DEVELOPMENT OF CUSTOMER SURVEY BY USING THE METHOD DESIGN FOR MODE OF APPLICATION

-Survey specifically designed for Hybrid plug-in car owners-

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"It is essential to listen carefully to find out how target customers perceive the product experience and what they want most- and then give it to them"

(Thomas O.Jones and W. Earl Sasser, Jr, 1995, p. 2)

ABSTRACT

In November 2011, Volvo Cars Company (VCC) launched the V60 hybrid plug-in, which was developed in close collaboration with Vattenfall. The lack of financial incentives in Sweden is a major contributor to low V60 PHEV sales in the country, and VCC together with Vattenfall needs to create a win-win situation in which car sales increase. The following research is focused on the implementation of the preliminary steps of the DMA method to develop a survey to obtain insight into the customer's needs of the Volvo car. The preliminary steps of the DMA include customer survey and data logging, which work in parallel. The use of survey as a tool for data collection has been studied. The sample of respondents was not large enough to create a customer picture, but the information contributes to improving the updated version of the questionnaire intended for a larger group of hybrid drivers. The implementation of the cross-functional teamwork has been critical, and the verbal information arising from the teamwork was found crucial in the process of identifying customer requirements. Findings summarized in this project will help identify the most important issues that should be included in the updated version as well as contribute to reinforcing parts of the methodology.

PREFACE

This master's thesis is a project for the MSC degree in Mechanical Engineering performed within the research subject of Computer Aided Design at the division of Product and Production Development, Luleå University of Technology.

I would like to show my gratitude to *Ove Isaksson*, my supervisor at Luleå University of Technology, who gave me the opportunity of conducting this project; thank you for all the support and coaching.

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Finally, I would like to thank *my family* and *Blai* for their unconditional support and complete trust in me.

Anna Martí Bigorra,
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TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF IMAGES

TABLE OF TABLES

ABBREVIATIONS

AC	Alternative Current
BEV	Battery Electric Vehicle
DC	Direct Current
DMA	Design for Mode of Application
DSOs	Distribution system operators
E-Mobility	Electro mobility
EREV	Extended Range Electric Vehicle
EV	Electric Vehicle
GHGs	Green House Gases
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
NSR	North Sea Region
PHEV	Plug-in Hybrid Electric Vehicle
QFD	Quality Function Deployment
VAT	Value-Added Tax
VCC	Volvo Cars Company

1. INTRODUCTION

The aim of this chapter is to briefly introduce the issues regarding the entry of Electric Vehicles (EV) into the market. There is a general discussion about the electric vehicle concerning technology, government facilities, potential customers and current consumers. At the end of this section, the reader can find the research objectives, the scope of the study as well as the method/methodology used in the research. The project planning is in APPENDIX A.

The transportation sector was completely dominated by the internal combustion engine until the electric vehicle appeared (Stephen Browna, David Pyke, Paul Steenhof, 2010). Every day, environmental sustainability becomes a greater concern for governments, and due to this, electric cars have taken a stronger position in the car market. Currently, these vehicles are a means to move the economies away from petroleum and reduce the environmental footprint of transportation. See Europe vehicle electrified sales of 2013 (ABB, 2014) in APPENDIX A (Figure 30).

In the short term, the major catalysts for increasing the number of electric vehicles are the government incentives for the EV related to economic stimulus and international competitiveness and efforts to mitigate climate change, as well as a push by governments to improve energy security (Stephen Browna, David Pyke, Paul Steenhof, 2010).

For instance, The Netherlands is a small country where government incentives and a strategic charging infrastructure result in a successful EV market. Moreover, Norwegian experience shows that people are willing to embrace the electric car due to the purchase cost being competitive with conventional vehicles. The reason is that the electrical vehicles are exempt from VAT and purchase tax in Norway (car prices in APPENDIX A-Figure 32) (Frydenlund, 2014). In addition, the customers can drive their electric vehicles for free through all toll plazas in Norway; parking and charging are also for free (Frydenlund, 2014). This fact compensates the customer for the shorter range compared with a conventional car and maintains a competitive market.

The electric vehicle (EV) market in Sweden is complicated due to lack of financial incentives (Sonnenschein, 2010). This fact keeps the purchase price and advantages of driving an electric car far from the customer expectations and the competitive market itself.

In November 2011, *Volvo Cars Company* launched the *V60 hybrid plug-in*[1] which was developed in close collaboration with *Vattenfall*. The Volvo car was defined as: *"The world's first diesel plug-in hybrid most technically advanced model ever- an electric car, hybrid car and muscle-car all rolled into one"* (Volvo Cars Group,

[1] See the V60 hybrid plug-in position in the Europe electrified vehicles sales (2013): Figure 30 Appendix A. Source: (Shahan, 2014)

2013b). In 2013, Holland, Belgium and Italy were the countries with increased demand (Volvo Cars Group, 2013a), however; the car has not been successfully sold in Sweden.

According to the Swedish Transport Agency and the department of vehicle selection, in March 2013, on the Swedish roads, there were 840 PHEVs of which 30% (252 cars) corresponded to *Volvo V60 hybrid plug-in* (Ellen Angelin and Dzenita Damjanovic, 2013). In addition, 17% of the distribution ownership in Sweden corresponded to the private sector in which only 19% (27 cars) corresponded to *V60 Hybrid plug-in,* while *Toyota Prius Plug-in* comprised 71% (101 cars) (Ellen Angelin and Dzenita Damjanovic, 2013).

Technical, economic and financial aspects are involved in the EV market. Customers want lower purchase prices, which can be achieved with higher volume of electric vehicles; higher volume of electric vehicles will be reached if the charging infrastructure is extended; and this will happen only if the customer's volume of electric cars increases (Malin Sundberg and Monica Fagraeus Lundström, 2013). Low battery capacity, high charging time and lack of infrastructure are the other main aspects that influence in the decision to buy an electric vehicle.

Concerning the charging time, some discussions are focused on so-called "fast charging". This mode of charging changes the battery state from empty to fully charged in less time. In V60 hybrid plug-in (as well as other PHEVs), fast charging is not available. 6A, 10A or 16A are the various intensities used via the Volvo control unit (Volvo Car Corporation, 2012), which limits the user to the power provided from the domestic socket outlet, making them more dependent on private parking and charging spots (Ellen Angelin and Dzenita Damjanovic, 2013). Ongoing processes exist in order to create a functional infrastructure for charging (standardization), but the investment required for the fast chargers is high and is not viable if the volume of the electric car drivers is low.

Volvo Cars Company needs to find the customer value of *V60 hybrid plug-in* to establish an emotional bond with the customer. Customer bonding is not easy to achieve or retain; it requires a focused strategy and hard work (Howard E.Butz, Jr and Leonard D. Goodsten, 1997, p. 67), and the current V60 hybrid plug-in sales leave questions to be asked about the bond between the customer and the company.

A more comprehensive customer study is essential to identifying the conditions necessary so that V60 hybrid plug-in will be an interesting option for the customer. *Volvo Cars Group* and *Vattenfall* have to create a win-win situation where the car sales increase: a business model that involves the *V60 hybrid plug-in*, as well as potential customers, in the car purchase.

1.1. Research objective and scope

The project is a part of The Faste Laboratory – A VINNOVA Excellence Centre for Functional Product Innovation, at Luleå University of Technology. Within the centre, the goal is to work with Volvo Cars and their partners to find a win-win situation that will lead to increased sales of the hybrid through increased customer focus.

Volvo Cars Company's (VCC) goals in this project are to create a better model of the battery's aging process; to map the energy distribution of different driving modes; to create a model of customer behaviour and to find out which values guide consumers' choices in different situations. The last two objectives are in common with Vattenfall, which is also interested in the results of this project to further develop business models within E-Mobility, an area in which the company has been working since 2006.

The thesis is focused on using the DMA method to develop a survey to obtain insight into who the customers of the *V60 hybrid plug-in* are and what their needs and expectations are concerning mainly electric driving and the climate comfort of the Volvo car. The research is based on the preliminary steps of the Design for Mode of Application (DMA), which is an effective internal method that streamlines the internal process of identifying customer requirements and anchoring it at the company (Dr. Ove Isaksson and Anna Karlsson, 2010a, p. 2).

The method's objective is to achieve a more efficient product development by improving the design requirements of the product that increases customer satisfaction. Moreover, what distinguishes this method from others is that it uses two separate, large customer-information sources: the survey and the measurement of the current product in use (Data logging). The survey provides information regarding customer opinions, needs and priorities as well as behaviours—issues impossible to measure—while the data-logging section is focused on customer information that can be hard to get from the survey, but is possible to measure in the car. The combination of both parts gives a picture about the main customer expectations, customer requirements as well as, in this case, the creation of the customer picture of the V60 PHEV drivers. This study is mainly focused on the survey part, but it has been working in parallel with data logging.

The product development of this plug-in hybrid vehicle (PHEV) is involved in a number of balancing issues such as between electricity range and climate comfort in the car: higher electric range entails less cabin temperature comfort. Balancing should be controlled by the customers' needs, *i.e.*, achieving the highest customer satisfaction by setting the correct design requirements for the car. For that reason, the part concerning the electric driving also involves the charging of the battery, and within the climate-comfort part, preconditioning the car is also included.

Additionally, answers from previous questionnaires sent to other Volvo car drivers, specifically model A and model B drivers[2], will be used to make a comparison in responses with some questions posed in this survey. The aim of this comparison is to check if there are significant gaps in the same car feature depending on the car group. Discovering how the view from the customer of the V60 PHEV picture differs from that of other Volvo car groups is another big issue involved in this research. Some of the questions posed in the survey will be used in other surveys in order to understand why potential drivers do not purchase the hybrid plug-in car.

The survey was sent to 15 customers of *Vattenfall* due to the need to pretest the survey before sending it to a larger customer group of *V60 hybrid plug-in* customers. Therefore, the project does not encompass the definitive version of the questionnaire, which will be sent in the near future. The project planning is in APPENDIX A.

Lastly, the research has special emphasis on the charging infrastructure, but all this information will be focused on improved understanding of the actual situation in Europe, and especially in Sweden, in terms of E-Mobility and infrastructure. This study is not focused on developing a strategic and efficient network of charging stations over Sweden, but on understanding the actual market offer, which will give better knowledge about customer charging opportunities and demands. This information is used to design suitable questions concerning charging facilities, opportunities and offers.

[2] Due to Confidentiality of Volvo Cars Company, the answers from the two different Volvo Car models used in the analysis are called A and B respectively.

2. LITERATURE SURVEY

This chapter provides a means to understand and clarify the current situation of EV with special focus in PHEV. Customer expectations of EV and the need to find a balanced situation are explained. In addition, the chapter also includes a discussion of the different barriers for the EV special focus in Sweden. A brief discussion about "e-mobility" in Europe as in Sweden is also included.

2.1. EV market in Europe

Acceptance of alternative propulsion technologies nowadays remains low in the EU overall, and Sweden still has a long way to go. In 2013, the majority of Europe's new cars were powered by gasoline or diesel motors (Figure 1- *Hybrids, electrics and natural gas- and ethanol-fuelled vehicles).

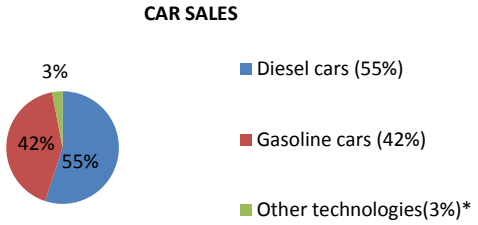


Figure 1: % of new cars of each type in Europe in 2013
Source: (The international council on clean transportation, 2013)

Electric vehicles need an improvement of battery life, number of deep discharge cycles as well as better battery behaviour (charging / discharging efficiencies) under cold/hot climatic conditions. These improvements would allow production volumes to increase and purchase cost to come down (Shaik Amjad, S. Neelkrishnan, R.Rudramoorthy, 2009).

Nevertheless, EV volume is increasing, and their penetration in the vehicle sector can have system-scale impacts on and interactions with electricity generation in the future (Stephen Browna, David Pyke, Paul Steenhof, 2010).

Analysis of current data suggests that by 2050 global energy demands will double due to the concept of smart cities, smart grids and sustainability in general (Calise, 2013). Concerning this increase of electricity consumption, some changes in power flows, grid losses and voltage profile patterns along the grid will be noticed (Joao A. Peças Lopes, Filipe Joel Solares and Pedro M. Rocha Almeida, 2011). For this reason, more efficient systems to deal with energy loss are needed. Smart, reliable and efficient energy without blackouts needs to be delivered, and mobility is a huge factor. More efficient and sustainable transportation is the key of any smart city (Calise, 2013). The near future needs intelligent systems, which means that electric vehicles and their charging

infrastructure will be paramount for these strategies both in short and long term (Calise, 2013).

Moreover, EV volume in the market can increase if internationally consistent standards can ensure compatibility between jurisdictions as well as EV-related infrastructure (Stephen Browna, David Pyke, Paul Steenhof, 2010). Good standardization will increase the economic efficiency of development as producers.

Traditionally, electricity distribution companies (DSOs) designed their networks according the peak of demand, but currently, with the expansion of renewables across Europe, a high level of management and monitoring tools is required due to the increased flows in electricity networks. The DSOs objective is to be more flexible, efficient and customer-centric, and these new challenges will be provided by the concept of Smart Grids and Active Distribution System Management (Eurelectric, 2009a). The concept of Smart Grids is to integrate behaviours and actions of all its users in order to manage demand in a better way, while active Distribution System Management is involved in tools that would allow DSOs to optimize investments and ensure an extension of infrastructure when it is more cost-efficient (Eurelectric, 2009a).

There is a need of standards for smart grids. Standards play an important role in technological development, and standardization is not only a tool for creating a widespread market, but also for ensuring customer convenience and encouraging innovation, productivity and economic efficiency. Smart grid standardization is an open process whose effort is to provide a smooth and cost-efficient rollout of smart electricity grids across Europe (Eurelectric, 2009b).

Currently, the European commission is involved in the development of three standardization mandates: Smart meters (M/441), e-mobility (M/468) and smart grids (M/498) (Eurelectric, 2009b). Nevertheless, a standardized charging solution across Europe has not been created yet, and customers still cannot benefit. There is a need to develop a new business model that engenders a competitive market for public and private charging points and gives more opportunities for the stakeholders in terms of service.

2.1.1. Charging opportunities in Europe

The charging infrastructure is suffering under the dilemma “chicken or the egg”. In other words: Are EVs dependent on infrastructure (availability of public stations) or are the public stations dependent on the EVs? It is a difficult question to answer.

Despite the consumers waiting to be able to charge whenever they want, they mainly prefer to charge at home (Accenture, 2011), and due to their range anxiety, the prospect of an extended network of charging stations would be an

attractive situation for them (Anna Craven, 2012). This is an issue that has been debated widely with consideration of the high capital investment involved in putting a new charging infrastructure in place—from 3000 SEK up to 350,000 SEK for fast charging stations (Svensk energi, 2010).

Considering all this information, the infrastructure facilities are likely to be underutilized due to the lack of EVs on the street and the preference of the customers to charge at home (Anna Craven, 2012) (Accenture, 2011), but it is the idea of a good charging infrastructure that holds a *symbolic value* for the consumer. It is in this latter issue that the *psychological benefit* appears, although the consumers do not necessarily actually need it.

Finding support in infrastructure development is essential, because it is an opportunity to enter the market despite the high cost of public charging points and the poor business-model proposition. It is the reality of public charging stations placed on the streets that can increase the awareness of the society as well as the familiarity with electric vehicles, avoiding in that way the already recognized "range-anxiety" (Anna Craven, 2012).

2.1.2. EV customers

Car owners (mainly Battery Electric Vehicle (BEV) owners) experience the so-called "range anxiety" (Mobashwir Khan, Klara M. Kockelman, 2012) which is a feeling of fear customers have if the car runs out of electricity. Customers want batteries with high energy-storage capacity and large electric load charging requirements (Joao A. Peças Lopes, Filipe Joel Solares and Pedro M. Rocha Almeida, 2011). A study made by Accenture (2011)[3] shows that:

- Customers want freedom over charging time: 67% of the respondents want to have control over when they charge, and the points they prefer to charge are (Figure 2)

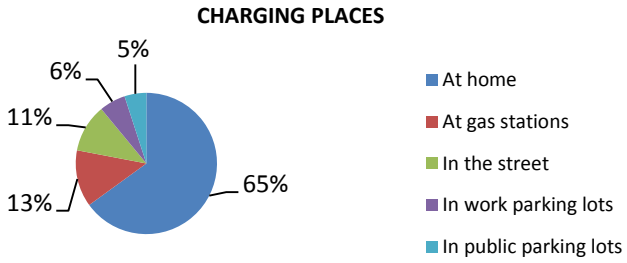


Figure 2: Charging places where customers prefer to charge (Accenture, 2011)

[3] Conducted with a survey of more than 7000 individuals in 13 countries, one of the countries is Sweden with 500 participants.

- Even though most of the respondents have knowledge about the EV (97%), more than two thirds of them still need more background about the vehicle before they can consider it for their next car purchase. In Sweden, 36% of the respondents claim to understand enough about EVs, and 64% are in favour of EVs replacing conventional cars over time. When asked if they would consider EVs as an option for their car purchase, 53% agreed, while the average of the respondents was 60%; this can be compared to 95% in China and 76% in Spain.

- Younger people are more concerned with the source of fuel than older drivers, and 45% of the respondents claim that the electric power source discourages them, at least as long as the main sources are nuclear power and fossil fuels. 33%, under average, of the Swedish respondents will want to know how the electricity to charge the vehicle is generated if they were to consider buying an EV.

In a study done by the company *Deloitte*, EV consumers can be defined as: *"environmentally conscious, tech savvy, trendsetting and politically active"* (Craig Giffi, Joe Vitale, Michelle Drew, Yuki Kuboshima, Masato Sase, 2011, p. 4).

2.2. Sweden and the Electric Vehicles

E-mobility is a challenge for technology, politics and the transportation industry. The landscape of EVs has been changed in recent years due to climate change, the increase of fuel cost and the economic crisis (Sonnenschein, 2010). All these factors do not directly affect the EV market, but they have created new national and regional investments as well as changes in customer behaviours.

Nowadays, Sweden's total population is estimated at 9.5 million, which is mainly located in the South of the country (World Population Review, 2014), and the country is involved in developing a more secure and sustainable society with an almost carbon-free electricity supply, which is mainly nuclear and water powered (since these are customer value related). Moreover, the country co-operates closely within the Nordic and Baltic electricity markets and infrastructure (International Energy Agency, 2013). In June 2006, Sweden implemented a programme called "Making Sweden an Oil Free Society" (Society, 2006) whose purpose is to reduce dependence on petroleum, natural gas and fossil fuel. The Swedish Parliament approved Sweden's energy policy in 2009, some of the objectives of which are shown in Table 1 and Table 2:

Table 1: Short- to medium-term targets for 2020. Source (International Energy Agency, 2013)

SHORT- TO MEDIUM-TERM TARGETS FOR 2020:
40% reduction in greenhouse gases (GHGs) At least 10% share of renewable energy in the transport sector 20% more efficient use of energy compared to 2008

Table 2: Long-term targets. Source (International Energy Agency, 2013)

LONG-TERM TARGETS:
By 2020: Sweden aims to phase out fossil fuels in heating. By 2030: Sweden should have a vehicle stock that is independent of fossil fuels. By 2050: the vision is that Sweden will have a sustainable and resource-efficient energy supply with zero net emissions of GHGs.

A committee has been created to present various research and proposals on how Sweden can reach the target: "*by 2030, Sweden should have a vehicle stock that is independent of fossil fuels*" (International Energy Agency, 2013). In 2011, traffic in Sweden produced approximately 145 g/km of CO_2 emissions, a value higher than the *EU-27 2011 Average* (136g/km) (The international council on clean transportation, 2013). In addition, more information from the International Energy Agency (2013) provides the insight that more than 45% of Sweden's total CO_2 emissions in 2010 came from the transport sector. For this reason, Sweden is nowadays involved in introducing more fuel flexible passenger cars as well as an increase the share of biofuels (International Energy Agency, 2013).

Even though Sweden does not subsidize the purchase of EVs, an incentive for EVs exists (Sonnenschein, 2010, p. 27). The Swedish taxation system supports the purchase of vehicles classified as environmentally friendly[4] with a tax exemption that is available during the first five years of ownership. This support has been strengthened due to the introduction of a new tax for "super environmental-friendly[5]" vehicles for the period of 2012–2015. The target is that from 2015, the CO_2 limits may not exceed 130 g CO_2[6] per km and 95 g CO_2[7] per km by 2020 (International Energy Agency, 2013).

An example of an environmental-friendly city is Malmö (Sweden). According to Malmö's website, it will be the Sweden's most climate-smart city, and in 2030 all

[4] Vehicles that can be driven entirely or partially on electricity, alcohol or gas with emissions below 120 g of CO2 per km.
[5] Vehicles that can be driven entirely or partially on electricity, alcohol or gas with emissions below 50 g of CO_2 per km.
[6] Regulation (EU) No 443/2009
[7] Regulation (EU) 510/2011

of Malmö will be supplied 100% by renewable energy (Malmö stad, a). One of the city's objectives is to advance the development of electric vehicles and contribute in their appearance in the near future, reducing CO_2 emissions. In 2009, less than 5 per cent of Swedish cars were environmentally friendly (e-on, 2009). More information about Malmö can be found in APPENDIX B.

2.2.1. Charging opportunities in Sweden

In 2010, the Swedish and Norwegian governments create a project called e-mobility NSR (North Sea region electric mobility network) (Martin Borgqvist, 2012). Many organizations and agencies are involved in this project, and its aim is to design and introduce a new charging infrastructure for electric cars. Figure 3 shows the main ideas with which the NSR project has been working since 2010. One of the highlighted aspects is the charging infrastructure project along E6 and E14 (Image 1), two important roads for both countries. The aim is to encourage Swedish and Norwegian drivers to use electrical vehicles.

With respect to charging systems that will work on both sides of the border (standardization), Sweden would have to make some changes in the law because Norway provides charging spots for free (Martin Borgqvist, 2012). The Energy Markets Inspectorate has proposed to Sweden an exception for electric grids reserved for recharging electric vehicles, but the proposal is still under discussion within the cabinet office (Martin Borgqvist, 2012, p. 10).

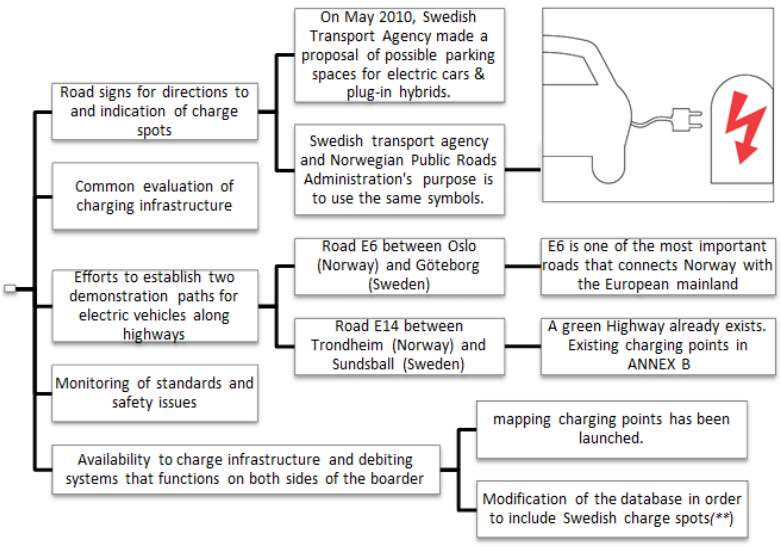


Figure 3: NSR objectives

Image 1: Location of possible demonstration roads

2.3. Volvo V60 hybrid plug-in: specifications and customer opinions

The boxes that appear throughout this section are comments from a study in which 18 V60 hybrid plug-in drivers (car owners, not company cars) were interviewed; 12 of the respondents answered qualitative questions and 6 respondents answered the quantitative ones.

Volvo V60 Hybrid plug-in is the plug-in hybrid electric vehicle from Volvo Cars Company. The car is described as "the world's first and only luxury diesel hybrid that also runs on pure electricity" (Volvo Cars Group, 2014c), and it is all-wheel drive. The front wheels are powered by a turbo diesel engine, while the rear wheels are powered by an electric motor (Image 2) (Volvo Cars Group, 2014c).

By merely pressing a button, the car can be driven in different ways: hybrid, pure and power (Image 2). While the PURE mode button allows the driver to drive in pure electricity up to 50 km with 0 emissions (gCO2/km) from the car, the HYBRID mode combines the internal combustion engine with the electric motor in order to give a balanced drive in terms of CO_2 emissions, 48 g/km (Volvo Cars Group, 2014c). Lastly, the POWER mode is characterized for changing the car into a powerful performance mode (215-hp turbo diesel engine + 70-hp electric motor) (Volvo Cars Group, 2014c). In this mode, the car can accelerate from 0 km/h to 100km/h in under 6 seconds, and the maximum speed is 230 km/h.

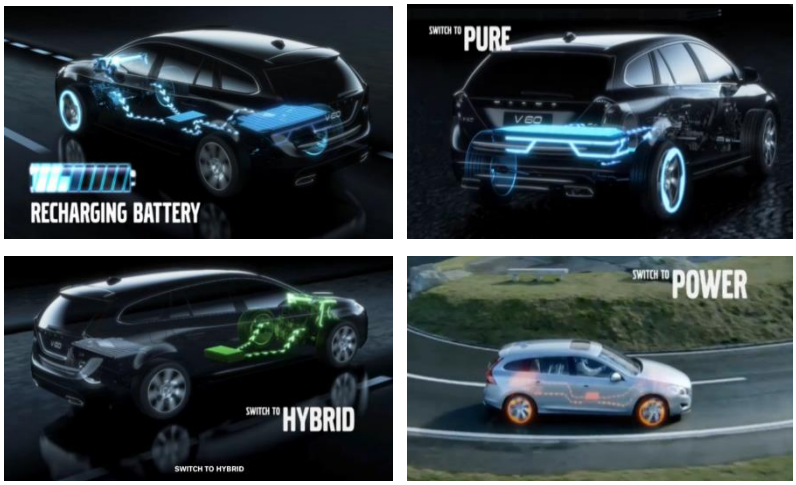


Image 2: Three driving modes (V60 hybrid plug-in)

The purchase criteria of the V60 hybrid plug-in drivers interviewed are 44% technology interest, 35% environmental interest and 21% economical interest. In the study, the car's performance and the driving modes were powerful factors for half of the respondents when they considered this car as a choice for purchase.
Source: (Ellen Angelin and Dzenita Damjanovic, 2013)

There are three types of charging connectors. The Volvo V60 hybrid plug-in supports type 2 (APPENDIX B-Image 5): the vehicle inlet is placed on the front left side and the charging connector is located in the storage compartment under the load-compartment floor hatch.

Some respondents expressed concerns with the battery capacity, about the handling of the cable and that they have to bring it along in the car. 75% of the V60 hybrid plug-in drivers interviewed would consider purchasing an extra charging cable, and one respondent expressed concern about difficulties managing the cable during wintertime. Other comments referred to the difficulty of rolling up the cable and how its assembly should be locked during charging in order to prevent theft.
Source: (Ellen Angelin and Dzenita Damjanovic, 2013)

In addition, the charging speed from discharged battery to a fully charged depends on the intensity of charging (Volvo Car Corporation, 2012):

- 16A: 4–5.5 h
- 10A: 4.5–7 h
- 6A: 7.5–10 h

Most of the respondents had concerns about having a charging opportunity at their workplace. In addition, they have difficulties in assessing their daily electricity consumption compared with their usage of fossil fuels. For that reason, 93% of the respondents would like to have the electrical consumption from charging the car specified on the electricity bill.
Source: (Ellen Angelin and Dzenita Damjanovic, 2013)

Lastly, it is possible to precondition the car when it is hot/cold outside. There are different ways to do it: in the car menu, via remote control and by mobile. It is possible to precondition the car while it is connected to the mains or while it is not. When parking indoors, the electrically-driven heater is activated. When parking outside, the fuel-driven heater is also permitted. Parking outside is configured in the car as a default (Volvo Car Corporation, 2012).

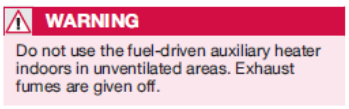


Image 3: Volvo's warning while preconditioning. Source: (Volvo Car Corporation, 2012)

In this study, one of the respondents mentions that the driver physically has to change the settings in the car if he wants to precondition it by the mobile application called "Volvo on call".
Source: (Ellen Angelin and Dzenita Damjanovic, 2013)

2.4. Volvo Cars Company challenges

Customers show interest in EV due to it is being a cleaner, more environmentally respectful car with a higher efficiency than internal-combustion-driven vehicles (Craig Giffi, Joe Vitale, Michelle Drew, Yuki Kuboshima, Masato Sase, 2011). These perceptions of EV are nonetheless not strong enough for them if the EV car does not meet their needs. Government incentives, the cost of charging the battery, charging time and fuel efficiency are aspects that play an important role in the car's value (Craig Giffi, Joe Vitale, Michelle Drew, Yuki Kuboshima, Masato Sase, 2011).

Customer expectations of EV are far from the car characteristics that electric vehicles can deliver at present (Craig Giffi, Joe Vitale, Michelle Drew, Yuki Kuboshima, Masato Sase, 2011). It is in the gap between these customer expectations and the actual EV situation where the designers have to work with special interests in order to diminish it.

Figure 4 represents aspects that play an important role in the design of V60 plug-in hybrid in terms of customer expectations. The contents of the green lines represent the main characteristics directly related with Volvo Cars Company, the red related with Vattenfall and, the blue, external factors that have a relevant impact on the purchase of EVs.

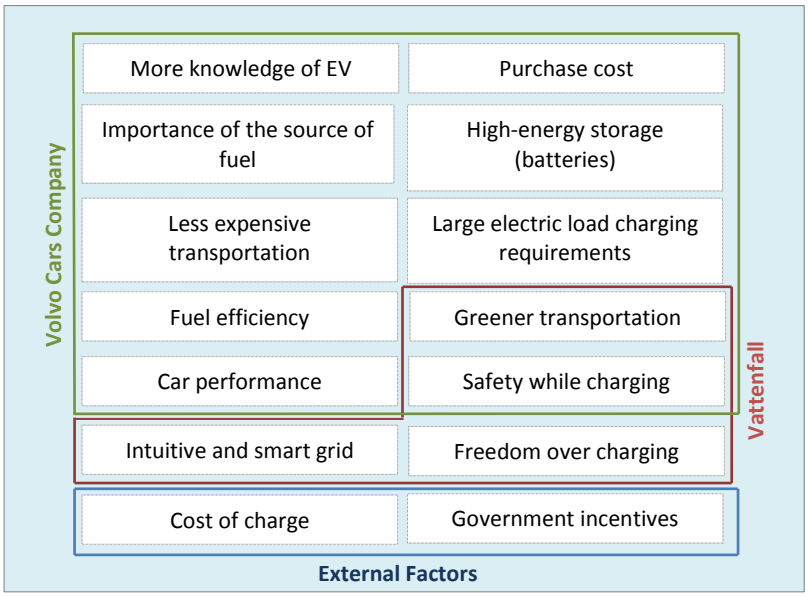


Figure 4: General customer requirements, EV

Environmental challenges

The low noise emissions, the zero pollutant emissions in electric driving mode as well as the possibility to reduce oil dependency are some of the advantages/strengths of a hybrid plug-in car. A less expensive and greener transportation alternative with all the performance qualities of a traditional car is the main customer preference and the most complicated to achieve (Craig Giffi, Joe Vitale, Michelle Drew, Yuki Kuboshima, Masato Sase, 2011). Cost and performance are the main issues that plug-in cars struggle with. Although a plug-in hybrid vehicle is more expensive than conventional cars (high battery cost), electricity cost is lower than fuel cost (Shaik Amjad, S. Neelkrishnan, R.Rudramoorthy, 2009), and batteries and motor require less maintenance over the life of the vehicle.

Charging infrastructure challenge

The use of electricity in electric vehicles requires consideration not only of the technology but also other issues such as safety, health considerations, overall infrastructure costs, fuel cost and acceptance by the public (Shaik Amjad, S.

Neelkrishnan, R.Rudramoorthy, 2009, p. 1109). Customers want intuitive and smart grid technologies as well as fast battery recharge and safety while charging (Stephen Browna, David Pyke, Paul Steenhof, 2010). In terms of charging opportunities, not only are private homes important but also a strategic infrastructure in public spaces. Fast charging stations, which reduce the time of charging but also decrease the battery lifetime, are also important with regard to charging time, even though in Volvo V60 hybrid this charging mode is still not available. The amounts of charging and self-discharging losses are one of the main worries not only for the manufacturers, but also for consumers and potential customers. When the loss rates are high, the overall efficiency of electric vehicles drops (Florian Hacker, Ralph Harthan, Felix Matthes, Wiebke Zimmer, 2009).

Battery challenge

Plug-in hybrid batteries have a range of 20 to 100 km, and although this range may seem short, a range of 50 km actually covers a full 80% of all car transports in Sweden (e-on, 2009). Range anxiety, therefore, is the primary reason to choose a PHEV over an EV, and the Accenture study proves that with respondents considering any form of EV for their next purchase if the vehicle range is more than 400 km, although the average consumer drives no more than 60 kilometres per day (Accenture, 2011, p. 20). In addition, the major drawback of plug-in hybrid cars is the purchase cost (Florian Hacker, Ralph Harthan, Felix Matthes, Wiebke Zimmer, 2009), and it is the expensive onboard energy storage (battery) what represents the major part of the car cost.

Progress in battery technology is required, and it is necessary to find a way to compete with conventional vehicles in order to achieve a relevant market share in terms of driving range and performance as well as with relevant production volumes (Florian Hacker, Ralph Harthan, Felix Matthes, Wiebke Zimmer, 2009).

Design challenge

The market for hybrid cars is demanding. With regard to battery and climate comfort, customers want cars with high electric range as well as high fuel efficiency, although fuel price has a significant impact on the cost of driving conventional ICE cars; a higher gas/petrol price results in a higher interest in EVs (Craig Giffi, Joe Vitale, Michelle Drew, Yuki Kuboshima, Masato Sase, 2011). An increase in electric mileage implies higher battery capacity and therefore longer charging time. Otherwise, good climate comfort implies reduced electric mileage (Figure 5). In other words, prioritizing some of these features involves decreasing the quality of the others.

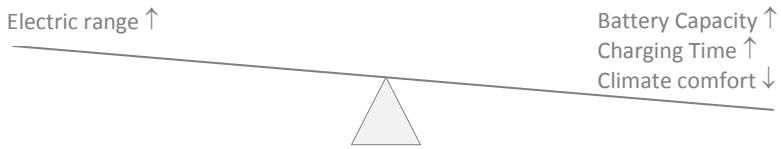


Figure 5: Balancing between Climate Comfort and Electric Range

Preconditioning the car while it is connected to the mains can be a useful tool in order to keep a good climate in the cabin and maintain the electric range. The question is how aware the customer is about this balanced situation as well as how best to optimize the electric range. Identifying the real customer needs is not an easy task. Nevertheless, it can be done using tools such as surveys and logging of data from a product in use, and manufacturers can then include customer needs in future product configurations (Dr. Ove Isaksson and Anna Karlsson, 2010b).

3. METHOD

This chapter explains the methodology used to carry out this project and the parts in which the DMA method is involved in this study. First, the reader can find a diagram of the whole process and a general explanation of the method. Then, each step of the DMA involved in this study as well as the procedure is explained in more detail. The entire survey is in APPENDIX D.

3.1. DMA method

Design for mode of application (DMA), is a method whose purpose is to translate customer needs into product characteristics (Figure 6). The method is based on (Dr. Ove Isaksson and Anna Karlsson, 2010a):

- Logging data from customer products: to verify and quantify how well established design requirements are satisfied.
- Customer survey: to understand the customer's preferences, feelings and behaviours.
- Integrating survey and data logging: to verify if target setting and balancing of design requirements are correct.

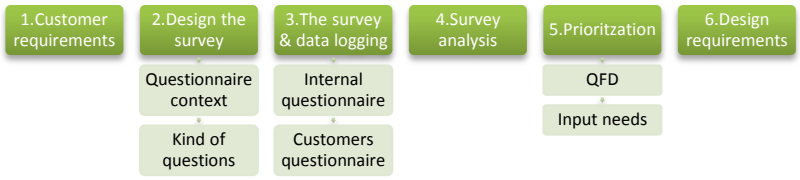


Figure 6: Main steps into the DMA method

The method is a means to understand the V60 hybrid plug-in customers and in turn improve the product development of the car. For this reason, good results in the DMA method will be obtained only with a good comprehensive customer study, as illustrated in Figure 7. The survey (customer questionnaire) together with data logging, which works in parallel with the survey, will contribute to building a preliminary customer profile.

Logged data from the customer product, together with the customer survey, are integrated in the Quality Function Deployment, QFD. The QFD is a methodology that systematically identifies customer demands on product features and design parameters. After that, these demands are translated into product characteristics for incorporation into the manufacturing process (Bergman, Bo and Klefsjö, Bengy, 2010, p. 124). The data are used to weight elements in the QFD relationship matrix (Dr. Ove Isaksson and Anna Karlsson, 2010b).

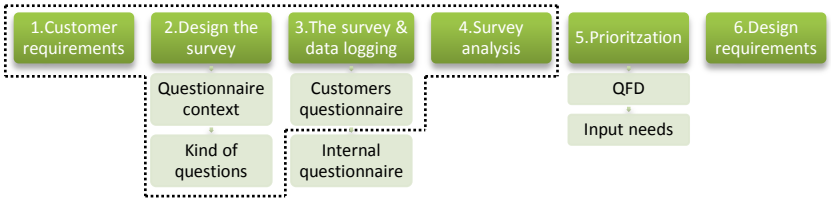
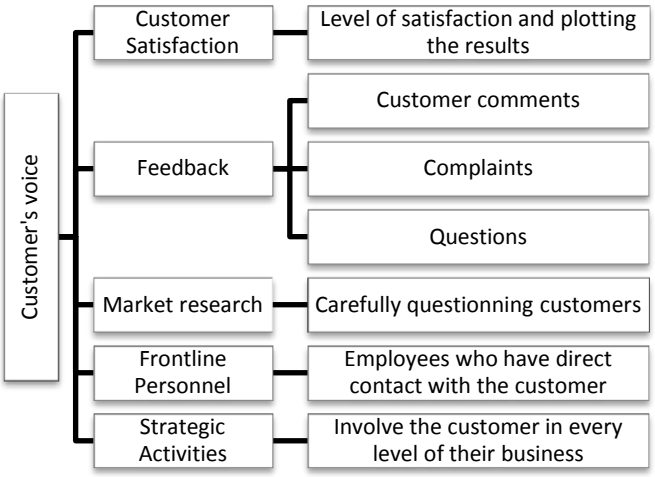


Figure 7: Steps on the DMA that encompass the study

3.1.1. Customer requirements

This step is the basis for identifying the customer's voice. According to an article from Oxford University called "Why satisfied Customer's Defect, 1995", there are five major categories of approaches that companies can use to listen to their customers, which are illustrated in Table 3. In this research, the customer's voice is the result of combining the information from the preliminary steps of the DMA (data logging and the survey).

Table 3: Customer's voice
Source: (Thomas O.Jones and W. Earl Sasser, Jr, 1995)



Dealer visits and customer surveys are the basis for understanding customer requirements. On one hand, the dealer visits give information about how the customers feel about the product, and this information may be an input in terms of customer issues, missing features and positive feedback. Hence, all of this information contributes in building knowledge of the real customer expectations. On the other hand, the customer survey is developed within cross-functional teamwork where the most critical questions are identified. The cross-functional

teamwork defines what the customer's attributes/requirements are, and this is very important, because different goals can be encountered in the same group, and achieving cohesiveness in a group contributes to good survey development (Keller, Robert T, 2001). Figure 8 illustrates which departments should participate in the cross-functional teamwork.

Figure 8: Cross-functional Teamwork

In the beginning of the project, a workshop with the different departments was organized. The aim was to identify the most critical questions by discussing the relevant quality dimensions from a customer's point of view. These quality dimensions are Durability, Reliability, Performance, Maintainability, Environmental friendliness, Appearance, Flawlessness and Safety (Bergman, Bo and Klefsjö, Bengy, 2010, pp. 20-21).

During the workshop, people from Vattenfall also participated, and the aim was to understand in what parts of the car they were collaborating and in what issues they would be more interested in in the survey.

After identifying the main customer attributes, a table was created in order to develop the customer needs in more detail. This table was divided into three columns, Primary, Secondary and Tertiary, and each column corresponded to a higher level of detail.

3.1.2. Design the survey

Survey is the methodology that determines which influence the components of products have on customer satisfaction (Elmar Sauerwein, Franz Bailom, Kurt Matzler and Hans H. Hinterhuber, 1996, p. 313). It is necessary to find those questions that clarify:

- Customer expectations of the product
- Customer prioritization concerning different characteristics
- Customer opinions
- Possible complaints

The questionnaire has to be appropriate, intelligible, unambiguous, unbiased, capable of coping with all possible responses, satisfactory, coded, piloted and

ethical (D.H.Stone, 1999). The questionnaire should contain qualitative, quantitative, closed as well as open questions that reflect opinions, beliefs or judgments. Behaviour, knowledge and attitudes need to be reflected in this survey.

Behaviour is concerned with time, duration or frequency. For that reason, it is necessary to find the time periods that meet the survey's needs and that make sense to the respondent (Fink, 2003, p. 71). Questions concerning very short periods of time or too long periods can affect the validity of answers about behaviour. Another important consideration is the use of lists in the answers. This may result in a loss of information due to the survey encouraging respondents to use only the categories named in the lists (Fink, 2003, p. 74). This problem can be solved by adding an "other" category to the list. This entails the presence of open-ended questions and a need to be prepared to interpret and catalogue these answers.

Customer knowledge about some characteristics is also an important consideration, the discovery of possible gaps in customer knowledge that can give rise to some attitudes or behaviour. Questions seeking to elicit customer knowledge should sometimes be disguised so as to reduce their threating appearance (Fink, 2003, p. 78). Knowledge questions can provide an "I don't know" category that gives people who might otherwise just guess a place to put their responses. However, sometimes respondents who are just lazy or who do not want to think about the question will use the "I don't know" option even when they might be able to come up with the correct answer (the "non-attitude" problem) (Glynis M Breakwell, Sean Hammond, Chris Fie-Schaw, Jonathan A. Smith, 2013) (Fink, 2003, p. 79).

Attitude is way of thinking and can be often used interchangeably with the terms opinion, belief, reference, feeling and value. Attitudes are very complex entities, difficult to define and measure (data-logging role). They are compared with knowledge and behaviour.

As shown in Figure 10, the questions are divided into three different groups. The questionnaire is mainly focused on *Question type 2* and *Question type 3.* In this project stage, some of the questions designed are avoided because they can be measured (more objective data in the analysis). The entire survey is in APPENDIX D.

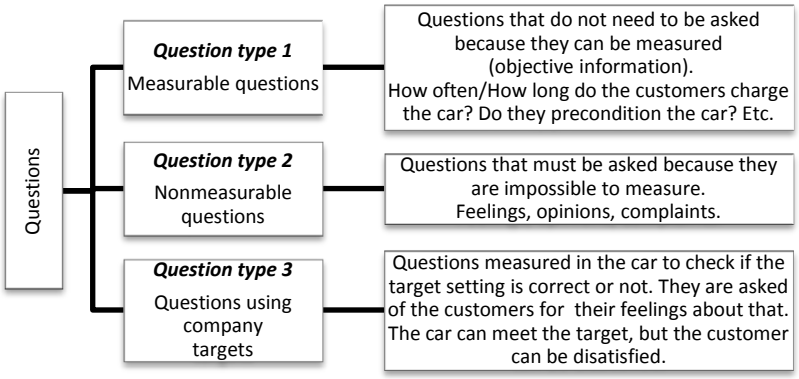


Figure 10: Type of questions identified in the project

Question type 1: Measurable questions
A questionnaire has to be sufficiently brief and as concise as possible while covering the subjects determined by the goals and objectives of the survey. For this reason, the questionnaire did not encompass those questions that can be measured in the car, providing more objective data and reducing the questionnaire's length.

When the survey becomes too long, the response rate and quality of answers goes down significantly. Mail-out questionnaires should not take more than 30 minutes to answer and ideally take about 15 minutes. (Yang, december 2007, p. 147)

Question type 2: Nonmeasurable questions
Questions that are mainly used to discover the customer's feeling about a feature, situation or characteristic of the car; these questions are impossible to measure in the car.

Questions type 3: Questions using company targets
This group combines information from the survey and data logging together. It is important to know if the car meets a specific target, but also to know the customer's opinion about that feature.

These questions give information on manner of use and an idea about what the company should focus on, creating inputs to "needs process" and investing less time and money in features that the customer really does not use, although he/she values their existence. In addition, this justifies why this data logging (use of the product) is to be compared with the design requirements—how customers

use the product does not always correspond to the way in which the designer originally intended (Dr. Ove Isaksson and Anna Karlsson, 2010b).

3.1.3. The Survey

The questionnaire was sent in a link via email to only 15 car owners. The reason for this small number of respondents is that before sending it to a wide range of customers, it is necessary to be sure that the information received from the questionnaire is relevant and that the questions are understandable.

This first pretest is a means to get a preliminary idea of customers' satisfaction in different situations, customers' opinions and possible complaints. All this information will contribute to defining a preliminary customer picture. It allows some questions to be rewritten or removed in case of misunderstandings or nonuseful information.

The research does not encompass this next step in the process, but it is important to understand the whole DMA method. Once the final questionnaire is done, it is answered by two different groups. The first group is represented by a larger number of V60 hybrid plug-in customers (customer questionnaire); their answers give the company a picture of the customer. The second group is represented by both companies, VCC and Vattenfall (internal questionnaire); their answers show what the internal customer picture is.

The main point is to compare the answers of the two groups and check where the differences are. This comparison is very important for both companies because big differences indicate that they do not accurately know, understand or appreciate what the customer expects from the product. In situations where the company is thinking differently or there is a big gap between the company and the customers, it is necessary to go deeper in the internal questionnaire. In this case, the questions must be answered by different company departments and then a comparison made between them. The aim of this comparison is to identify where the differences, the lack of communication or the possible shortcomings of the company are that result in poor customer satisfaction. This information introduces new insights into the companies and anchors to them a correct picture of the customer.

3.1.4. Survey analysis

Analysis of the results of a customer survey and discussion how conclusions can be drawn is an essential step (Elmar Sauerwein, Franz Bailom, Kurt Matzler and Hans H. Hinterhuber, 1996, p. 313). The survey analysis is a means to understand what parts of the survey it is necessary to focus on and to get a preliminary idea of what the customer requirements on the V60 hybrid plug-in are. The information will be useful to contribute new inputs in the updated version of the questionnaire.

To carry out the analysis, the questionnaire's answers have been divided into different groups (Figure 11). Individual analysis encompasses the group of questions that need to be analysed individually because they only involve the V60 Hybrid Plug-in. The group analysis encompasses those parts of the survey that can be compared with other Volvo Cars surveys (same question formulation), specifically model A and model B previous questionnaires.

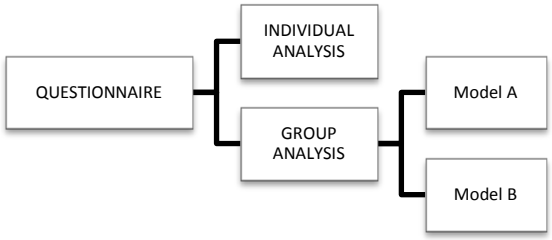


Figure 11: Questionnaire analysis

MATLAB 2013b (script used in Figure 12) was used to analyse the data on various Volvo car groups.

```
a=importdata('data.xlsx');
figure (1)
[p,t,st]=anova1(a.data.sheet1(:,8),a.textdata.sheet1(:,3),'of
f');
[c,m,h,nms]=multcompare(st,'display','on');
title('…')
```

Figure 12: Script used in MATLAB to plot the results.

The first function that appears in the script is **[p,t,st] = anova1(...)**. ANOVA1[8] performs a one-way analysis of variance, and the function evaluates the hypothesis that all the samples have the same mean against the alternative that they are different (MATLAB, 2014a):

$$\begin{cases} H_o: \mu_1 = \mu_2 = \mu_3 \\ H_1: \mu_1 \neq \mu_2 = \mu_3 \;||\; \mu_1 = \mu_2 \neq \mu_3 \;||\; \mu_1 \neq \mu_2 = \mu_3 \end{cases}$$

ANOVA compares the variation between groups with the variation within groups in order to calculate the F-ratio and then the p-value. If $p<0.05$, at least one group mean is significantly different from the others, but the problem is that if Ho is false, it is impossible to know which of the specific groups differed. To find this out, the Multiple Comparisons Test is used. It is a test that determines which estimates are significantly different. **Multi Comparison of Group Means**

[8] It is possible to use ANOVA because there are at least three groups: V60 PHEV, model A, model B. Sometimes an extra one is included under the name: Annan Volvo. In case only two groups need to be compared, t-test must be used.

[c,m,h,nms] = multcompare(...).This function returns a graph with the estimates of each group with comparison intervals around them. Two groups are considered significantly different if their intervals disjoint and not significantly different if their intervals overlap (MATLAB, 2014 b).

4. RESULTS AND ANALYSIS

This chapter contains the result from the method and the survey. At the end of the chapter, the reader can find a section that sums up the most important information from the survey analysis.

4.1. Customer requirements

The cross-functional teamwork of this project is formed by people from different Volvo departments as well as Vattenfall. This cross-functional teamwork is a means to define the customer attributes/requirements of the Volvo V60 hybrid plug-in.

When the cross-functional teamwork was defined, a workshop was organized. The first part of the workshop was based on explaining the aim of the DMA method and the method's contribution in VCC. The other part of the workshop was focused on identifying the most important customer quality dimensions. After the workshop, the main customer attributes were identified and summarized in a table. Then this table (APPENDIX C- Table 11) was developed to a higher level of detail to facilitate identification of future questions. The information discussed in the workshop was:

Battery development group:

Customer opinion about charging time and public charging stations was one of the main issues in the discussion. They commented that a significant number of V60 hybrid plug-ins are sold in Holland due to the tax benefits.

Other important points in the discussion were: Customer awareness about the electric range and the charging time, as well as customer knowledge about the strong relation between climate and range. Special battery arrangements in extreme temperatures encompassed an important part of the discussion as well; *"if the battery temperature is -30ºC, there is no problem only if the car is used quite often".*

The last issues discussed by this group were more related to the data-logging part:

- Knowledge about how often the customers charge the battery
- Does the customer tend to charge the battery at every opportunity, regardless of charge remaining, or only during extended stops? (Volvo behaviour)
- Identify how the customers drive (speed, acceleration, distance)

Climate group:

The climate group's interest focused on knowing the interaction between the customer and the software. Other important issues discussed were the role of the car manual in the customers' daily life and how much the customer understands about the car.

Concerning preconditioning, the group was interested in knowing how the drivers normally start preconditioning and how satisfied they were with the mobile app. The last part of the discussion concerned new car features, especially two:

- To warm up the steering wheel while preconditioning.
- Allow the customer to preset the option of de-icing the windows while preconditioning. If the car is parked outside, but it is under a porch during preconditioning, the car may activate the de-icing option and therefore use more electricity/fuel than it really needs. This feature generated some discussions about safe driving.

Balancing V60 Hybrid plug-in group:

Customer preferences concerning climate comfort and electric range were considered the most important for this group.

In addition, the group focused discussion on finding a pedagogical way to show to the customer how much range is lost depending on the climate option they select on the car menu ("MYCAR"). Moreover, during the discussion the balancing group proposed to split up the V60 hybrid plug-in drivers into two groups, one group that represents customers interested in more detailed information about how much electricity is lost depending on the car settings and another group encompassing customers that are satisfied with the actual information and could be annoyed by additional information.

Another important aspect of the discussion was: Is a new mode needed in the car? This question was formulated because during pure mode, the climate comfort in the cabin is closed.

The last relevant comment in the discussion was about the exhaust pipe of the heater, which is placed in the front wheel. The problem is that this pipe can eject smoke during the pure mode driving. So, the balancing group was interested to know the customer feeling if they experienced the situation.

Vattenfall

Customer behavior, habits while charging and how often they charge are the main issues for Vattenfall. Moreover, together with VCC, it is interested in

identifying a customer driving pattern (further work) by using the information from survey and data logging. This driving pattern will help in the design of a strategic network of charging stations and, at the same time, help to improve the EV market in Sweden. Both companies want to create this driving pattern with specific variables and in a general way. The reason is that this model should be able to work in other regions, and therefore there is a need to compare different markets and study the viability of putting a new charging network into place.

4.2. Designing the survey and the survey

Once the customer attributes were identified, the survey context (Table 4) was defined. It is important to define the survey context before designing the questionnaire in order to focus the questions on important issues for the company and within the boundaries of the project (electric driving and climate comfort). Before sending the survey via email, there was another workshop in Vattenfall aimed at showing the questions already designed as well as some data-logging recommendations. In the last part of the workshop, actual drivers of the V60 hybrid plug-in participated in the discussion, and some of their comments were used to design the questions. The drivers who participated in the workshop are the ones who later received the questionnaire via email and whose cars are going to be measured (data logging) during one year.

When the questions where designed, they were sent to Volvo Cars Company and Vattenfall to check if they were in agreement or they would like any changes to be made. The questionnaire is in APPENDIX D

Table 4: Survey information

PURPOSE
Create a preliminary customer picture of the V60 hybrid plug-in concerning the battery and the climate comfort. The aim is to understand: - Customer opinion about different car features (mainly climate settings and preconditioning) - Interaction between the customer and the menu system (MYCAR) - Customer prioritizations in terms of electric mileage, climate comfort and charging time. - Identify possible hidden customer needs - Customer opinion concerning charging stations (fast charging & inductive charging) - Customer complaints about charging procedure, charging stations, preconditioning, ***etc***.
RESPONDENTS
9 of 15 V60 hybrid plug-in owners from *Vattenfall* that received the car in March 2014
SURVEYOR
Mailed questionnaire (via link). Number of questions: 33
RESPONSES
Open and Closed questions. These last can be answered by ratings, rankings and single answers.

TIMING
The questionnaire is designed in a way that the respondent could do it in a maximum of 30 minutes, not more.
RESOURCES
Questions in English. The updated version needs translation into Swedish, at least.
PRIVACY
All responses will be anonymous. Only the car identification number is given in order to measure data from these cars (survey and data logging: processes in parallel). The results of the survey will be confidential for Volvo Cars Company.

4.3. Survey analysis

The sample of customers surveyed varies depending on each car group. Therefore, the V60 Hybrid plug-in sample corresponds to 9 out of 15 respondents (pilot survey) while model A sample is 373 respondents and model B sample is 251 respondents. In some graphics the categorization “Annan Volvo” also appears, which means “Other Volvo” and represents the group of surveyed people who were not owners of the model A or model B but drive other Volvo models.

4.3.1. User Information

This section covers general customer information such as age, gender and region where they drive. Comparing both groups it is possible to see the dominant age is 50–59 in V60 PHEV drivers (Figure 13), being similar in the model A and model B driver groups in which most of drivers are from 50–59 and 60–69 respectively (APPENDIX E-Figure 35).

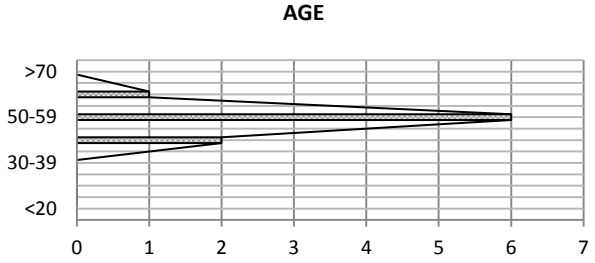


Figure 13: V60 Hybrid plug-in driver's range

77.8% of the respondents are male and 22.2% female [*question 1.3*], and 100% of the respondents drive the car in Stockholm [*question 1.4*], but two respondents also drive it in Uppsala. The other Volvo Car Groups, model A and model B, are driven in different areas (APPENDIX E-Figure 36 & Figure 37), but the top three are:

Table 5: Top three provinces where model A and model B are located

model A (373 respondents)	*Stockholm(18%), Västra Götaland (17%) and Skåne (11%)*
Model B (251 respondents)	*Skåne (18%), Västmanland (17%) and Norrbotten (11%)*

Most of the respondents have cars in their households (66.7%) [q*uestion 1.5*]. Three of them have other Volvo models: two respondents the Volvo V70 and one respondent the Volvo V70 ethanol. The other respondents have cars such as: Mazda RX5, Golf, and BMW X 5. This information is relevant because their level of satisfaction/dissatisfaction has a link with the other car/s that they have in their household. If the V60 hybrid plug-in has at least the same feature quality than their other car, they will feel satisfied; when the quality of the feature is better than in the other car they have in the household, they will be more satisfied.

4.3.2. Customer preferences

Surprisingly, slightly more than half of the respondents (56%) consider the car to live up their expectations in terms of driving distance [*question 2.1*], while the 44% who answered no were concerned that the car does not get closer to 50 km/day without recharging. Especially, one respondent answered: "*I don't think I ever got further than 42 km in actual driving, even though I really try to drive smoothly*" [*question 2.2*].

About the introduction of the hybrid car, the answers vary (Figure 14). Some of the customers consider the introduction was good (punctuation between 9 and 10), but some of them, three in particular, consider the introduction poor (between 2 and 4) [*question 2.3*]. In the updated version, this question should be carefully modified to better understand the reasons for a "poor" car introduction. Better car introduction contributes to better knowledge. Better car knowledge contributes to better customer satisfaction.

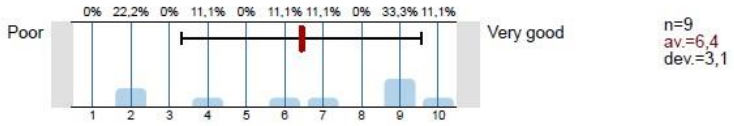


Figure 14: Customer opinion of the introduction of the V60 PHEV

Additionally, when they have to choose the importance for them of *Electric range, climate comfort inside the cabin, charging time* and *Preconditioning of the car* [*question 2.4–2.7*], the most important for most of the customers (9 out of 10 respondents) is the Electric range. Their second prioritization is the climate

comfort inside the cabin followed by charging time followed by preconditioning of the car (Figure 15). About charging time, most of the respondents answered as an acceptable charging time 1hour or between 1 and 2 hours, while one respondent answered half an hour [*question 4.9*]. In addition, this respondent is the one who answered in question 3.10: "*I am not satisfied with not being able to fast charge the V60"*, which justifies these low acceptable charging times. In contrast, one customer answered as an acceptable charging time 4 hours [*question 4.9*].

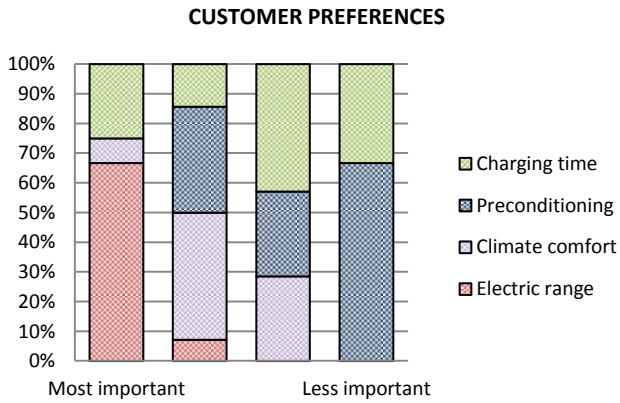


Figure 15: Customer preferences

Probably, most of the customers have chosen the "*Electric range*" as their first preference because the greater the electric range, the less expensive the driving. A reason that justifies why preconditioning is in the last position is that the survey is answered from people from the same area (Stockholm) where the climate conditions are not extreme and preconditioning is not that necessary. Probably in other regions where the climate plays a more important role, preconditioning would be more important for the V60 hybrid plug-in drivers.

The last two questions of this section have special interest for Vattenfall and Volvo Cars Company. The aim is to know what the customer would find more attractive to be included in the deal (concerning money) [*question 2.8–2.11*], and what would provide the most added value to the car [*question 2.12–2.17*]).

The results from the first question show that drivers would like included in the deal: inductive charging at home (Wireless charging) as a first option and a free charging box for home as a second one (Figure 16).

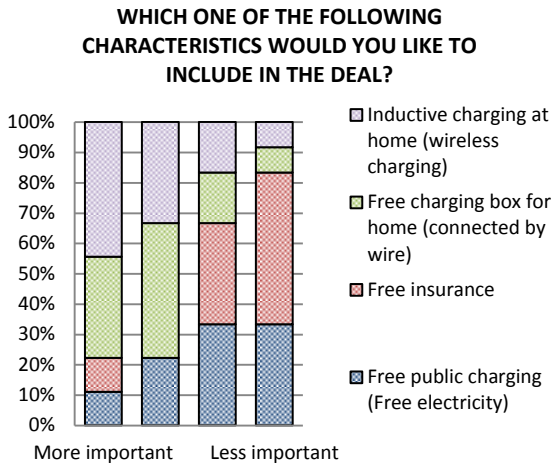


Figure 16: Which one of the following characteristics would you like to include in the deal?

From the second question, the three alternatives that would provide more added value to the car are: Reserved parking spot with possibility to charge the car, more charging stations and the possibility to drive in the bus lane (Figure 17). Feedback on electrical usage is the last one, but when it is asked what information they would like to see concerning the battery [*question 4.8*], 45% of the respondents are interested to know *"Electric range (km) still able to drive depending on the drive speed"* (Figure 18).

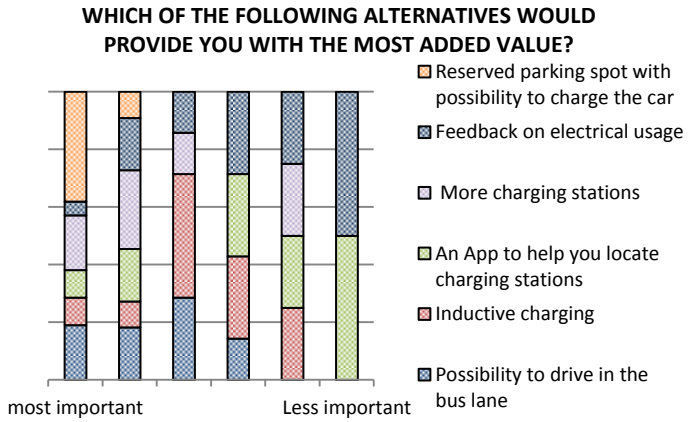


Figure 17: Alternatives that will provide more added value to the car – Customer preferences

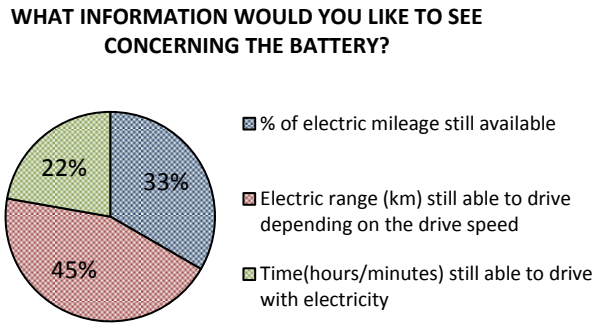


Figure 18: What information would you like to see concerning the battery?

4.3.3. Customers' way of driving

The aim is to understand for what purposes the customers use their cars [*question 3.1–3.6*]. The issue is that if it is possible to know for what they use their cars daily or usually, together with data logging it is possible to discover the real electric range they actually need. The combination of both parts (Survey and data logging) would also contribute to check if they really need charging spots on their way to work, home, shopping, *etc*.

Figure 19 shows how often the V60H customers drive their cars to different places (model A and model B in APPENDIX E-Figure 38&Figure 39). The comparison between car groups shows that, even though V60 PHEV is a small sample, the three Volvo car groups use their cars with similarly (Table 6).

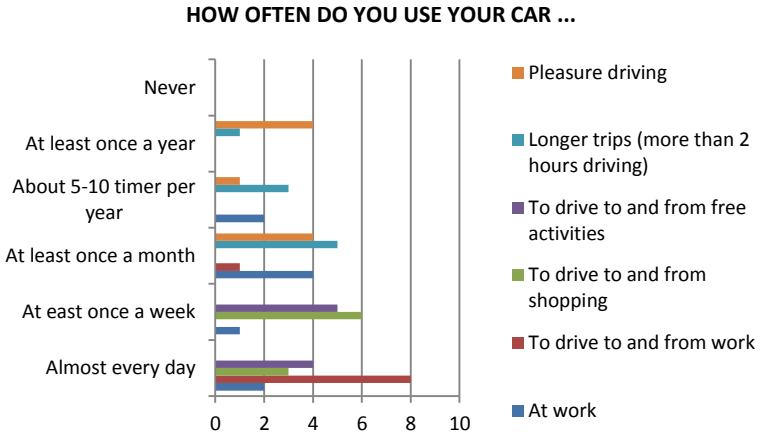


Figure 19: How often do the V60 PHEV drivers drive to . . .

Table 6: Comparison between different Volvo car groups.

	V60 PHEV	Model A	Model B
For work	$\geq 1 time/month$	never	never
To and from work	Almost every day	Almost every day	Almost every day
To and from shopping	$\geq 1 time/week$	$\geq 1 time/week$	$\geq 1 time/week$
To and from free activities	$\geq 1 time/week$	$\geq 1 time/week$	$\geq 1 time/week$
For longer trips	5–10 times/year $\geq 1 time/month$	5–10 times/year	5–10 times/year
For pleasure driving	≥ 1time/year $\geq 1 time/month$	$\geq 1 time/week$	$\geq 1 time/week$

4.3.4. Battery charging

The V60H customers surveyed answered that they charge the battery of their car at home and at work almost every day [*question 3.7-3.10*]. Moreover, Figure 20 shows that the respondents charge more at work than at home. This is because the V60H group is from Vattenfall, and the company provides the charging spot at the workplace. The issue here is that in public stations, they only charge between 5–10 times per year. In addition, customers are very dissatisfied with the availability of charging stations [*question 4.1*] (APPENDIX E-Figure 40), and one respondent commented [*question 4.7*]: *"it is annoying to bring the Volvo cable everywhere. Most stations do not have any cable, but a female contact".*

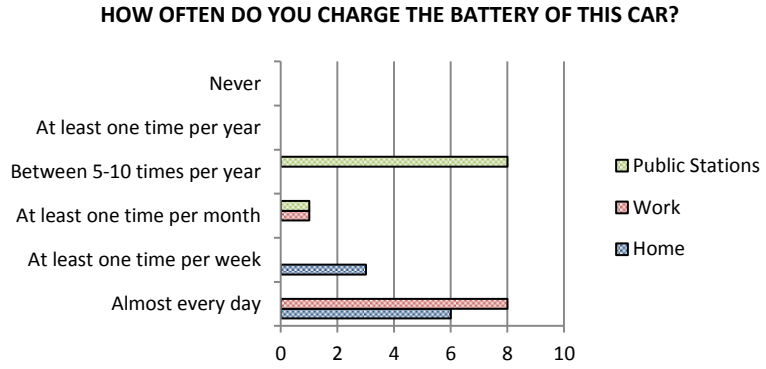


Figure 20: Places where the drivers charge the car

For most of the respondents, the equipment typically used to charge the battery [*question 4.2-4.4*] is Volvo's cable. The charging box (attached cable) is also used, but it is in the second position (graphic in APPENDIX E-Figure 41). 78% of the respondents are satisfied with the charging procedure [*question 4.5*], but there are some concerns about the charging cable. They would like to see an improvement of "the *handling of the cable*" and "*Fitting of the connector in the charging point of use*" (APPENDIX E-Figure 42).

4.3.5. Preconditioning

Car preconditioning is considered an easy task for the customer [*question 5.1*] with an average of 7.6 out of 10, even though some customers ranked it with low values (Figure 21) but never less than 5.

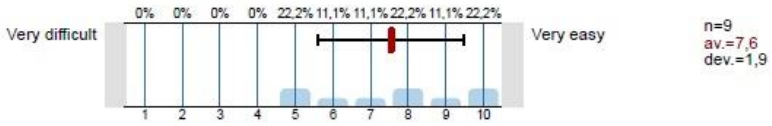


Figure 21: How easy is to configure the car preconditioning?

In addition, they usually start the car preconditioning [*question 5.2-5.5*] via mobile while remote control is hardly used (Figure 22). If these values are compared with the other Volvo car groups (Figure 23), it is possible to see that they also eschew the remote control, but they usually start the preconditioning by Information display.

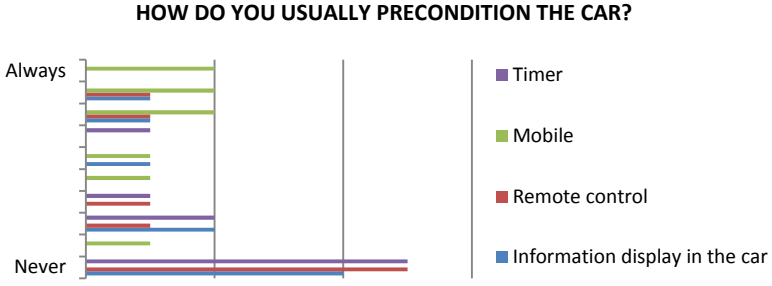


Figure 22: Frequency with which V60PHEV drivers use the various options to precondition the car

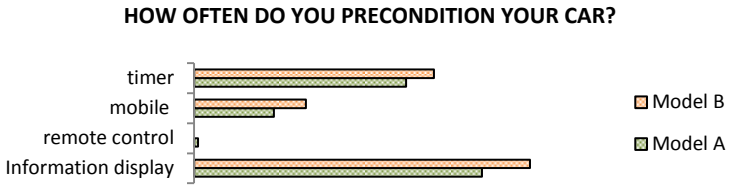


Figure 23: Frequency with which Model A/Model B drivers use the various options to precondition the car

4.3.6. Climate comfort

V60 PHEV drivers represent the group that performs more climate settings [*question 6.1*], and according to the graphic in APPENDIX E (Figure 43), there is a significant difference between groups. In order to know if the customers of

Stockholm behave differently or not, the analysis is done again focusing only on the drivers who use the car in Stockholm. In this case the difference is even bigger, with the V60 hybrid plug-in the group making more climate settings in the menu system (MYCAR) (Figure 24).

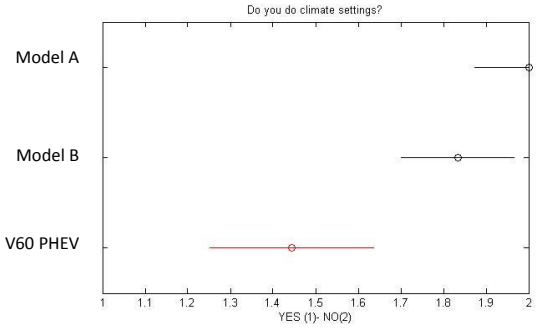


Figure 24: Climate settings – Stockholm
(V60 PHEV, Model A and Model B)

V60 PHEV drivers are the ones who find the climate system more difficult to configure [*question 6.2*], even though in this case there are no significant differences between Volvo car groups (Figure 25).

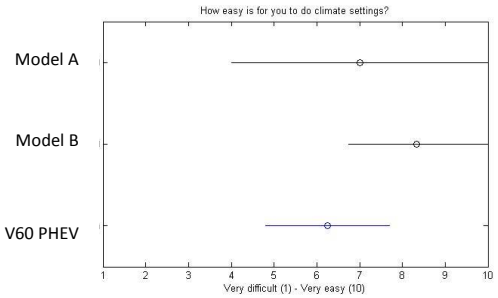


Figure 25: How easy it is to configure the climate settings – Stockholm
(V60 PHEV, model A and model B)

V60 hybrid plug-in drivers are satisfied with the time required to reach the desired climate comfort in the car when it is hot/cold outside [*question 6.3–6.4*] (APPENDIX E-Figure 45&Figure 46).

V60 PHEV drivers feel satisfied with the temperature inside the cabin after preheating/precooling the car [*question 5.6–5.7*] (APPENDIX E-Figure 47).

The drivers are also satisfied with the climate system's ability to keep the windows free from mist (APPENDIX E-Figure 48) and ice (Figure 26) during driving as well as after preconditioning (in APPENDIX E-Figure 49) [*question 5.8–5.9 and question 6.5–6.6*].

About the question concerning the system's ability to keep the windows free from ice while driving, Volvo V60 hybrid plug-in drivers' satisfaction is higher than in other groups (Figure 26). For this reason, the same comparison is made focusing only on Stockholm. The conclusions are the same, but in this case, there is a significant difference between model A and model B drivers who drive their cars in Stockholm (Figure 27).

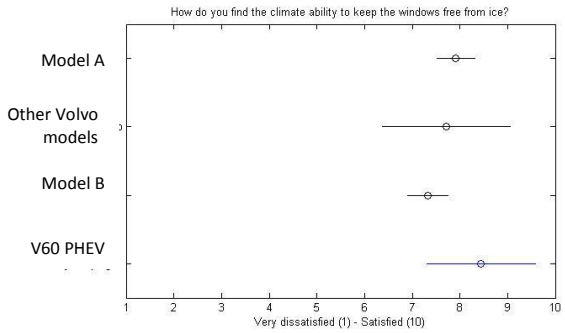


Figure 26: Climate system ability to keep the windows free from ice (V60 PHEV, model A and model B)

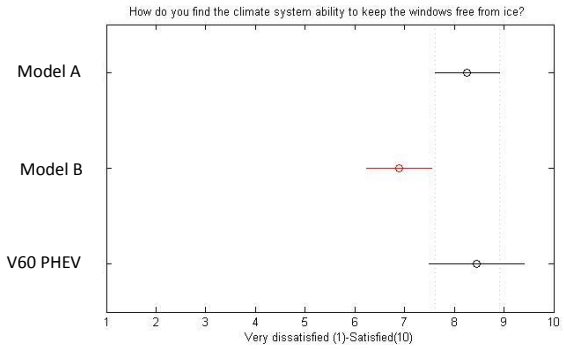


Figure 27: Climate systems ability to keep Windows free from ice – Stockholm. (V60 PHEV, model A and model B)

Lastly, 100% of V60 PHEV respondents consider the air humidity of the car to be good, neither too moist nor too dry, as the other two Volvo car groups (Figure 28).

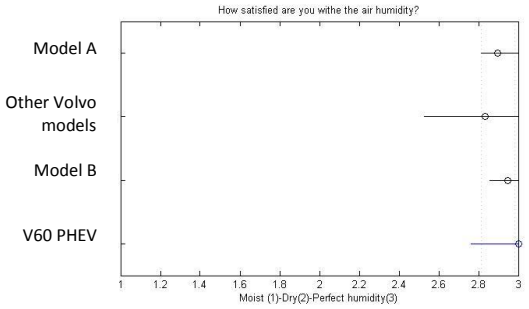


Figure 28: air humidity.
(V60 PHEV, model A and model B)

5. DISCUSSION AND CONCLUSIONS

Strengths and weaknesses of the method are discussed in this section together with the evaluation of the survey results.

The aim of this project has been to design a suitable survey to find new insights into who the V60 Hybrid Plug-in customer is. To design the survey, the preliminary steps of the DMA method were used. Thus, this project intends not only to identify some characteristics that represent the customer of the PHEV, but also to prove how well implemented methodology used was (Figure 29).

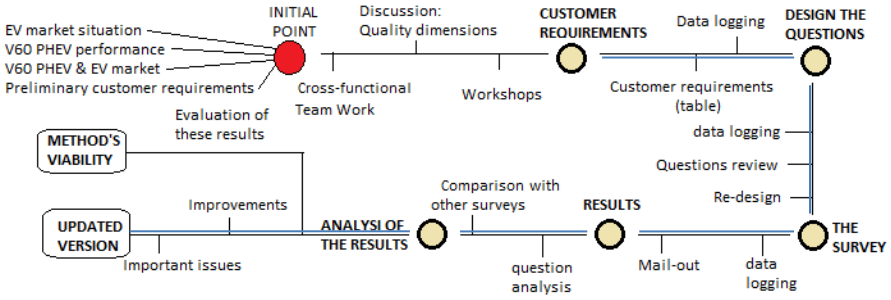


Figure 29: Methodology used through the project[9]

The cross-functional teamwork

Creating cross-functional teamwork is a difficult task because satisfactory internal communication between groups is difficult to achieve owning to the differing functional goals, training and orientations (Keller, Robert T, 2001). Nevertheless, it is the variety of goals and orientations of the different departments that contribute to a successful survey development.

The implementation of the Cross-functional Teamwork has been critical in the method due to:

- Schedule incompatibility acting as a hindrance to participation in the workshop.
- The lack of strategic departments such as Marketing, Sales and Customer Service or Product Planning in the cross-functional teamwork. *Claes Britsman*, the director customer Satisfaction & Data Analysis, made comments by email on survey questions.

Hence, the workshop was divided into three different schedules and the discussion was first focused on questions previously designed. These questions were based on car specifications and the owner's manual. During the workshop, the discussion was focused more on new car features or particular car

[9] The blue line in the diagram represents the parts of the methodology in which data logging is involved.

specifications than on identifying the different quality dimensions from the point of view of a customer. For that reason, once the preliminary questions where designed, they were sent to the different departments again in order to involve them in a more general point of view. In further analysis, the internal questionnaire can be considered the strength of the method because it will show how much each department accurately knows, understands and appreciates what the customer expects from the product.

Involving the different departments of the company more in the same workshop in order to help structure and increase the importance of verbal information for product development is crucial for further analysis.

The survey and data logging

The survey has given new customer information in such different areas as battery charging, preconditioning and climate comfort. Nevertheless, some of the results had been difficult to analyze due to the small sample size as well as for some of the previously settled characteristics of the sample, for example, same province and workplace. For this reason, some questions needed to be carefully analyzed taking into account that the sample was formed by a special group (9 respondents from Vattenfall).

Even though the information cannot be generalized due to the small sample size, the results show an idea of the major customer concerns, preferences and opinions about some car features. Hence, it is possible to use some of the information obtained in the survey to predict what issues are important to include in the balancing. Nevertheless, it is necessary beforehand to create the updated version of the questionnaire and send it to a wide range of V60 PHEV customers. The information obtained then should be enough to make and set the correct design requirements for the car.

Data logging is still not available in the analysis, nor is the updated version of the questionnaire. Therefore, it is not possible to prove how important the combination of the survey and data logging result are in terms of identifying new insights in terms of picture of the customer.

New customer insights and recommendations for the updated version

66.7% of the surveyed customers are between 50 and 59 years old and are mainly men (77.8%). The respondents mainly drive their cars in the region of Stockholm, and some of them also in Uppsala, a region near Stockholm. Half of the respondents who have another car in their household have a Volvo.

In general, customers are not satisfied with the car introduction; 5 out of 9 respondents ranked the introduction of the V60 PHEV with low qualification[10]. This fact suggests that in the updated version, it is necessary to design a question that can identify the specific shortcomings that customers experienced in the car introduction. All this information will contribute to providing the customer with more quality information about the car performance and, hence, provide the customer with more knowledge about the car. The new information that the survey provides could then also be used in the marketing of the car. This situation would lead to a better use of the car and perhaps fewer complaints concerning some features.

-Electric range, charging time, preconditioning and climate comfort-

The most important characteristic for the V60 PHEV drivers interviewed is the *electric range*. The greater electric range, the less expensive is the driving. More than a half of the respondents, specifically 53%, consider that the car lives up to their expectations in terms of driving distance. Nevertheless, the respondents who were not satisfied complained that "*the car does not even reach the 50 km in pure mode*".

In the updated questionnaire, this question must be redesigned, because "in terms of driving distance" can be misunderstood for the respondents. The aim is to know how satisfied they are with the electric driving distance (electric range).

The second and third most important issues for them are *climate comfort* followed by *charging time*. Respondents' opinions vary in regard to acceptable charging time. While most of them would find 1 hour or between 1 and 2 hours an acceptable period of charging, 4 hours or half an hour are some of the other answers. These answers can be linked with customer need in terms of fast charging. The respondent who considered half an hour as an acceptable time is the only one who complained about the lack of possibility to fast charge in the V60 PHEV. Furthermore, although the climate in the Stockholm region is not extremely cold or hot, the amount of drivers who prioritize comfortable climate is relatively high.

Unfortunately, this questionnaire leaves unanswered how much climate comfort the customer would sacrifice in order to get further in pure mode, an issue important to include in the final version.

Preconditioning is the least important issue for the customer. Considering that the respondents are all located in the same area, these results may not be generalized, because in this region, the climate is not as extreme as in other regions where preconditioning can be essential in the driver's daily life.

[10] VCC considers good punctuation of the feature when the customer qualified it with a 7 or more.

The respondents find it easy to precondition the car, and most of them use the mobile phone to start the car preconditioning, while none of them use the remote control. Information from previous model A and model B surveys shows that the car drivers usually start car preconditioning by way of the information display, but never by remote control in these groups either. This information means that in any of the three Volvo car groups, the remote control is seldom used, important input for future car improvements.

-The most attractive alternative to be included in the deal-

V60 PHEV respondents find inductive charging at home the most attractive alternative to be included in the deal, followed by a free charging box for the home (connected to the wire) followed by free public charging (free electricity).

Inductive charging is the first option, and it has a direct relation to the charging procedure. Inductive charging means no cable is needed to charge the car. Even though 78% of the respondents are satisfied with the charging procedure, some of them are concerned about the handling of the cable and the fitting of the connector in the charging point of use. So, somehow this choice reflects the inconvenience for the customers of the charging cable. The cable typically used while charging is Volvo's cable, so all the concerns about the charging procedure are relevant for the product development of the car.

The second alternative: *the charging box connected to the wire* is probably considered as the second most important alternative because of its high price (around 20,000 SEK)

The third alternative: *free public charging (free electricity)* is also important for the customers, but it is in a lower position. The surveyed group charges at home and at work almost every day, which means that their daily charging needs are usually covered. This fact does not justify their dissatisfaction with the availability of charging stations, places where they charge their cars
5–10 times per year. The value is low, and this can be due to public charging stations existing, but not working, or perhaps the offer is too low, or the charging stations are placed far from the driver's usual route, or maybe they consider charging the car in a public charging station too expensive. So, understanding the reason for these low numbers of charges in public charging stations could contribute to an understanding of this customer dissatisfaction.

-The added value-

The analysis shows that the "Reserved parking spot with possibility to charge the car" is the alternative that would provide the most added value to the car. "More charging stations" and "possibility to drive in the bus lane" follow. Even though "Electric feedback" is the last option that will contribute added value to the V60 PHEV, 45% of the respondents would like to see the electric range still available, depending on the driving speed.

-Climate comfort-

Concerning the climate comfort of the car, V60 PHEV respondents are the ones who make the greatest number of settings in the car compared with the other Volvo Cars Groups, but they are also the ones who find it most difficult. Additionally, they are satisfied with the ability to keep the windows free from mist/ice, with the time required to reach the climate comfort when it is hot/cold outside and with the air humidity in the car.

Overall conclusion

The survey is a means to pretest the questionnaire and detect the most interesting questions to focus on. During the project, various procedures were used to reinforce some of the weaknesses of the method, and the survey results give some new insights into the nature of the V60 hybrid plug-in customer.

The aim of the updated version of the survey is to obtain customer requirements that can be introduced into the car-balancing process. For this reason, the questionnaire needs to be more focused on those questions that give feedback about possible shortcomings in the car introduction, customer opinion on electrical range without misunderstandings and focus on the customers' problems with the charging cable. Concerning this last issue, the updated version should include new insights in terms of customer opinions about charging procedure (inductive charging or cable charging). Lastly, it would be interesting to go in depth with those questions that involve customer opinion on the offer of charging spots.

Improving the survey's weaknesses and focusing on a specific aim will result in a successful analysis of customer needs that will then be translated into new inputs in product development.

6. FUTURE WORK

In this section, the future work in which Volvo Cars Company and Vattenfall are involved is explained.

The first step in this research area is to identify what questions Volvo Cars Company and Vattenfall would be most interested in and then designing an updated version of this survey. There are two different ways to go about this, and Volvo Cars Company may choose path concerning the charging procedure that will guide the design of the survey. The two options are:

- Inductive charging (technological challenge): receive feedback about how inductive charging is accepted by the customers. Would they accept higher charging time in order to eliminate the problems with the charging cable?
- Easier handling of the cable

This survey should be sent to a wide range of V60 hybrid plug-in customers, which will allow the companies to obtain relevant results for inclusion (together with data logging) in the product development of the V60 hybrid plug-in.

Customer feelings, behaviors and opinions about the V60 hybrid plug-in are important information to know for the purpose of designing a product that accurately satisfies the customer. Nevertheless, other information also important to understand is the reasons why other Volvo customers did not buy the hybrid plug-in model. Focusing on this group of customers can give new information to the designers and manufacturers and transform potential customers into future actual customers. Hence, a survey to drivers who purchased a Volvo, but not the hybrid, is of special interest for both companies.

Concerning the previous survey sent to model A and model B car owners, more than half of them would be willing to answer a deeper survey. This fact means that this group would be a good candidate to send this new survey to, as the group is already identified and therefore, the survey can be completely focused on questions with high interest.

In addition, Vattenfall and Volvo Cars groups are very interested in identifying the driving pattern of the actual V60 hybrid plug-in customers in order to locate where the charging stations should be placed. To obtain this driving pattern, both survey and data logging will make important contributions. The survey will provide the customer opinion about charging in public stations, and data logging will provide information such as charging frequency, GPS position, driving speed, time between stops, *etc*. In 2015, Volvo Cars Group will measure approximately 200 V60 hybrid plug-ins.

Going further in the driving pattern, Volvo Cars Group is also interested in creating a model that can be included in the design process of the hybrid plug-in

car. This model should identify how the customers usually drive and how they behave in different scenarios.

It is a long way to go but, as the head of the e-mobility program at Vattenfall, Ulrich Frieser, has said: "**The future drives electric."**

REFERENCES

http://www.elbil.no/. (2014). (Norsk Elbilforening) Retrieved 04 09, 2014, from http://www.evnorway.no/: http://www.evnorway.no/

ABB. (2014, 02 23). Retrieved 05 16, 2014, from http://www.abb.com/: http://www.abb-conversations.com/2014/02/top-electric-cars-in-17-european-countries-charts/

Accenture. (2011). *Plug-in electric vehicles: Changing perceptions, heding bets.* Accenture.

Anna Craven. (2012). *Electromobility in Sweden: Facilitating Market Conditions to Encourage Consumer Uptake of Electric Vehicles.* Uppsala.

Bergman, Bo and Klefsjö, Bengy. (2010). *Quality from Customers Needs to Customers Satisfaction.* Hungary.

Calise, M. (2013, October 10). EVSE: The low-hanging fruit of SMART CITY buildout. 92. (Charged, Interviewer)

Craig Giffi, Joe Vitale, Michelle Drew, Yuki Kuboshima, Masato Sase. (2011). *Unplugged: Electric vehicle realities versus consumer expectations.* Deliotte.

D.H.Stone. (1999). Design a questionnaire. 326-339.

Department of Energy EERI Energi Efficiency andRenewable energy EERI. (2005). *http://www.mpoweruk.com/infrastructure.htm*. Retrieved 05 15, 2014, from http://www.mpoweruk.com: http://www.mpoweruk.com/infrastructure.htm

Dr. Ove Isaksson and Anna Karlsson. (2010a). Identification and anchoring of customer requirements based on a customer questionnaire and an in-house survey.

Dr. Ove Isaksson and Anna Karlsson. (2010b). Product configuration using Design Mode of Application.

Dr. Ove Isaksson and Anna Karlsson. (n.d.). Identification and anchoring of customer requirements based on a customer questionnaire and an in-house survey. .

Dr. Ove Isaksson and Anna Karlsson. (n.d.). Product configuration using Design Mode of Application.

Ellen Angelin and Dzenita Damjanovic. (2013). *Investigation of Charging Solutions for Users of Plug-in Hybrid Electric Vehicles.* Stockholm: KTH Industrial Engineering and Management.

Elmar Sauerwein, Franz Bailom, Kurt Matzler and Hans H. Hinterhuber. (1996). The Kano moel: How to delight your customers. 313-327.

e-on. (2009). *E-mobility. An element of Sustainable Mobility.* Malmö: E.ON Svergie AB.

Eurelectric. (2009a). *http://www.eurelectric.org/power-distribution/*. Retrieved 04 24, 2014, from http://www.eurelectric.org/: http://www.eurelectric.org/power-distribution/smart-grids-asm/

Eurelectric. (2009b). *http://www.eurelectric.org/power-distribution/*. Retrieved 04 24, 2014, from http://www.eurelectric.org/: http://www.eurelectric.org/power-distribution/standardisation/

EV Norway. (n.d.). *http://www.evnorway.no/*. Retrieved 05 16, 2014, from http://www.evnorway.no/: http://www.evnorway.no/

Fink, A. (2003). *How to Ask Survey Questions.* SAGE Publications.

Florian Hacker, Ralph Harthan, Felix Matthes, Wiebke Zimmer. (2009). *Environmental impacts and impact on the electricity market of a large scale introduction of electric cars in Europe.* European Topic Centre on Air and Climate Change.

Frydenlund, S. (2014). *http://www.elbil.no/*. (Norsk Elbilnoforeting) Retrieved 04 10, 2014, from http://www.elbil.no/elbilforeningen/english-please/717-the-norwegian-electric-vehicle-association.

Glynis M Breakwell, Sean Hammond, Chris Fie-Schaw, Jonathan A. Smith. (2013). *Research Methods in Psychology.* ebrary, Inc.

Green Highway. (2013). Retrieved from http://www.greenhighway.nu/: http://www.greenhighway.nu/laddstationer/#

Howard E.Butz, Jr and Leonard D. Goodsten. (1997). Measuring the value: Gaining the strategic Advantatge. 63-77.

IEC. (2014, 04). *http://www.iec.ch/etech/*. Retrieved 05 16, 2014, from http://www.iec.ch: http://www.iec.ch/etech/2014/etech_0414/store-3.htm

International Energy Agency. (2013). *Energy Policies of IEA countries. Sweden-The fraework: energy policy and climate change.* OECD/IEA,2013.

Joao A. Peças Lopes, Filipe Joel Solares and Pedro M. Rocha Almeida. (2011). Integration of Electric Vehicles in the Electric Power System. *Proceedings of the IEEE*, 168-183.

Keller, Robert T. (2001). "Cross-functional project gtoups in research and new product developement: Diversity, communications, job stress, and outcomes.". *Academy of manafement journal* , 547-555.

Malin Sundberg and Monica Fagraeus Lundström. (2013). *Framtiden för snabbladdning och marknadsaktörerna inom eMobilitys syn på laddinfrastruktur.* Stockholm: Industruial Engineering and Management, KTH.

Malmö stad. (a). *http://www.malmo.se/Medborgare/*. Retrieved 04 23, 2014, from http://www.malmo.se/: http://www.malmo.se/Medborgare/Miljo--hallbarhet/Miljoarbetet-i-Malmo-stad.html

Malmö stad. (b). Retrieved 04 23, 2014, from http://www.malmo.se: http://www.malmo.se/Kommun--politik/Om-oss/Statistik.html

Malmö stad. (c). *http://www.malmo.se/Medborgare/Miljo--hallbarhet/Att-gora-hallbara-val/Malmo-Green-Map.html*. Retrieved 04 23, 2014, from http://www.malmo.se: http://www.opengreenmap.org/node/6303

Martin Borgqvist. (2012). *Experiences from the Norwegian-Swedish cooperation on electric vehicle infrastructure.* Lindholmen Science Park AB.

MATLAB. (2014 b). *http://www.mathworks.se/help/stats/multcompare.html#f2030174*. Retrieved 05 20, 2014, from http://www.mathworks.se: http://www.mathworks.se/help/stats/multcompare.html#f2030174

MATLAB. (2014a). *http://www.mathworks.se/help/stats/anova1.html*. Retrieved 05 20, 2014, from http://www.mathworks.se/: http://www.mathworks.se/help/stats/anova1.html

Mats Williander and Camila Stålstad. (2013). New bussiness Models for Electric Cars. 11.

Mobashwir Khan, Klara M. Kockelman. (2012). Predicting the market potential of plug-in electric vehicles using multiday GPS data. *ELSEVIER*, 225-233.

Shahan, Z. (2014). *Clean Technica. http://cleantechnica.com/*. (Sustainable Enterprises Media, Inc) Retrieved 04 09, 2014, from http://cleantechnica.com/2014/02/12/electric-car-sales-norway-denmark-sweden-january-2014/

Shaik Amjad, S. Neelkrishnan, R.Rudramoorthy. (2009). Review of design considerationsand technological challenges for successful development and deployment of plug-in hybrid electric vehicles. *ELSEVIER-Renewable and Sustainable Energy Reviews*, 1104.

Society, M. S. (2006, 06 21). Retrieved 04 22, 2014, from http://www.government.se/sb/d/574/a/67096: http://www.government.se/content/1/c6/06/70/96/7f04f437.pdf

Sonnenschein, J. (2010). *Preparing for the Roll-Out of Electriic Vehicles - Exploring how cities can become plug-in ready.* Lund, Sweden: IIIEE theses 2010:XX.

Stephen Browna, David Pyke, Paul Steenhof. (2010). Electric vehicles: The role and importance of standards in an emerging market. *Energy Policy (elsevier)*, 10.

Svensk energi. (2010). *Laddinfrastruktur för elfrodon.* Svensk Energi - Swedenenergu - AB .

Tennesse Valley Authority. (n.d.). *http://www.tva.gov/environment/technology/car_vehicles.htm#erev*. Retrieved 05 15, 2014, from http://www.tva.gov: http://www.tva.gov

The international council on clean transportation. (2013). *European Vehicle Market Statistics.* ICCT.

Thomas O.Jones and W. Earl Sasser, Jr. (1995). Why satisfied customers defect.

Vattenfall. (n.d.). Retrieved from Vattenfall: www.corporate.vatenfall.com

Volvo Car Corporation. (2012). *V60 H owners manual.* Sweden, Göteborg: Volvo Car Corporation.

Volvo Cars. (n.d.). Retrieved from www.volvocars.com

Volvo Cars Group. (2013a, May 16). *www.volvocars.com*. Retrieved 04 10, 2014, from https://www.media.volvocars.com/global/en-gb/media/pressreleases/49095.

Volvo Cars Group. (2013b, November 11). *www.volvocars.com*. (Volvo Car Group) Retrieved 04 10, 2014, from https://www.media.volvocars.com/global/en-gb/models/v60-plug-in-hybrid/2014.

Volvo Cars Group. (2014c). *http://www.volvocars.com/uk/campaigns/v60-plugin-hybrid/Pages/default.aspx*. Retrieved 05 03, 2014, from http://www.volvocars.com/: http://www.volvocars.com/uk/campaigns/v60-plugin-hybrid/Pages/default.aspx

World Population Review. (2014, 04 2). *http://worldpopulationreview.com*. Retrieved 04 23, 2014, from http://worldpopulationreview.com/countries: http://worldpopulationreview.com/countries/sweden-population/

Yang, K. (december 2007). *Customer Survey Design, Administration, and Analysis.* Six Sigma operational Methods.

APPENDIX A

Europe Electrified Vehicles Sales

Concerning the Europe electrified vehicles sales in 2013; *Nissan Leaf* was the first in the rank followed by *Renault Zoe* and then *Mitsubishi Outlander Plug-in*. In the fourth position there was the *Volvo V60 Plug-in* (Figure 30) and then the *Renault Kangoo ZE* (ABB, 2014).

Even though Volvo V60 hybrid plug-in was the fourth electric car more sold in Europe, only a low percentage (around 8%) corresponded to Sweden market in 2013 (Figure 31).

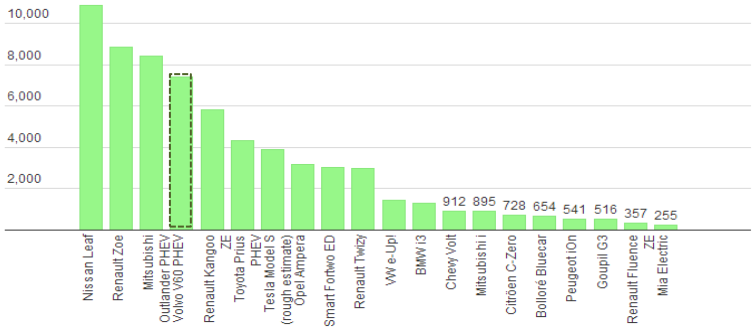


Figure 30: Europe electrified vehicles sales (2013)
Source: (ABB, 2014)

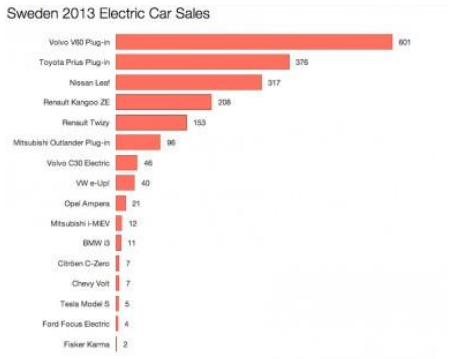


Figure 31: Sweden 2013 Electric Car Sales
Source: (ABB, 2014)

In Figure 32 it is illustrated the purchase price for selected cars in Norway during 2011-2014. More information in EV NORWAY (EV Norway).

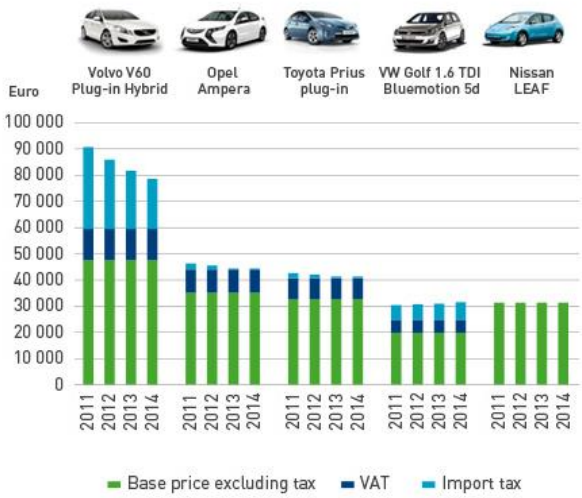


Figure 32: Purchase of different cars in Norway (2011-2014)
Source: (EV Norway)

In Figure 33 it is illustrated what are the main steps followed in the master thesis as well as the duration of each stage (Gantt diagram).

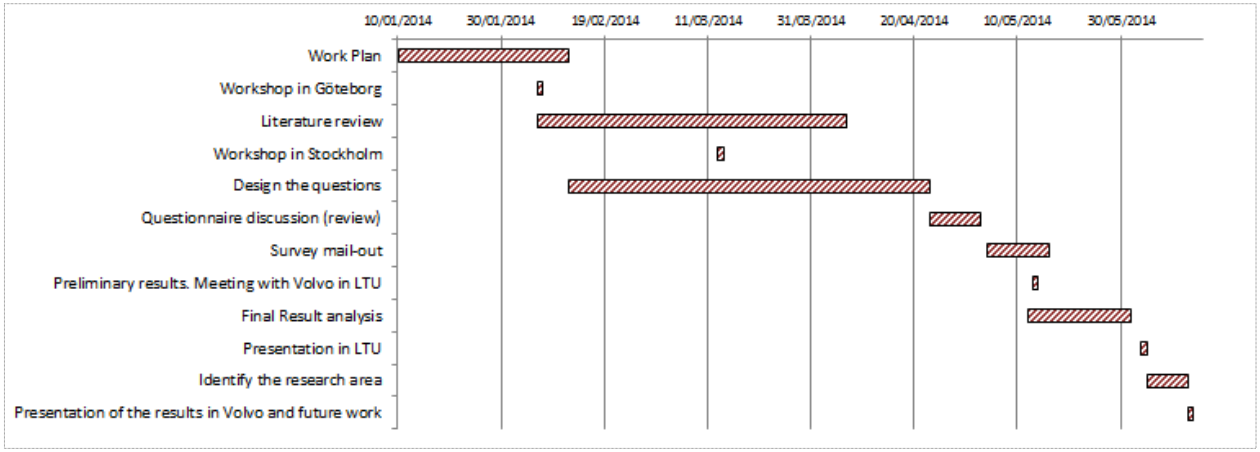


Figure 33: Project planning

APPENDIX B

Electric Vehicles: Types of charging

There are two possible ways to charge the car: conductive charging (AC or DC supply) and inductive charging. According to an article from International Electro-technical Commission (2014), conductive charging is classified in four safety modes (Table 7) (IEC, 2014):

Table 7: Safety modes (EV infrastructure)

MODE	CHARGING SPEED	DESCRIPTION	PICTURE
Mode 1 (AC)	Slow charging	Standard household-type socket outlet	 Household socket and extension cord
Mode 2 (AC)	Slow charging	Standard household-type socket outlet with an in-cable protection device	 Domestic socket and cable with a protection device
Mode 3 (AC)	Slow charging or Fast charging	Specific EV socket-outlet and plug with control and protection function permanently installed	 Specific socket on a dedicated circuit
Mode 4 (DC)	Fast charging	External charger	 CC connection

In Sweden, all PHEV correspond to safety mode 2 and two different types of charging connectors can be used (type 1 and type 2). Depending on the car model, the charging connector is different (due to the vehicle inlet part).

- Type 1 (Image 4) is the most common charging cable connector in the PHEV. It is a single phase vehicle coupler (IEC, 2014).

Image 4: Charging connector (type 1)

- Type 2 (Image 5) is the charging connector used in Volvo V60 hybrid pug-in (Volvo Car Corporation, 2012). It is single and three-phase vehicle coupler (IEC, 2014).

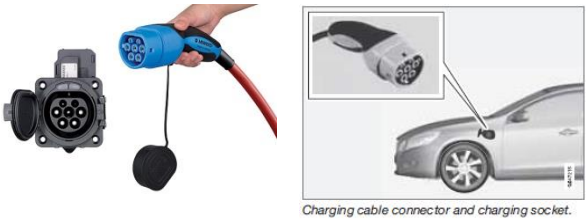


Image 5: Charging connector (type 2)

In addition, there are three main ways of connect the car to the electric supply equipment: Cable permanently attached, Detachable cable assembly and Cable is permanently attached to the Electric Vehicle Supply Equipment (EVSE) with a vehicle inlet mating connector.

SWEDEN: Charging points along E40

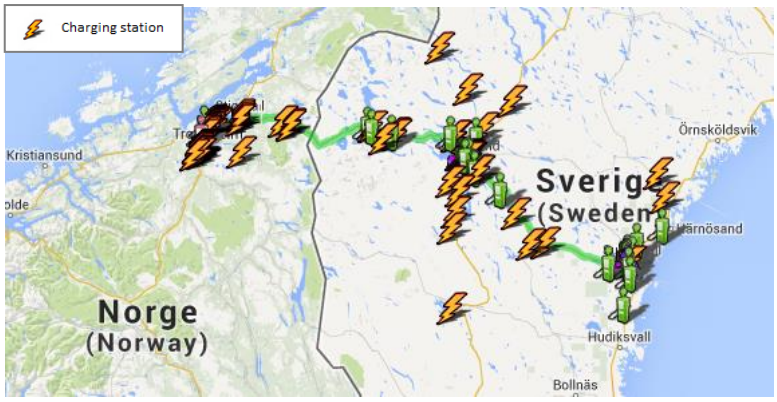


Figure 34: Existing charging points along E40 (Sweden).
Source: (Green Highway, 2013)

Malmö, Sweden

Malmö has a population of 290.000 inhabitants in the region of Skåne (south Sweden), and the city is connected with Copenhagen (Denmark) through the Öresund bridge (Malmö stad, b). The city has been involved in different projects: E-mission, Green eMotion and Plug-in city, where only Green eMotion does not finish yet (Malmö stad, c):

Table 8: E-mission Project (Malmö)

E-mission		
	Goals:	Increase the awareness of the citizen about electric vehicles
		Increase the use of Electric Vehicles in Öresund Region public
	Areas:	Mapping future charging stations
		Plans for charging infrastructure
		Suitable payment models
	Partners & Stacke-holders:	Municipality of Copenhagen
		Capital Region
		City of Malmö
		Helsingborg
		Öresundkraft
		RegionSkåne
		HM Skåne
	financed by:	E.ON Sweden AB
		Better Place Denmark A/S
		Center for Grøn Transportation Rail Authority
		Gate 21
		Move About ApS
		Transport Administration South
		Danish Electric Car Alliance
	Project period:	01.01.2011 – 31.12.2013

Table 9: Green eMotion Project (Malmö)

Green eMotion		
	Goals:	Develop the EV market
	Areas:	Develop charging infrastructure
		Demonstration of new technologies
	Financed by:	
		European Union
	Project period:	01.03.2011 – 01.03.2015

Table 10: Plug-in City project (Malmö)

Plug-in City	*Goals:*	Reduce emissions of exhaust gases Possibility to use electric cars in large-scale
	Areas:	Infrastructure for electric vehicles focusing on the Western Harbor and Hyllie/Svågertrop
	Period:	01.08.2009-01.08.2012

In addition, the charging points placed over the city are strategically located and they are situated around the parks as well as ride places in order to avoid congestion traffic in the city centre (Sonnenschein, 2010). In the Image 6 is possible to see the charging station network placed for vehicle fuels which have reduced impacts, including hybrid electric, bio-fuel or hydrogen compressed natural gas or bottled fuels.

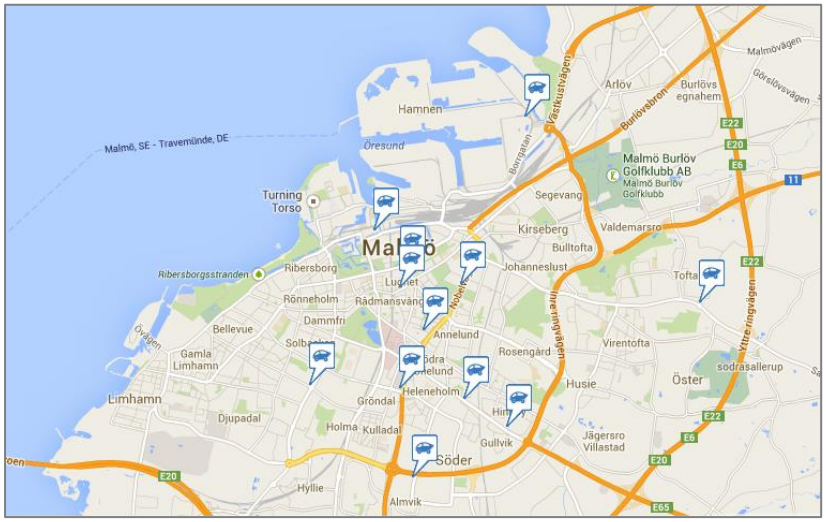


Image 6: Filling stations in Malmö. Source: (Malmö stad, c)

APPENDIX C

Table 11: Quality dimensions (Customer point of view-V60 hybrid Plug-in)

PRIMARY	SECONDARY	TERTIARY
Max. Electric driving distance (performance)	Full battery charged at start	Fast charging
	Efficient electric drive	Able to charge the battery during driving mode
	Able to charge the battery during preconditioning	
	High battery efficiency in low temperatures	
Low fuel consumption while driving (performance)	High battery capacity	
	Efficient drivetrain	Diesel engine/Electric motor
Good pre-conditioning (performance)	Easy to precondition the car	Possibility to configure the car preconditioning in the car
		Possibility to configure the car preconditioning from a distance in case customer get distracted
		Intuitive and fast way to configure the climate settings
	Fast cooling	Short period of time to cool the car
		Achieve good temperature inside the cabin (warm climate)
	Fast heating	Short period of time to heat the car
		Achieve good temperature inside the cabin (cold climate)
		Good seat heating
		Steering wheel (new proposal)
	Achieve good temperature inside the cabin	
	Low fuel consumption while preconditioning	High battery capacity
	Comfortable temperature when I enter my car	Maintain the temperature in the cabin when preconditioning reaches

		desired temperature
Good climate comfort (performance)	Achieve comfortable temperature in AUTO mode	Minimal changes on the manual climate settings
Good battery (maintainability)	Low cost of maintenance	Slow aging battery
		No need to change the battery
	Long intervals between charging	
Charging facilities (maintainability)	Charging possibilities in different places	Standardization
		Good placing of charging plug
	Simple to use charging cable	Easy handling of the cable
		Intuitive indications according to different intensities
	Easy to connect to the mains	Charging connector fit well in all the charging possibilities
Feel safe during the charging period (safety)	Protection against the electric shock.	Feeling of safety when inserting charging cable
		Feeling of safety when disconnecting the charging cable
Good visibility (safety)	Good air conditioning	Effective defrost of windscreen and side windows
		Effective rear defrost
		Effective demisting
Economy (durability)	Good secondhand value	

APPENDIX D

Confidentiality of Volvo Cars Company

APPENDIX E

Customer information

Most of the model A/model B drivers are between 60-69 years old. The Figure 35 shows the pattern for the different Volvo car groups.

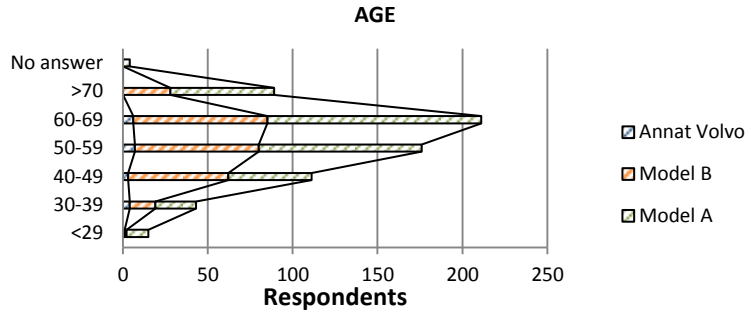


Figure 35: Age (model A and model B)

The following figures (Figure 36 and Figure 37) show in what provinces model A and model B are driven. It is important to know in what area these cars are used to understand some of the customer complaints, for example in terms of climate comfort.

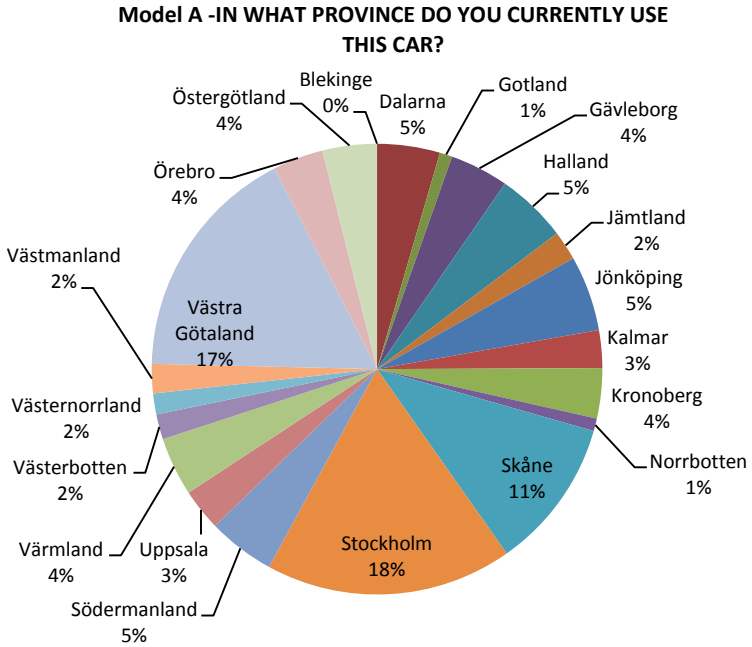


Figure 36: Province where model A is currently driven

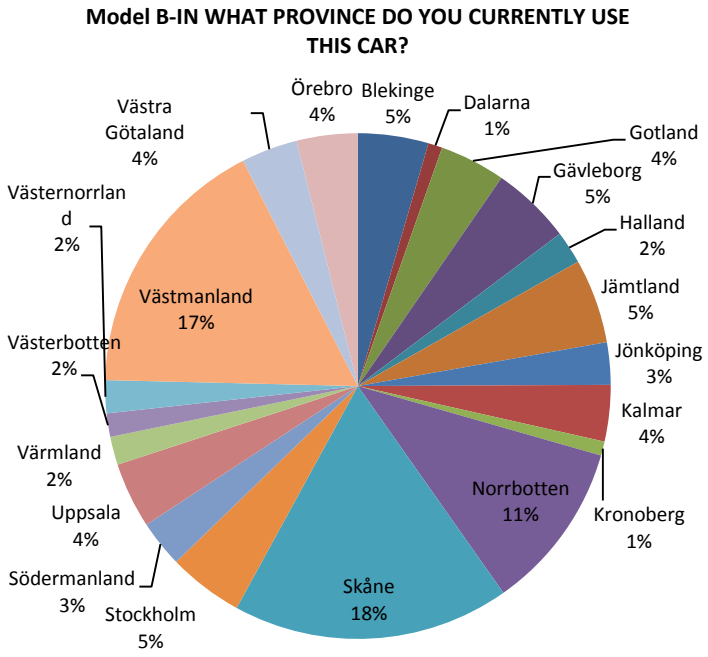


Figure 37: Province where model B is currently driven

Customer way of drive

Figure 38 and Figure 39 show for what purpose the model A and model B drivers use their car for.

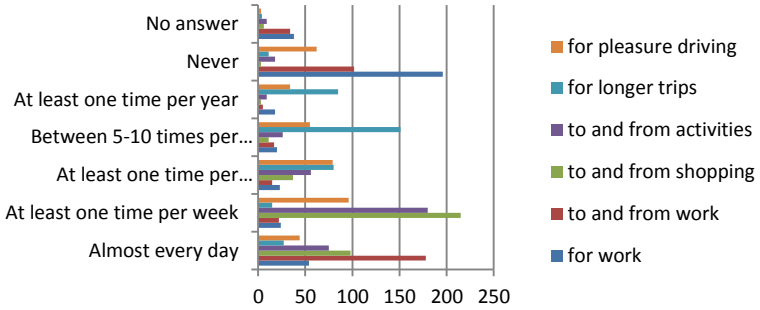


Figure 38: How often the customer use model A for... (Different activities)

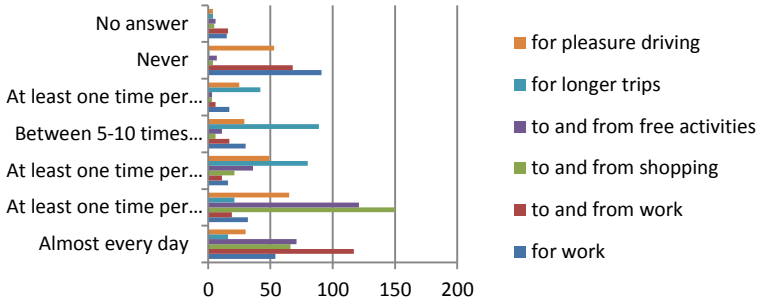


Figure 39: How often the customer use model B for... (Different activities)

Battery Charging

In Figure 40 it is shown the dissatisfaction of the group of V60 PHEV customers interviewed with the availability of charging stations.

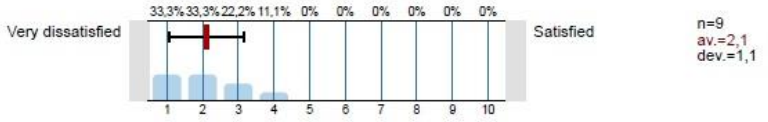


Figure 40: Customer satisfaction with availability of charging stations

Concerning V60 hybrid plug-in, Figure 41 shows Volvo's Cable and Charging box (Attached cable) are the most used. Figure 42 shows what improvements would like the customer in the battery charging procedure.

EQUIPMENT TYPICALLY USED WHILE CHARGING

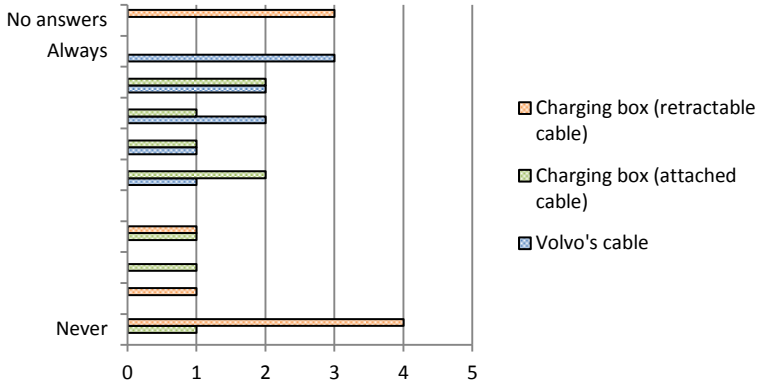


Figure 41: Equipment V60 PHEV drivers typically use while charging the battery

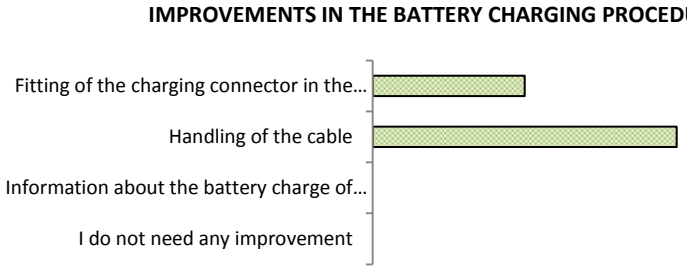


Figure 42: Customer opinions of improvements in charging procedure

Climate comfort

The following figures are concerning the climate comfort. For instance, the first one (Figure 43) shows if the different Volvo Car groups do climate settings in their car. The group who do more climate settings is the V60 hybrid plug-in group.

Figure 44 shows how difficult the different Volvo drivers find to configure climate settings in the menu system (MYCAR). The car group which usually make more climate settings is V60 PHEV is the one which find more difficult to do climate settings.

Figure 45 and Figure 46 shows the customer satisfaction of the different Volvo car groups concerning the time it takes to reach the climate comfort when it is hot or cold outside. In both cases, the level of satisfaction is high.

Figure 48 shows customer opinion about the availability to keep the windows free from mist.

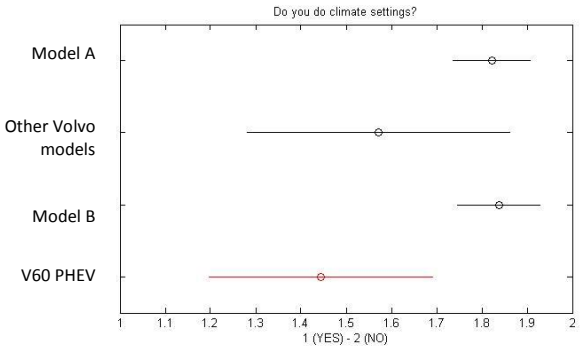


Figure 43: Climate settings-General
(V60 PHEV, Model A and Model B)

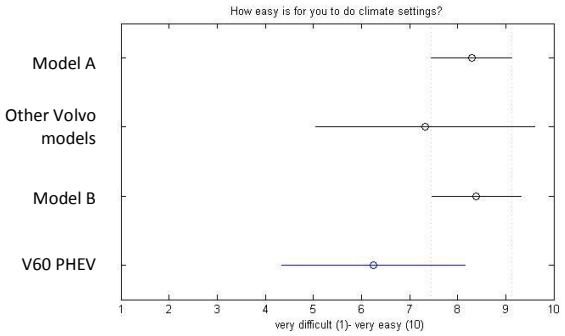


Figure 44: How easy is for you to do climate settings- General (V60 PHEV, Model A and Model B)

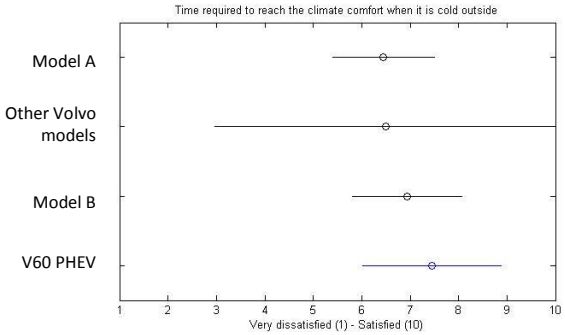


Figure 45: Time required for reach a good temperature (cold outside)

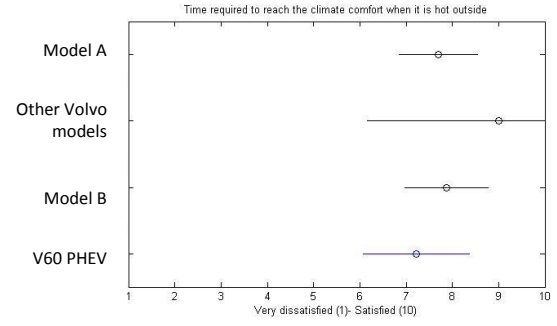


Figure 46: Time required for reach a good temperature (hot outside)

-Assumption-

In Figure 45&Figure 46it is represented together the data from questions slightly different between Volvo car groups. Even though both questions have the same objective there is the risk that model A and model B drivers could misunderstand the question and punctuate it considering preconditioning.

- *V60 PHEV questionnaire: <u>Without preconditioning</u>, what is your perception of how long it takes to achieve a good temperature in the car at the start when it's cold/hot outside?*
- model A / model B *questionnaire: What is your perception of how long it takes to achieve a good temperature in the car at the start when it's cold/hot outside?*

Figure 47 represent how satisfied are the customers with the temperature inside the cabin. Most of them are satisfied with both situations: during preheat/precool the car

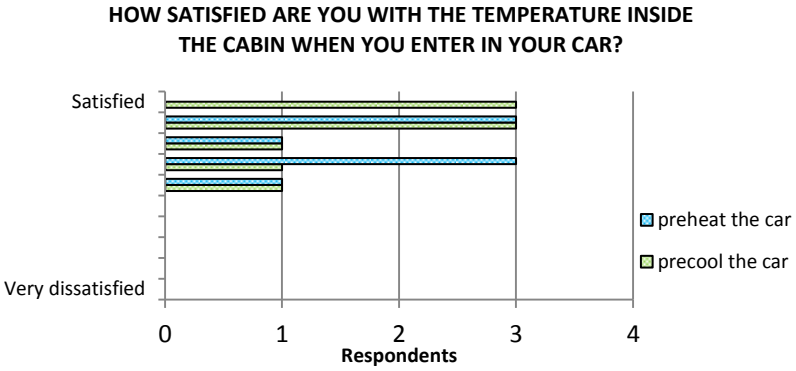


Figure 47: customer satisfaction about the temperature inside the cabin after preconditioning

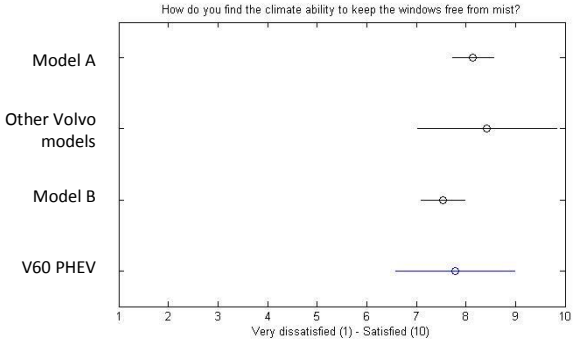


Figure 48: Ability to keep the windows free form mist

Figure 49 shows the customer satisfaction of the climate system ability to keep the windows free from ice/mist once the car is preconditioned.

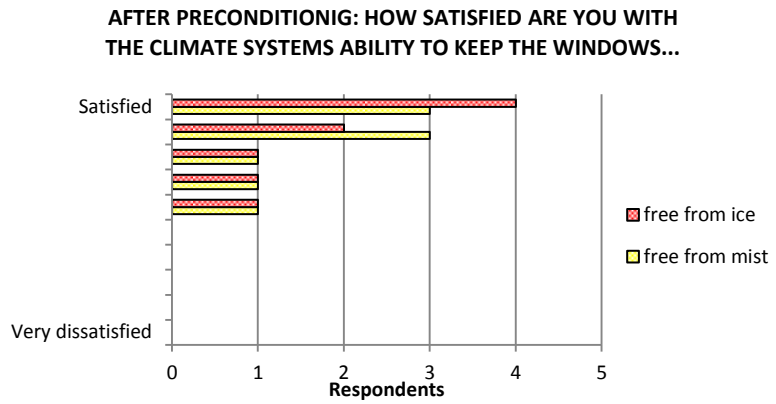


Figure 49: customer satisfaction about the climate systems ability to keep the windows free from ice/mist after preconditioning