmental concern construct should be addressed with more data and analyses, as its validity in the model was questionable. Thus, further studies by scholars from the Saudi society on this construct and rest of the constructs for that matter will be needed for a better understanding of the uniqueness of the Saudi society.

The top of the pyramid of this dissertation research theme, see Figure 2, is the right policy that delivers what it promised to deliver (not part of the scope of this research). Figuring out the right policy is not easy, as evident by the fact that to this time, despite having HEV for more than 16 years, ICE is still dominating roads. Therefore, HEV diffusion policy must be subjected to many rounds of testing. While testing a policy can happen by piloting it, it is costly and sometimes backfire. On the other hand, simulation provides a more economical and efficient way of policy testing. Going forward in my life, I plan to conduct HEV diffusion simulation research. The general and preliminary idea of modeling here is based on the famous Bass diffusion model. This model has been extensively used in the literature and simply states that consumers adopt new product

only through two avenues, either been innovators, or being imitators. As we saw in chapter 6 that the Saudi society is more sensitive to social norms than attitude placed against a product, Bass diffusion model seems appropriate for HEV modeling early stages. Bass diffusion model translates to a generic and well-established Systems Dynamics (SD) model, presented in Figure 20. The observer to the figure below sees that I assumed consumers are assumed to be either ICE or HEV consumers. This idea is based on Warren (2010) type 1 rivalry, which simply deals with consumers as potential consumers, who might choose to buy your product, or your competitor's. The modeling exercise is supposed to go over many iterations as well as consultation with the local market key entities, on an agile modeling practice. This practice would allow for expanding this preliminary model to capture more parameters and therefore build more confidence it is outcomes.

Upon establishing a more complex, and validated model, several scenarios are candidates for explorations. There has been a semiofficial announcement about a vehicle retirement program as a response to transportation sector challenges mentioned earlier, through a joint effort of Ministries of Interior, Finance, and Transport (Alharbi 2015). Thus, the SD model would be used explore the application of such program and how should this effect HEV diffusion.

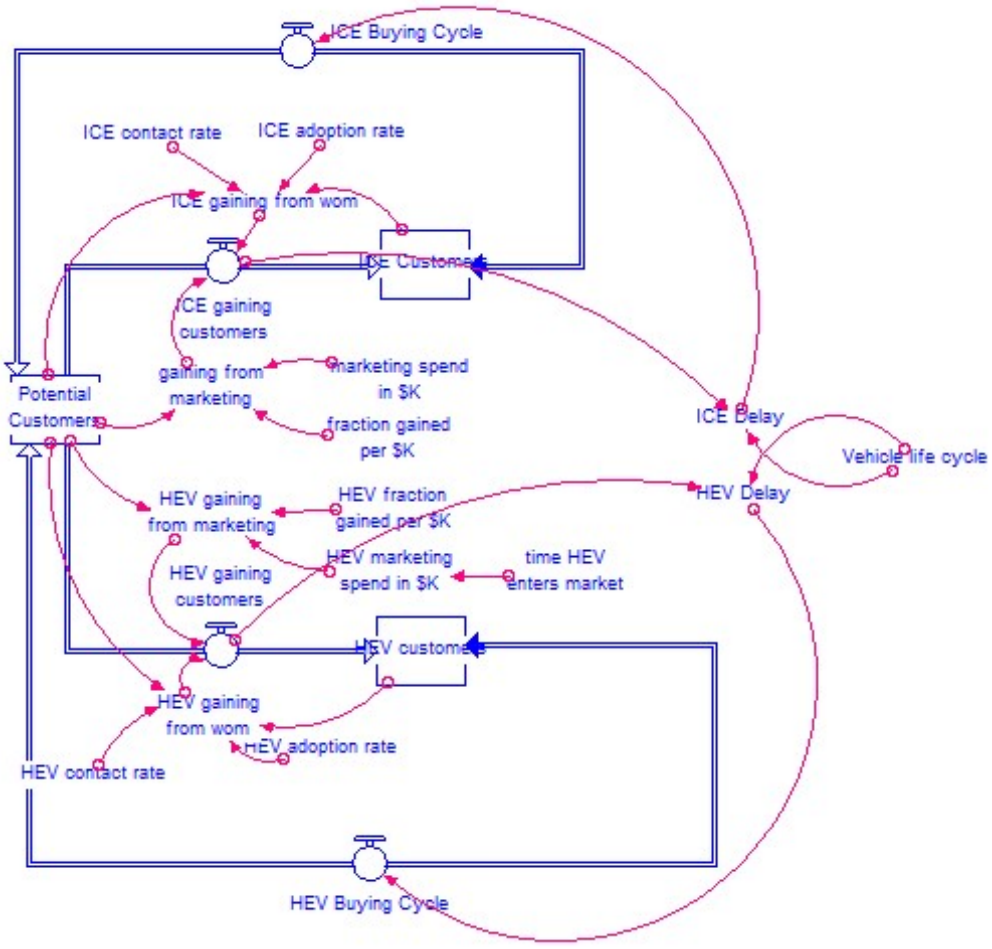


**FIGURE 20 PRELIMINARY SD MODEL FOR HEV DIFFUSION IN SAUDI ARABIA**

Recently, the government of Saudi Arabia reduced fuel subsidy, in a step seemed to be one in many steps to reduce further. However, the fuel price is still among the lowest in the world. The efficacy of such steps would also make an interesting case for sensitivity testing in SD the model. These two scenarios will be used to change the SD structure or some constants of the model. Thus, in addition to the above scenarios, there will be tests and sensitivity analyses for different model parameters until a sufficient model confidence level is obtained, then use it to propose the right HEV diffusion policy.

# APPENDIX A: IRB APPROVAL

WORCESTER POLYTECHNIC INSTITUTE

Worcester Polytechnic Institute IRB# 1
HHS IRB # 00007374

**1 April 2015**
**File:15-102**

**Re: IRB Application for Exemption #15-102 "Assessing attitude toward new-energy vehicles and its potential in Saudi Arabia"**

Dear Prof. Zeng,

The WPI Institutional Review Committee (IRB) has reviewed the materials submitted in regards to the above mentioned study and has determined that this research is exempt from further IRB review and supervision under 45 CFR 46.101(b): (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

**This exemption covers any research and data collected under your protocol from 1 April 2015 until 31 March 2016** unless terminated sooner (in writing) by yourself or the WPI IRB. Amendments or changes to the research that might alter this specific exemption must be submitted to the WPI IRB for review and may require a full IRB application in order for the research to continue.

Please contact the undersigned if you have any questions about the terms of this exemption.

Thank you for your cooperation with the WPI IRB.

Sincerely,

Kent Rissmiller
WPI IRB Chair

# APPENDIX B: ONLINE QUESTIONNAIRE

Online survey

Assessing attitude toward efficient vehicles and its potential in Saudi Arabia

Student Investigator: Khalid Alzahrani

In this study, we will investigate motivations behind vehicles purchases for the people of Saudi Arabia. You will be asked to respond to an online questionnaire, which is expected to last for about 20 minutes. We expect that there will be no risk of the filling this questionnaire, however if you think that your eyes can be adversely affect from spending around 20 minutes to fill this questionnaire, please don't participate. No compensation for medical care can be provided by WPI. You do not give up any of your legal rights by signing this statement. Your refusal to participate will not result in any penalty to you. You may decide to stop participating in the research at any time. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit. Data obtained in this experiment will become the property of the investigators and WPI. If you withdraw from the study, data already collected from you will remain in the study. Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you. For more information about this research or about the rights of research participants, or in case of research-related injury, contact: Khalid Mohammed, Manufacturing Engineering Department, WPI, 100 Institute Road, Worcester, MA (Tel. +966555561954). You may also contact the chair of the WPI Institutional Review Board (Prof. Kent Rissmiller, Tel. 001-508-831-5019, Email: kjr@wpi.edu) or WPI's University Compliance Officer (Michael J. Curley, Tel. 001-508-831-6919). By selecting "Agree" below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

- ❍ Agree
- ❍ Disagree

Welcome

Thank you for taking the time to participate. Please note that this research study is not designed to try to sell or market any particular type of vehicle. To make sure all respondents satisfy the questionnaire participation requirement, please answer the following question. Are you 18 years old or older?

- ❍ Yes
- ❍ No

If No Is Selected, Then Skip To End of Survey

This section of the survey is designed to know your opinions about the environment, and also to show how familiar are you with some types of passenger vehicles.

To what extent do you agree or disagree with the following statements:

| | Strongly Disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| I think environmental problems are becoming more and more serious in recent years. | ❍ | ❍ | ❍ | ❍ | ❍ |
| I think human beings should live in harmony with nature in order to achieve sustainable development. | ❍ | ❍ | ❍ | ❍ | ❍ |
| I think we are not doing enough to save scarce natural resource from being used up. | ❍ | ❍ | ❍ | ❍ | ❍ |
| I think individuals have the responsibility to protect the environment. | ❍ | ❍ | ❍ | ❍ | ❍ |

Before we go further, it is important to explain that throughout this study, the researcher is only considering passenger vehicles (commercial fleets are not considered).

For each of the following 3 points, use the scale between the opposite meanings from the left to the right, to choose the value that best represents you. When it comes to diesel vehicle, I consider myself:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Unfamiliar: Familiar | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| Inexperienced: Experienced | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| Not knowledgeable: Knowledgeable | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |

Please watch the following short educational video about diesel vehicles (The video is only 45 seconds)

Using the scale between the opposite meanings from the left to the right, please choose the value that you think represents you for each one.
When it comes to Hybrid Electric Vehicle, HEV (in this study, it only refers to HEV that does NOT require Plug-in), I consider myself:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Unfamiliar: Familiar | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| Inexperienced: Experienced | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| Not knowledgeable: Knowledgeable | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |

Please listen to the following short educational video about Hybrid (The video is only 72 seconds)

This section of the survey is designed to know your attitude toward adopting HEV, subjective norm, and perceived control of such adoption.

Using the scale between the opposite meanings from the most left to the most right, please choose the value that you think represents you for each one.
For me, adopting a HEV is...

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Unfavorable: Favorable | ❍ | ❍ | ❍ | ❍ | ❍ |
| Undesirable: Desirable | ❍ | ❍ | ❍ | ❍ | ❍ |
| Unpleasant: Pleasant | ❍ | ❍ | ❍ | ❍ | ❍ |
| Negative: Positive | ❍ | ❍ | ❍ | ❍ | ❍ |

To what extent do you agree or disagree with the following statements:

| | Strongly Disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Most people who are important to me think I should adopt a HEV when adopting a vehicle in the near future. | ❍ | ❍ | ❍ | ❍ | ❍ |
| When considering adopting a HEV, I wish to do what people who are important to me want me to do. | ❍ | ❍ | ❍ | ❍ | ❍ |
| If I buy a HEV, then most people who are important to me would also buy a HEV. | ❍ | ❍ | ❍ | ❍ | ❍ |
| People whose opinions I value would prefer that I adopt a HEV when adopting a vehicle in the near future. | ❍ | ❍ | ❍ | ❍ | ❍ |

To what extent do you agree or disagree with the following statements:

| | Strongly disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| The price of a HEV is important to me and I can afford it when I decide to adopt. | ❍ | ❍ | ❍ | ❍ | ❍ |
| The maintenance and repair of a HEV is important to me when I decide to adopt. | ❍ | ❍ | ❍ | ❍ | ❍ |
| I can find where to buy a HEV if I wanted to. | ❍ | ❍ | ❍ | ❍ | ❍ |

To what extent do you agree or disagree with the following statements:

| | Strongly disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| I am willing to adopt a HEV when adopting a vehicle in the near future. | ❍ | ❍ | ❍ | ❍ | ❍ |
| I intend to adopt a HEV when adopting a vehicle in the near future. | ❍ | ❍ | ❍ | ❍ | ❍ |
| I plan to adopt a HEV when adopting a vehicle in the near future. | ❍ | ❍ | ❍ | ❍ | ❍ |

This section of the survey is designed to know more about your current vehicle ownership and your next vehicle purchase plan.
How many vehicles do you have? (both owned and leased vehicles).

❍ 0
❍ 1
❍ 2
❍ 3
❍ 4
❍ 5
❍ More than 5

Answer If How many vehicles do you have? (both owned and leased vehicles) 0 Is Selected

Can you please explain why you don't own/lease any vehicle?

Answer If How many vehicles do you have? (both owned and leased vehicles) 0 Is Not Selected

What is the make, model and year of your current vehicle? (the one you mostly use if you have more than 1 vehicle).

Make, example: Toyota.
Model, example: Camry.
Year, example: 2002.

Answer If How many vehicles do you have? (both owned and leased vehicles) 0 Is Not Selected

Please tell us a little more about your ….. by selecting the options below that best describe it:

| | 1 | 2 |
|---|---|---|
| Automatic transmission: Manual transmission | ❍ | ❍ |
| Was purchased new: Was purchased used | ❍ | ❍ |
| Gasoline: Diesel | ❍ | ❍ |

Answer If How many vehicles do you have? (both owned and leased vehicles) 0 Is Not Selected

In your own words, what is the MAIN reason you (or your household) chose to buy/lease your current ……. (please specify)?

Answer If How many vehicles do you have? (both owned and leased vehicles) 0 Is Not Selected

What is the estimate of the number of kilometers your …… is driven in a year ?

- ❍ 5000
- ❍ 10000
- ❍ 15000
- ❍ 20000
- ❍ 25000
- ❍ 30000
- ❍ 35000
- ❍ 40000
- ❍ 45000
- ❍ 50000
- ❍ More than 50000

Answer If How many vehicles do you have? if you don't have one, please put 0 (both owned and leased vehicles) Text Response Is Greater Than 0

When was ….. purchased or leased? If you don't remember, please choose your best guess.

- ❍ 1 year ago or less
- ❍ 2 to 4 years ago
- ❍ 5 to 7 years ago
- ❍ 8 to 10 years ago
- ❍ 11 to 13 years ago
- ❍ 14 to 16 years ago
- ❍ More than 16 years
- ❍ I have not owned or leased a vehicle

When do you expect to purchase or lease another vehicle?

- ❍ In 1 year or less

- ❍ In more than 1 and less than 2 years
- ❍ In more than 2 and less than 3 years
- ❍ In more than 3 and less than 4 years
- ❍ In more than 4 and less than 5 years
- ❍ Not before at least 5 years
- ❍ I have no plans to own or lease a vehicle

Answer If When do you expect you or anyone in your household will purchase or lease another vehicle? "No one plans to buy or lease another vehicle" Is Not Selected

How important are the following sources of information when you (or one of your household) decide to purchase next vehicle? Please indicate the importance placed on each source of information below.

| | Not at all important | Very Unimportant | Somewhat Unimportant | Neither Important nor Unimportant | Somewhat Important | Very Important | Extremely Important |
|---|---|---|---|---|---|---|---|
| Dealership: talking to experts and going for a test drive. | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| Magazines or other publications: reading consumers reports, automotive news, etc. | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| Word of mouth: talking to your family, friends and acquaintances. | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| Your own experience. | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| Online reviews. | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| Other, please specify: | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |

Answer If When do you expect you or anyone in your household will purchase or lease another vehicle? "No one plans to buy or lease another vehicle Is Not Selected

Considering your next vehicle purchase or lease, can you rank the following factors from the most important in influencing your purchase or lease decision to the least?, (you can change the order by dragging and dropping factors until you reach the order you like)

_____ Performance of engine
_____ Fuel economy (kilometer per liter)
_____ Ability to see the road (ride height)
_____ Seating capacity
_____ Cargo space / truck bed space
_____ Safety rating
_____ Price
_____ Favorable financing
_____ Reputation of manufacturer
_____ Services offered by the nearby dealer
_____ Appearance
_____ Luxury amenities and/or special features
_____ Towing capacity (e.g., for boats or trailers)
_____ Operating and maintenance costs

Answer If When do you expect you or your household will purchase or lease another vehicle? I have no plans to own or lease a vehicle Is Not Selected

For your next purchase or lease you will likely choose a vehicle with which type of engine?

❍ 4 cylinders engine
❍ 6 cylinders engine
❍ 8 cylinders engine
❍ 12 cylinders engine

Answer If When do you expect you or your household will purchase or lease another vehicle? I have no plans to own or lease a vehicle Is Not Selected

For your next purchase or lease, you will likely choose a vehicle with which characteristics?

| | 1 | 2 |
|---|---|---|
| Automatic transmission: Manual transmission | ❍ | ❍ |
| New vehicle: Used vehicle | ❍ | ❍ |
| Gasoline: Diesel | ❍ | ❍ |

Answer If When do you expect you or anyone in your household will purchase or lease another vehicle? “No one plans to buy or lease another vehicle Is Not Selected

How much money in Saudi Riyal are you considering to pay for your next vehicle?

- ❍ less than 50,000
- ❍ 51,000 to 70,000
- ❍ 71,000 to 90,000
- ❍ 91,000 to 110,000
- ❍ 111,000 to 130,000
- ❍ 131,000 to 150,000
- ❍ 151,000 to 170,000
- ❍ 171,000 to 190,000
- ❍ 191,000 to 210,000
- ❍ 211,000 to 230,000
- ❍ More than 231,000

If you buy the vehicle that you have in mind now as a "new" vehicle, how much do you think you will be able to sell it for in 5 years as a % from the purchase price?

_____ % from the purchase price

For the same vehicle that you have in mind, how many years of warranty do you think come with it if you purchase it "new" now? (Warranty here means: basic warranty and power-train warranty, but not corrosion warranty)

- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ 6
- ❍ 7
- ❍ 8
- ❍ 9
- ❍ 10

Answer If Please tell us a little more about your ……. Gasoline …..Is Equal to 1

Current Gasoline fuel cost per liter in Saudi Arabia is around 60 Halalas. Some people say that changes in the price of gasoline could change their opinion about alternative vehicles. Thinking about the next several years, how high would the gasoline price need to be in Saudi Arabia

before you would seriously consider purchasing or leasing an alternative vehicle to your current … vehicle?

- ❍ 50 Halalas per liter and above
- ❍ 1 SAR per liter and above
- ❍ 2 SAR per liter and above
- ❍ 3 SAR per liter and above
- ❍ 4 SAR per liter and above
- ❍ 5 SAR per liter and above

Answer If Please tell us a little more about your ……..Gasoline ….."Diesel" Is Not Equal to 1

Current diesel fuel cost per liter in Saudi Arabia is around 26 Halalas. Some people say that changes in the price of diesel could change their opinion about alternative vehicles. Thinking about the next several years, how high would the diesel price need to be in Saudi Arabia before you would seriously consider purchasing or leasing an alternative vehicle to your current …. vehicle?

- ❍ 50 Halalas per liter and above
- ❍ 1 SAR per liter and above
- ❍ 2 SAR per liter and above
- ❍ 3 SAR per liter and above
- ❍ 4 SAR per liter and above
- ❍ 5 SAR per liter and above

Thank you again for taking the time to participate in our study. Only 8 demographic questions are remaining. (Please don't forget to enter your email when you are asked if you are interested to participate in the raffle)

Where do you live in Saudi Arabia? (if the city is not on the list, please choose the closest)

What is your nationality?

What is your gender?

- ❍ Male
- ❍ Female

What is your age category?
- ❍ 18–24
- ❍ 25–34
- ❍ 35–49
- ❍ 50–64
- ❍ 65 and over

What is your highest level of education?
- ❍ Did not complete high school
- ❍ High school
- ❍ Some college/associate
- ❍ Bachelor's degree
- ❍ Master's degree
- ❍ Advanced graduate work or Ph.D.

What is your household structure?
- ❍ Married (no offspring)
- ❍ Married (with dependent spring)
- ❍ Married (all offspring are non-dependent)
- ❍ Single parent (with dependent offspring)
- ❍ Single parent (all offspring are non-dependent)
- ❍ Single: living with my family
- ❍ Single: living alone
- ❍ Other

What is your household size? (Including you)
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ 6
- ❍ 7
- ❍ More than 7

Who is the main income provider?

- ❍ Myself
- ❍ My spouse
- ❍ My father
- ❍ My mother
- ❍ Both of my parents
- ❍ One or more of my children
- ❍ Other _____

What is your net monthly income in Saudi Riyal?

- ❍ Less than 1200
- ❍ Between 1201 and 2800
- ❍ Between 2801 and 4000
- ❍ Between 4001 and 6000
- ❍ Between 6001 and 9000
- ❍ Between 9001 and 12000
- ❍ Between 12001 and 15000
- ❍ Between 15001 and 18000
- ❍ Between 18001 and 21000
- ❍ Between 21001 and 24000
- ❍ Between 24001 and 27000
- ❍ Between 27001 and 30000
- ❍ More than 30000

Please share your email (this is optional, but if you want to participate in the raffle, your email is the only way we can contact you if you win the raffle).

# APPENDIX C: PROFESSOR MORRIS' EXCEL TEMPLATE

The Kerley works on the method of "revised preferences." That is, if more than two people are running for an office, and candidates are eliminated on the basis of their votes, then voters' preferences are revised with each elimination. Let's suppose five candidates are running for the same office. Voters are asked to rank candidates as 1 for first choice, 2 for second, and so on. If candidates are ranked in order of first choice votes and the one with the lowest number of ones is eliminated, we can go back and ask the voters to re-rank the remaining voters. If the voters have good memories, are rational, and if their preferences are transitive, then a voter who ranked the eliminated candidate as a 3 would go back and keep her top two choices as 1 and 2, but would re-rank her previous fourth and fifth choices as 3 and 4, respectively. This process is repeated until only two are left. Each of the remaining two candidates will have only 1's and 2's and the one with the highest number of 1's wins. In case of a tie, the winner is decided by a coin toss. Theoretically, we would get the same result if we had conducted all possible two-person

There are a couple of complications, however. If someone ranks any two candidates the same, those votes and all lower votes (lower in terms of preferences) are eliminated. Also, if a voter ranks only three (out of five) candidates as 2, 3 and 5, then on the basis that these three candidates are the voter's first, second and third choices, they are re-ranked as 1, 2 and 3,

Instructions

1) Users of this program should be reasonably proficient in Excel and be familiar with the Kerley Method.

2) Click one of the election tabs along the bottom of the spreadsheets display area. You can click on the "Instructions" tab to view these instructions. Click the "Clear" button in the upper left of an election sheet to clear any data that was saved previously. This is important! As a precaution, you will be asked if you really want to erase the sheet, and you will press the "Yes" button in

3) If you need more election sheets than provided, go to the Kerley Method worksheet and click the New Sheets button. A form will pop up which will ask you how many sheets you want. Specify the number wanted using the button and press OK.

4) Enter the names of the candidates along the top row of the bordered area starting in cell D7; for example, Sam, Sue and Jane in cells D7, E7 and F7. Next, enter the vote rankings from each ballot below each of the candidates. If the first ballot has Sam ranked 3, Sue ranked 1, and Jane ranked 2, then enter 3, 1 and 2 in cells D8, E8 and F8. Make sure each ballot has at least one vote marked in it. Otherwise an error will occur during setup.

5) Enter the "Office" in cell D5. When you do Setup, the name of the worksheet will automatically take on the office name. Since no two Excel sheets may have the same name, make sure all of the offices have different names. It is not necessary to do anything about the Number of Candidates and Number of Votes cells. They will be computed for you. .

6) Now hit the Setup macro button. This will copy the results into the "Kerley Method" worksheet and make adjustments necessitated by gaps and ties in rankings.

7) After you have clicked "Setup," the Kerley Method sheet is displayed. Enter the number of winners desired using the toggle switch in cell F3. Press the "Kerley" button, then press either Semi-Automatic (to view each step) or Automatic (to run to completion) to run the Kerley method.

8) Assuming there is only one winner for an election, the Kerley Method winds up with the two highest candidates in the first two columns and x's in the others. The one with the highest number of 1's wins. If there is a tie in the number of 1's, the highest number of 2's wins. There should be only 1's and 2's left after the program has run.

9) You will be notified of ties, both in the final solution and en route to it. You can identify where ties occur by examining the Matrix of Election Results, located to the right of the adjusted votes. This matrix gives the results of each possible one-on-one election, so that a zero indicates a tie has occurred. You probably don't care about ties, since ties are broken randomly during the Kerley method.

10) At the present stage of development, try not to make too many changes in the worksheet. Formatting changes are OK, and inserting and deleting rows and columns beyond H10 are OK. Don't make any changes at all to the Formulas worksheet; it contains formulas necessary to the operation of macros. It's hidden, anyway, so you shouldn't even know it's there.

11) Make sure you keep a record of each election in its worksheet. You can print the final results from the Kerley Method worksheet. Make sure you keep adequate backups and keep a history of backups. Large Excel files have a habit of going bad for no reason at all, so the backup you just made may have gone bad without your knowing it. Always keep a clean copy of the original as a backup.

12) At present, the macros are set up for a maximum of 20 candidates and 1,000 votes. If you want more, increase the appropriate array sizes in the macros.

13) Because of the way in which candidates are eliminated, the Kerley Method does not always result in the "best" choices. The Condorcet Method is an attempt to arrive at the set of winners fulfilling the Condorcet Criterion. That is, the winner(s) would attain majorities in head-to-head elections against all non-winner(s). It's not guaranteed to identify the set of Condorcet winners, but in testing, it always has. Sometimes, of course, no Condorcet solution exists, in which case the Kerley Method is used by default.

## APPENDIX D: ELECTION RESULTS MATRIX

| | *Price* | *Reputation of manufacturer* | *Safety rating* | *Performance of engine* | *Seating capacity* | *Operating and maintenance costs* | *Luxury amenities and/or special features* | *Appearance* | *Services offered by the nearby dealer* | *Fuel economy* | *Cargo space / truck bed space* | *Favorable financing* | *Ability to see the road* | *Towing capacity* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Price* | 0 | 185 | 210 | 229 | 296 | 323 | 281 | 353 | 315 | 315 | 409 | 473 | 453 | 539 |
| *Reputation of manufacturer* | -185 | 0 | 20 | 30 | 73 | 40 | 54 | 92 | 116 | 74 | 274 | 248 | 344 | 456 |
| *Safety rating* | -210 | -20 | 0 | 16 | 64 | 76 | 80 | 104 | 68 | 112 | 272 | 258 | 350 | 426 |
| *Performance of engine* | -229 | -30 | -16 | 0 | 95 | 66 | 54 | 122 | 108 | 110 | 306 | 254 | 338 | 446 |
| *Seating capacity* | -296 | -73 | -64 | -95 | 0 | 5 | -29 | -3 | 23 | 5 | 307 | 189 | 275 | 451 |
| *Operating and maintenance costs* | -323 | -40 | -76 | -66 | -5 | 0 | 18 | 44 | 48 | 40 | 192 | 232 | 286 | 454 |
| *Luxury amenities and/or special features* | -281 | -54 | -80 | -54 | 29 | -18 | 0 | 30 | 48 | 48 | 240 | 214 | 298 | 430 |
| *Appearance* | -353 | -92 | -104 | -122 | 3 | -44 | -30 | 0 | 10 | 18 | 186 | 204 | 274 | 392 |
| *Services offered by the nearby dealer* | -315 | -116 | -68 | -108 | -23 | -48 | -48 | -10 | 0 | 22 | 180 | 174 | 260 | 412 |
| *Fuel economy* | -315 | -74 | -112 | -110 | -5 | -40 | -48 | -18 | -22 | 0 | 212 | 206 | 266 | 456 |
| *Cargo space / truck bed space* | -409 | -274 | -272 | -306 | -307 | -192 | -240 | -186 | -180 | -212 | 0 | 32 | 88 | 304 |
| *Favorable financing* | -473 | -248 | -258 | -254 | -189 | -232 | -214 | -204 | -174 | -206 | -32 | 0 | 50 | 258 |
| *Ability to see the road* | -453 | -344 | -350 | -338 | -275 | -286 | -298 | -274 | -260 | -266 | -88 | -50 | 0 | 284 |
| *Towing capacity* | -539 | -456 | -426 | -446 | -451 | -454 | -430 | -392 | -412 | -456 | -304 | -258 | -284 | 0 |

# APPENDIX E: REASONED ACTION THEORY AGAINST CLUSTERS

Intention to adopt HEV

| Adopting HEV Intention | | Strongly Disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree | Total | Agree + Strongly Agree |
|---|---|---|---|---|---|---|---|---|
| AHEVI_1 | | I am willing to adopt a HEV when adopting a vehicle in the near future. | | | | | | |
| Cluster number | 1 | 15% | 19% | 32% | 27% | 8% | 75 | 35% |
| | 2 | 6% | 12% | 28% | 40% | 14% | 138 | 54% |
| | 3 | 12% | 18% | 40% | 23% | 7% | 209 | 30% |
| | 4 | 8% | 15% | 38% | 30% | 9% | 104 | 38% |
| | 5 | 5% | 18% | 37% | 30% | 10% | 79 | 41% |
| Total | | 56 | 99 | 215 | 179 | 56 | 605 | |
| AHEVI_2 | | I intend to adopt a HEV when adopting a vehicle in the near future. | | | | | | |
| Cluster number | 1 | 13% | 20% | 36% | 27% | 4% | 75 | 31% |
| | 2 | 4% | 17% | 25% | 44% | 9% | 138 | 54% |
| | 3 | 9% | 22% | 32% | 29% | 8% | 209 | 37% |
| | 4 | 7% | 15% | 38% | 32% | 9% | 104 | 40% |
| | 5 | 4% | 13% | 38% | 38% | 8% | 79 | 46% |
| Total | | 45 | 109 | 198 | 205 | 48 | 605 | |
| IHEV_3 | | I plan to adopt a HEV when adopting a vehicle in the near future. | | | | | | |
| Cluster number | 1 | 12% | 17% | 25% | 35% | 11% | 75 | 45% |
| | 2 | 3% | 12% | 20% | 51% | 14% | 138 | 64% |
| | 3 | 11% | 16% | 34% | 29% | 11% | 209 | 40% |
| | 4 | 6% | 16% | 31% | 36% | 12% | 104 | 47% |
| | 5 | 10% | 8% | 41% | 33% | 9% | 79 | 42% |
| Total | | 49 | 86 | 182 | 220 | 68 | 605 | |

Theory of Reasoned Action: Social norm

| Social Norm | | Strongly Disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree | Total | Agree + Strongly Agree |
|---|---|---|---|---|---|---|---|---|
| SN_1 | | Most people who are important to me think I should adopt a HEV when adopting a vehicle in the near future. | | | | | | |
| Cluster number | 1 | 21% | 23% | 29% | 21% | 5% | 75 | 27% |
| | 2 | 11% | 14% | 38% | 28% | 9% | 138 | 37% |
| | 3 | 14% | 23% | 37% | 20% | 6% | 209 | 25% |
| | 4 | 21% | 12% | 40% | 18% | 9% | 104 | 27% |
| | 5 | 13% | 16% | 37% | 29% | 5% | 79 | 34% |
| SN_2 | | When considering adopting a HEV, I wish to do what people who are important to me want me to do. | | | | | Total | |
| Cluster number | 1 | 17% | 31% | 23% | 20% | 9% | 75 | 29% |
| | 2 | 15% | 14% | 16% | 39% | 15% | 138 | 54% |
| | 3 | 19% | 22% | 28% | 24% | 7% | 209 | 31% |
| | 4 | 13% | 20% | 21% | 35% | 11% | 104 | 45% |
| | 5 | 15% | 23% | 24% | 27% | 11% | 79 | 38% |
| Total | | 99 | 129 | 139 | 176 | 62 | 605 | |
| SN_3 | | If I buy a HEV, then most people who are important to me would also buy a HEV. | | | | | Total | |
| Cluster number | 1 | 8% | 11% | 43% | 31% | 8% | 75 | 39% |
| | 2 | 7% | 9% | 36% | 39% | 10% | 138 | 49% |
| | 3 | 7% | 20% | 40% | 26% | 7% | 209 | 33% |
| | 4 | 7% | 13% | 40% | 32% | 8% | 104 | 39% |
| | 5 | 5% | 23% | 42% | 23% | 8% | 79 | 30% |
| Total | | 41 | 93 | 240 | 182 | 49 | 605 | |
| SN_4 | | People whose opinions I value would prefer that I adopt a HEV when adopting a vehicle in the near future. | | | | | Total | |
| Cluster number | 1 | 7% | 13% | 37% | 33% | 9% | 75 | 43% |
| | 2 | 6% | 14% | 29% | 34% | 17% | 138 | 51% |
| | 3 | 8% | 21% | 34% | 31% | 6% | 209 | 37% |
| | 4 | 13% | 13% | 31% | 36% | 8% | 104 | 43% |
| | 5 | 8% | 16% | 35% | 33% | 8% | 79 | 41% |
| Total | | 49 | 101 | 199 | 199 | 57 | 605 | |

Theory of Reasoned Action: Attitude

| Attitude | | Very | Quite | Neither/nor | Quite | Very | Total | Agree + Strongly Agree |
|---|---|---|---|---|---|---|---|---|
| A1 | | Unfavorable to Favorable | | | | | | |
| Cluster number | 1 | 13% | 16% | 32% | 23% | 16% | 75 | 39% |
| | 2 | 15% | 12% | 19% | 25% | 29% | 138 | 54% |
| | 3 | 14% | 11% | 27% | 25% | 22% | 209 | 48% |
| | 4 | 13% | 13% | 22% | 29% | 23% | 104 | 52% |
| | 5 | 22% | 10% | 28% | 18% | 23% | 79 | 41% |
| Total | | 91 | 72 | 152 | 149 | 141 | 605 | |
| A2 | | Undesirable to Desirable | | | | | | |
| Cluster number | 1 | 11% | 19% | 24% | 33% | 13% | 75 | 47% |
| | 2 | 14% | 11% | 22% | 26% | 27% | 138 | 53% |
| | 3 | 10% | 13% | 33% | 24% | 19% | 209 | 44% |
| | 4 | 14% | 12% | 21% | 32% | 21% | 104 | 53% |
| | 5 | 10% | 18% | 30% | 30% | 11% | 79 | 42% |
| Total | | 71 | 83 | 164 | 169 | 118 | 605 | |
| A3 | | Unpleasant to Pleasant | | | | | | |
| Cluster number | 1 | 8% | 19% | 27% | 23% | 24% | 75 | 47% |
| | 2 | 12% | 8% | 22% | 32% | 27% | 138 | 59% |
| | 3 | 7% | 11% | 28% | 33% | 21% | 209 | 54% |
| | 4 | 13% | 8% | 23% | 30% | 26% | 104 | 56% |
| | 5 | 8% | 18% | 24% | 28% | 23% | 79 | 51% |
| Total | | 57 | 70 | 152 | 183 | 143 | 605 | |
| A4 | | Negative to Positive | | | | | | |
| Cluster number | 1 | 8% | 8% | 31% | 28% | 25% | 75 | 53% |
| | 2 | 14% | 7% | 19% | 28% | 32% | 138 | 60% |
| | 3 | 6% | 8% | 23% | 25% | 38% | 209 | 63% |
| | 4 | 13% | 7% | 22% | 27% | 32% | 104 | 59% |
| | 5 | 13% | 16% | 27% | 22% | 23% | 79 | 44% |
| Total | | 61 | 52 | 142 | 157 | 193 | 605 | |

# APPENDIX F: FUTURE VEHICLE PURCHASE AGAINST CLUSTERS

| | Cluster # | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | 10th | 11th | 12th | 13th | 14th |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Performance of | Cluster 1 | 15% | 9% | 12% | 18% | 11% | 14% | 3% | 3% | 1% | 4% | 3% | 4% | 4% | 0% |
| | Cluster 2 | 8% | 7% | 7% | 11% | 8% | 8% | 9% | 10% | 8% | 6% | 7% | 3% | 4% | 3% |
| | Cluster 3 | 7% | 9% | 9% | 13% | 9% | 9% | 6% | 7% | 9% | 5% | 4% | 3% | 5% | 4% |
| | Cluster 4 | 6% | 13% | 6% | 4% | 13% | 8% | 6% | 10% | 8% | 8% | 2% | 6% | 6% | 3% |
| | Cluster 5 | 4% | 8% | 11% | 13% | 8% | 14% | 15% | 3% | 5% | 4% | 5% | 6% | 4% | 1% |
| tal of all clust | | 8% | 9% | 9% | 12% | 10% | 10% | 7% | 7% | 7% | 6% | 5% | 4% | 5% | 3% |
| Fuel economy | Cluster 1 | 1% | 11% | 8% | 9% | 11% | 11% | 1% | 8% | 16% | 8% | 3% | 7% | 3% | 3% |
| | Cluster 2 | 4% | 9% | 5% | 11% | 5% | 10% | 4% | 10% | 4% | 13% | 6% | 4% | 8% | 6% |
| | Cluster 3 | 3% | 4% | 12% | 8% | 11% | 8% | 8% | 10% | 9% | 8% | 6% | 7% | 2% | 5% |
| | Cluster 4 | 2% | 9% | 5% | 8% | 9% | 9% | 8% | 12% | 8% | 11% | 6% | 4% | 4% | 4% |
| | Cluster 5 | 4% | 4% | 5% | 4% | 11% | 14% | 4% | 8% | 5% | 22% | 5% | 8% | 8% | 0% |
| tal of all clust | | 3% | 7% | 8% | 8% | 9% | 10% | 6% | 10% | 8% | 11% | 5% | 6% | 5% | 4% |
| Ability to see th | Cluster 1 | 1% | 3% | 5% | 3% | 1% | 1% | 9% | 7% | 7% | 5% | 15% | 8% | 18% | 16% |
| | Cluster 2 | 1% | 1% | 1% | 3% | 4% | 3% | 5% | 10% | 7% | 11% | 8% | 16% | 18% | 12% |
| | Cluster 3 | 2% | 2% | 2% | 4% | 4% | 2% | 8% | 6% | 8% | 8% | 13% | 13% | 18% | 8% |
| | Cluster 4 | 1% | 4% | 4% | 5% | 4% | 8% | 8% | 5% | 8% | 10% | 12% | 9% | 14% | 7% |
| | Cluster 5 | 3% | 6% | 1% | 4% | 3% | 5% | 3% | 5% | 14% | 9% | 11% | 13% | 13% | 11% |
| tal of all clust | | 2% | 3% | 3% | 4% | 3% | 4% | 7% | 7% | 9% | 9% | 12% | 12% | 17% | 10% |
| Seating capacity | Cluster 1 | 3% | 3% | 4% | 5% | 8% | 7% | 14% | 12% | 8% | 8% | 9% | 7% | 5% | 7% |
| | Cluster 2 | 10% | 10% | 10% | 10% | 10% | 7% | 6% | 8% | 7% | 8% | 4% | 4% | 1% | 3% |
| | Cluster 3 | 4% | 9% | 7% | 8% | 6% | 12% | 9% | 8% | 7% | 11% | 7% | 5% | 2% | 5% |
| | Cluster 4 | 8% | 6% | 11% | 8% | 6% | 10% | 9% | 9% | 4% | 6% | 12% | 3% | 5% | 2% |
| | Cluster 5 | 5% | 9% | 6% | 8% | 9% | 3% | 6% | 8% | 6% | 5% | 8% | 11% | 5% | 11% |
| tal of all clust | | 6% | 8% | 8% | 8% | 8% | 9% | 8% | 9% | 7% | 8% | 8% | 6% | 3% | 5% |
| Cargo space | Cluster 1 | 1% | 3% | 1% | 3% | 4% | 4% | 5% | 9% | 4% | 12% | 12% | 20% | 9% | 11% |
| | Cluster 2 | 1% | 7% | 6% | 7% | 5% | 6% | 4% | 10% | 9% | 10% | 8% | 12% | 7% | 9% |
| | Cluster 3 | 1% | 2% | 2% | 4% | 6% | 8% | 5% | 7% | 9% | 9% | 13% | 14% | 9% | 11% |
| | Cluster 4 | 4% | 4% | 7% | 5% | 9% | 1% | 7% | 7% | 6% | 3% | 5% | 16% | 14% | 11% |
| | Cluster 5 | 0% | 3% | 5% | 5% | 6% | 9% | 13% | 10% | 6% | 8% | 11% | 8% | 9% | 8% |
| tal of all clust | | 2% | 4% | 4% | 5% | 6% | 6% | 6% | 8% | 8% | 8% | 10% | 14% | 9% | 10% |
| Safety rating | Cluster 1 | 9% | 8% | 11% | 5% | 12% | 7% | 7% | 5% | 14% | 9% | 3% | 4% | 4% | 1% |
| | Cluster 2 | 13% | 7% | 9% | 9% | 9% | 8% | 8% | 9% | 4% | 4% | 7% | 6% | 1% | 5% |
| | Cluster 3 | 12% | 10% | 10% | 7% | 10% | 6% | 10% | 6% | 5% | 10% | 4% | 3% | 3% | 4% |
| | Cluster 4 | 23% | 8% | 9% | 8% | 7% | 5% | 5% | 7% | 3% | 4% | 8% | 7% | 3% | 2% |
| | Cluster 5 | 15% | 4% | 5% | 10% | 8% | 8% | 8% | 8% | 9% | 4% | 3% | 5% | 9% | 6% |
| tal of all clust | | 14% | 8% | 9% | 8% | 9% | 7% | 8% | 7% | 6% | 7% | 5% | 5% | 4% | 4% |
| Price | Cluster 1 | 36% | 14% | 16% | 11% | 8% | 4% | 3% | 1% | 3% | 3% | 0% | 0% | 1% | 0% |
| | Cluster 2 | 21% | 13% | 13% | 5% | 9% | 7% | 13% | 1% | 4% | 2% | 1% | 4% | 2% | 2% |
| | Cluster 3 | 31% | 13% | 14% | 9% | 6% | 6% | 5% | 2% | 4% | 2% | 3% | 3% | 0% | 0% |
| | Cluster 4 | 20% | 12% | 10% | 16% | 5% | 8% | 4% | 3% | 3% | 6% | 4% | 0% | 4% | 4% |
| | Cluster 5 | 27% | 16% | 15% | 10% | 9% | 3% | 4% | 5% | 3% | 4% | 4% | 0% | 1% | 0% |
| tal of all clust | | 27% | 13% | 14% | 10% | 7% | 6% | 6% | 3% | 4% | 3% | 3% | 2% | 2% | 1% |
| Favorable finan | Cluster 1 | 0% | 3% | 3% | 4% | 4% | 5% | 8% | 12% | 5% | 12% | 15% | 11% | 9% | 8% |
| | Cluster 2 | 5% | 9% | 8% | 7% | 3% | 5% | 1% | 6% | 5% | 4% | 8% | 13% | 13% | 13% |
| | Cluster 3 | 1% | 7% | 4% | 6% | 7% | 4% | 4% | 9% | 7% | 5% | 9% | 10% | 16% | 10% |
| | Cluster 4 | 0% | 5% | 2% | 4% | 8% | 5% | 6% | 5% | 8% | 11% | 13% | 7% | 16% | 9% |
| | Cluster 5 | 5% | 8% | 4% | 5% | 3% | 3% | 1% | 9% | 13% | 5% | 5% | 14% | 18% | 9% |

| | Cluster # | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | 10th | 11th | 12th | 13th | 14th |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tal of all clust | | 2% | 7% | 4% | 6% | 5% | 5% | 4% | 8% | 7% | 7% | 10% | 11% | 15% | 10% |
| Reputation of n | Cluster 1 | 11% | 16% | 8% | 7% | 9% | 4% | 8% | 7% | 7% | 7% | 11% | 3% | 1% | 1% |
| | Cluster 2 | 15% | 5% | 10% | 7% | 7% | 8% | 9% | 9% | 9% | 7% | 4% | 1% | 4% | 4% |
| | Cluster 3 | 19% | 8% | 5% | 5% | 10% | 8% | 5% | 6% | 9% | 6% | 4% | 7% | 4% | 3% |
| | Cluster 4 | 14% | 8% | 2% | 8% | 5% | 10% | 16% | 5% | 7% | 5% | 6% | 9% | 3% | 1% |
| | Cluster 5 | 15% | 11% | 8% | 10% | 5% | 8% | 5% | 6% | 5% | 6% | 9% | 8% | 1% | 3% |
| tal of all clust | | 16% | 9% | 6% | 7% | 8% | 8% | 8% | 7% | 8% | 6% | 6% | 6% | 3% | 3% |
| Services offere | Cluster 1 | 8% | 3% | 8% | 7% | 8% | 8% | 12% | 4% | 9% | 7% | 14% | 4% | 1% | 7% |
| | Cluster 2 | 4% | 9% | 9% | 11% | 9% | 6% | 8% | 5% | 8% | 4% | 7% | 5% | 9% | 6% |
| | Cluster 3 | 3% | 8% | 8% | 7% | 5% | 8% | 10% | 8% | 11% | 8% | 7% | 4% | 7% | 4% |
| | Cluster 4 | 3% | 5% | 9% | 9% | 8% | 6% | 7% | 9% | 13% | 6% | 5% | 9% | 7% | 3% |
| | Cluster 5 | 6% | 6% | 8% | 10% | 6% | 9% | 8% | 8% | 1% | 10% | 10% | 5% | 6% | 6% |
| tal of all clust | | 4% | 7% | 8% | 9% | 7% | 7% | 9% | 7% | 9% | 7% | 8% | 5% | 7% | 5% |
| Appearance | Cluster 1 | 5% | 8% | 12% | 14% | 3% | 5% | 9% | 9% | 9% | 8% | 1% | 3% | 4% | 8% |
| | Cluster 2 | 4% | 4% | 7% | 6% | 12% | 6% | 8% | 10% | 14% | 6% | 7% | 6% | 7% | 3% |
| | Cluster 3 | 7% | 6% | 10% | 7% | 7% | 12% | 7% | 7% | 6% | 7% | 7% | 6% | 6% | 4% |
| | Cluster 4 | 6% | 9% | 4% | 5% | 8% | 11% | 7% | 11% | 12% | 6% | 6% | 3% | 6% | 5% |
| | Cluster 5 | 4% | 5% | 8% | 8% | 8% | 14% | 6% | 11% | 10% | 8% | 4% | 6% | 3% | 6% |
| tal of all clust | | 6% | 6% | 8% | 7% | 8% | 10% | 7% | 9% | 10% | 7% | 6% | 5% | 5% | 5% |
| Luxury amenitie | Cluster 1 | 8% | 5% | 3% | 9% | 11% | 14% | 5% | 14% | 9% | 3% | 3% | 5% | 5% | 5% |
| | Cluster 2 | 4% | 7% | 9% | 8% | 10% | 11% | 9% | 4% | 4% | 9% | 10% | 5% | 4% | 4% |
| | Cluster 3 | 5% | 9% | 8% | 11% | 7% | 7% | 10% | 12% | 4% | 8% | 10% | 3% | 2% | 4% |
| | Cluster 4 | 7% | 9% | 9% | 7% | 6% | 5% | 10% | 8% | 7% | 8% | 7% | 10% | 2% | 4% |
| | Cluster 5 | 6% | 8% | 5% | 11% | 14% | 10% | 9% | 6% | 6% | 9% | 5% | 4% | 1% | 5% |
| tal of all clust | | 6% | 8% | 7% | 9% | 9% | 9% | 9% | 9% | 6% | 8% | 8% | 5% | 3% | 4% |
| Towing capacity | Cluster 1 | 0% | 0% | 0% | 4% | 0% | 4% | 3% | 1% | 3% | 5% | 7% | 22% | 22% | 30% |
| | Cluster 2 | 1% | 1% | 0% | 1% | 0% | 2% | 7% | 2% | 5% | 10% | 11% | 15% | 17% | 28% |
| | Cluster 3 | 1% | 3% | 2% | 2% | 2% | 1% | 4% | 3% | 5% | 6% | 7% | 14% | 18% | 31% |
| | Cluster 4 | 0% | 0% | 2% | 1% | 2% | 3% | 4% | 2% | 6% | 8% | 6% | 11% | 15% | 39% |
| | Cluster 5 | 3% | 3% | 5% | 1% | 4% | 0% | 5% | 3% | 1% | 1% | 15% | 8% | 20% | 32% |
| tal of all clust | | 1% | 2% | 2% | 2% | 2% | 2% | 5% | 3% | 4% | 7% | 9% | 14% | 18% | 32% |
| Operating and | Cluster 1 | 0% | 15% | 8% | 1% | 9% | 12% | 12% | 7% | 4% | 8% | 5% | 3% | 12% | 3% |
| | Cluster 2 | 8% | 10% | 5% | 5% | 8% | 12% | 9% | 6% | 10% | 6% | 8% | 6% | 4% | 3% |
| | Cluster 3 | 3% | 10% | 8% | 8% | 9% | 9% | 8% | 10% | 6% | 6% | 5% | 6% | 8% | 4% |
| | Cluster 4 | 5% | 7% | 19% | 11% | 9% | 10% | 2% | 6% | 6% | 7% | 7% | 5% | 0% | 5% |
| | Cluster 5 | 4% | 10% | 14% | 1% | 8% | 3% | 14% | 11% | 15% | 6% | 5% | 5% | 3% | 1% |
| tal of all clust | | 4% | 10% | 10% | 6% | 9% | 9% | 9% | 8% | 8% | 6% | 6% | 5% | 5% | 3% |

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# RESUME

**Khalid Alzahrani**

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## EDUCATION

**Worcester Polytechnic Institute- Worcester, MA, USA**

| | | |
|---|---|---|
| PhD in the Manufacturing Eng. (Industrial Eng.) | GPA: 4.0 | 05/2012- 06/2016 |
| Graduate Certificate in SD Modeling - Part timer | GPA: 4.0 | 05/2013- 12/2016 (Exp) |
| Master in Information Technology - Part timer | GPA: 3.9 | 05/2013- 12/2016 (Exp) |
| Master of Business Administration, MBA | GPA: 3.9 | 08/2010- 05/2012 |
| MS in Manufacturing Engineering (Industrial Eng.) | GPA: 4.0 | 08/2010- 05/2012 |

**King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia**

B.S. Industrial Systems Engineering and Operations Research 08/2002- 01/2007

*WORKING PAPERS AND CONFERENCE PRESENATION*

- "Who are green drivers? Segmenting potential early Hybrid Electric Vehicle adopters in Saudi Arabia, using clustering analysis". 2016 with Adrienne Hall-Phillips and Amy Z. Zeng
- "Applying theory of reasoned action to understand consumers' intention to adopt hybrid electric vehicles in Saudi Arabia", 2016 with Adrienne Hall-Phillips and Amy Z. Zeng
- Conference presentation at Industrial & Systems Engineering Research Conference Proceedings May 3, 2014, Canada: "Status Quo of New-Energy Vehicles: A Multi-Stakeholders' Perspective"
- Conference presentation at Industrial & Systems Engineering Research Conference May 23, 2016, USA: "Would Saudis buy Hybrid Electric Vehicles?"

*RELEVANT PROFESSIONAL EXPERIENCES*

**Senior Management Consultant**, Oliver Wyman, Dubai, UAE 12/2012- 08/ 2013

- I handled the PMO for a project to design a Nuclear Holding Company for one of the GCC countries.

- Helped develop an OTT strategy for a leading telecom company in Saudi Arabia
- Designed IT strategy for one of the GCC central banks

**Technical Support Engineer**, Aramco, Distribution Operations 01/2008- 06/2009

- Provided distribution operations technical support for 21 bulk plants around Saudi Arabia
- Supported air fuel operations in all the Saudi Arabia airports
- Optimized the distribution network
- Conducted lean six sigma project for hauling operations
- Created and reviewed support and preventive maintenance procedures

I have achieved the best rating for all appraisals

**Graduate Qualifying Project** (MBA, WPI)

- A complete review of NSTAR "Massachusetts, USA based company" Home Heating Protection Plan business, aiming to increase sales, improve service and profitability.

*OTHER EXPERIENCES*

- **Lecturer (on leave)**, Al-Baha University, Albaha, Saudi Arabia 11/2013 - Present
- **Workforce Optimization Intern**, Travelers, Strategic Services, CT, USA 06/2012- 07/2012
- **Graduate Assistant,** WPI**,** Foisie school of business 11/2011- 05/2012
- **Cost and Estimating Engineer**, SNC LAVALIN, Calgary, Canada 02/2007- 11/2007
  - Performed and ensured an effective cost control function for ongoing project
  - Interpreted contract, managed financial risk, performed estimating and forecasting
  - Maintained current cost control database
  - Reviewed proposed schedule changes with project personnel, client and contractors
- **Productivity Engineer intern** (Coop), SAGCO, Jeddah, Saudi Arabia 10/2005-12/2005
  - Production Line's Productivity Measurements
  - Six Sigma Quality Initiative
- **Production line supervisor intern** (Coop), SJ JOHNSON, Saudi Arabia 06/2005-09/2005
  - Supervised Production line
  - Introduced a new product "Oust" to the market for the first time
  - Prepared the new Aerosol Production line erection

## PROFESSIONAL CERTIFICATIONS & SKILLS

- Certified Project Management Professional (**PMP**).
- Certified Lean Six Sigma Green Belt
- Certified Cost Technician
- **Modelling and statistical packages:** Netlogo, Arena, Vensim, IThink, SQL, SPSS, STATA
- **Languages:** Arabic and English.

## PROFESSIONAL ASSOCIATION MEMBERSHIPS

- Saudi Society of Industrial & Systems Engineering (SSISE), King Abdul Aziz University, Jeddah, 2004-07.
- The Association for the Advancement of Cost Engineering International (AACEI) as a member, Chinook Section, Calgary, Canada and Arabian Gulf section 2007 – Present, Registration No.41319
- Project Management Institute (PMI) as a member of Southern Alberta section and Arabian Gulf section. 2007 registration No 936790
- American Society of Quality (ASQ) as a regular member of International Chapter, Saudi Arabia Section since April 2008.Member # 63621479
- Saudi Council for Engineers, since 2008.
- Institute of Industrial Engineers (IIE) since 2011, membership # 880097667

## HONORS AND AWARDS

- Recipient of the international honor society of **Beta Gamma Sigma** membership
- King Abdullah scholarship recipient (twice)