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Hybrid Car Owners' Preferences for Electric Vehicles

by

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Abstract

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A data analysis is performed to quantify consumer preferences for full electric vehicles (FEVs) and plug-in electric vehicles (PHEVs). The role of the current car type was specifically examined by comparing the preferences of hybrid car owners to conventional car owners. Current owners of a hybrid car are an interesting car owners segment for EV adoption as they already bought a more environmental-friendly car before and already have experience with (partially) electric drivetrains. Car choice in influenced by instrumental, symbolic and affective factors. Consequently, consumer preferences for instrumental attributes are quantified. In addition, the role of symbolic and affective factors in consumer willingness to buy is examined. Finally, the preferences of PHEV drivers for future FEV adoption are explored.

Three existing data sets were made available for this data analysis. The first data set contains data from a stated choice experiment about instrumental attributes, and is therefore used to quantify conventional and hybrid car owners' preferences for instrumental FEV/PHEV attributes. The second data set contains Likert scale data from a survey about symbolic and affective factors. This data set originates from a follow-up survey on the first survey on instrumental attributes. The third data set contains data about current PHEV driver experiences with and preferences for EVs and the charging infrastructure. This data originates from the 2014 Dutch National Survey Electric Driving (NSED). This data set is used to search for indications in the preferences of PHEV drivers that suggest a high likelihood of buying a FEV as a next car.

The preferences for instrumental car attributes have been examined by estimating mixed logit models for both conventional car owners and hybrid car owners. The instrumental attributes examined in the models were: purchase price, monthly costs, driving range, recharge time and additional detour time for appropriate fuel stations.
Conventional car owners show a high negative intrinsic preference of around €18,000 for PHEVs and FEVs compared to conventional cars, excluding the price difference between EVs and conventional cars. Accounting for this price difference increases the negative intrinsic preference further by €5,000-€10,000. This negative intrinsic preference is high with respect to their purchase price of around €40,000. This implies that substantial subsidies are need to bridge the gap between conventional cars and EVs. Hybrid car owners are shown to have a less negative intrinsic preference for FEVs and PHEVs.
Conventional car owners are willing to pay €25.80/km additional range and respectively €6.04/km and €28.36/km for reduced FEV and PHEV charging times. Hybrid car owners are less willing

to pay for increased instrumental functionality than conventional car owners. This implies that policies stimulating technological development of EVs have less effect for hybrid car owners than for conventional car owners.

The role of symbolic and affective factors in the preference for FEVs and PHEVs was examined by estimating ordinal logit models for both conventional and hybrid car owners. Symbolic and affective scales, personal identity factors and socio-economic variables were used as independent variables in the analysis.
Symbolic and affective factors play a statistically significant positive role in the willingness to buy a FEV or a PHEV. This also yields for a positive perception of EV reliability, flexibility and environmental performance. This implies that EV sales can also be stimulated by policy measures like FEV experience programs. Furthermore, it is shown that people with a pro-environmental personal identity are more likely to buy a FEV or a PHEV. Hybrid car owners are shown to find the environmental performance more important, whereas conventional car owners find flexibility and reliability more important. Consequently, FEV experience programs are more effective fro conventional car owners, whereas promotional campaigns emphasizing on the environmental benefits of EVs are expected to be more effective for hybrid car owners.

The preferences of PHEV drivers are explored with the data set of the NSED. PHEV drivers are shown to match the early adopter characteristics of being younger, more highly educated and having more cars in the household than the average conventional car owner. Furthermore PHEV driver's car uses patterns are similar to that of current FEV drivers, suggesting that PHEV driver car use pattern is also feasible with a FEV. PHEV drivers find fuel cost and emissions the most important monetary and non-monetary factors. These findings are beneficial for FEV adoption. PHEV drivers find purchase price more important than maintenance costs, whereas the opposite yields for FEV drivers. This is unfavorable for future FEV choice of PHEV owners as FEVs generally have a higher purchase price than PHEVs.

Summary

Motivation and research objective Electric vehicles (EVs) are seen as an important means of reducing transport-related CO_2-emissions, as they only emit a fraction of the CO_2-emissions compared to conventionally power cars. As electric vehicles are very different in terms of cost and use, consumer preferences for EVs may be very different than for conventional cars. Therefore, consumer preferences for EVs have been the subject of many studies in the past years. The role of the current car at EV preferences has not been addressed yet, although is likely that current car experiences influence future car preferences. In this light, hybrid car owners are an interesting car owners segment. Hybrid car owners already chose to buy a partially electric car before and have experience with (partially) electric drive-trains.
This research will quantify car owners preferences for instrumental attributes of full electric vehicles (FEVs) and plug-in hybrid vehicles (PHEVs) and the role of symbolic and affective factors at their willingness to buy a FEV/PHEV. At this, the research specifically examines the differences between conventional car owners and hybrid car owners. In addition, an exploratory analysis is performed on current PHEV owners' preferences for a FEV. PHEV owners, in addition to hybrid car owners, are also an interesting car owners segment as PHEVs are even more similar to FEVs than hybrid cars.

Literature review Car use and ownership is driven by instrumental, affective and symbolic factors. Additionally, a choice maker's perception of the instrumental, symbolic and affective performance of cars is affected by his own attitude and the subjective norm of the choice maker's important relatives towards the intended car choice. The main part of previous research on alternative fuel vehicles (AFVs) preferences focuses on the importance of their instrumental performance: taking the driver from A to B. This concerns attributes like purchase price, fuel costs, range and recharge times. In addition, cars choice is influenced by symbolic and affective factors. The symbolic role of cars is that owners can express their identity by the type of car they own. Affective factors address the emotions related to cars like joy and excitement. Furthermore, a car owner's perception of the instrumental, symbolic and affective factors depends on his perceived personal identity. A pro-environmental identity or high technological interest are shown to increase the attractiveness of AFVs. Finally, socio-economic characteristics like age, eduction level and car use characteristics like annual mileage and number of cars in the household affect the preferences for AFVs.

Research approach This research opted to use existing databases over new data collection for resource reasons. Data collection among hybrid car owners is costly as their population in the Netherlands is small. The first data set contains data from a stated choice experiment about instrumental attributes of AFVs, collected by Hoen and Koets [1]. This data set is used to examine the conventional and hybrid car owners preferences for instrumental attributes of FEVs and PHEVs with mixed logit models. The second data set contains Likert scale data from a survey on symbolic and affective factors. It is a follow-up survey to the previous stated choice survey and collected by PBL. This data set is used to examine the role of symbolic and

Table 1: Willingness to pay results for conventional and hybrid car owners

Factor	Conventional car owners Willingness to pay	Hybrid car owners Willingness to pay
FEV intrinsic	€-18,908	>€-18,279
PHEV intrinsic	€-18,365	>€-17,549
FEV range	€25.80/km	<€25.08/km
FEV recharge time	€6.04/min	<€5.67/min
PHEV recharge time	€28.36/min	<€22.95/min

affective factors at the willingness to buy a FEV or a PHEV with ordinal logit models. The third data set contains data about PHEV drivers' experiences with and preferences for EVs and the charging infrastructure. The data originates from the 2014 Dutch National Survey Electric Driving, fielded by Accenture et al. [2]. This data set is used to search for indications in the preferences of PHEV drivers that suggest a high likelihood of buying a FEV as a next car, by correlation analyses and t-tests.

Instrumental attribute preferences Mixed logit models were estimated on the data set of Hoen and Koetse's stated preference survey to quantify the preferences of conventional and hybrid car owners for instrumental FEV and PHEV attributes. The data set contained 1899 conventional car owner and 128 hybrid car owner respondents. Each respondent was presented eight choice tasks. Each choice task consisted of a varying composition of three of the six following car types: conventional, hybrid, PHEV, FEV, flexifuel and fuel cell. The attributes presented in the choice task were: purchase price, monthly cost, range, recharge/refuelling time, additional detour time, the number of models and policy measures. The number of models and policy measures were excluded from the mixed logit models during model development due to insignificance. Three mixed logit models were developed. First, two separate models for the conventional car owners and hybrid car owners were estimated. Additionally, a full sample model with a scale factor applied between the two segments was developed as the hybrid car owners model delivered mainly insignificant results due to the low sample size.

Table 1 shows the main results on the instrumental attribute preferences. Both conventional and hybrid car owners have a negative intrinsic preference for FEVs and PHEVs compared to conventional cars 'ceteris paribus'. Taking the higher purchase price of FEVs and PHEVs into account, the negative instrinsic preference figures of Table 1 increase with an additional €5,000-€10,000. These negative intrinsic preferences are large compared to the average sales prices of €40,000 for FEVs and PHEVs, as this already includes the current EV stimulation purchase tax subsidy of around €4,000 compared to a conventional car. Hybrid car owners have a higher instrinsic preference for FEVs and PHEVs compared to conventional car owners.

Both conventional and hybrid car owners are willing to pay substantially for additional instrumental functionality of FEVs and PHEVs. Table 1 shows that hybrid car owners have a lower willingness-to-pay for additional range and reduced recharge times than conventional car owners. This suggests hybrid car owners are more satisfied with current FEV and PHEV range and recharge times than conventional car owners.

Market share simulations based on the data set and the mixed logit models revealed a large difference between stated preference market shares and 2014 real world sales figures. This implies a large gap between car owners' stated preference and actual choice behavior.

The role of symbolic and affective factors The role of symbolic and affective factors in the preference for FEVs and PHEVs was examined by estimating ordinal logit models on the follow-up data set collected by PBL. The data set contained 1203 conventional car owner respondents and 199 hybrid car owner respondents. A respondent's stated willingness-to-buy a FEV/PHEV on a 0% – 100% scale was used as the choice variable for the models. Four types of factors were used as independent variables in the models. First, a symbolic and an affective scale, based on respectively four and five qualitative statements, were developed to reflect the role of symbolic and affective factors during car purchase. A factor analysis was performed on 20 statements about personal identity regarding car use. Four personal identity factors were extracted: environmental norm, car authority, technological interest and perceived behavioral control. Additionally, the current perception of FEV and PHEV acceleration, flexibility, reliability and environmental performance were included. Finally, the influence of socio-economic variables gender, age, social class and urbanization level was assessed in the model.
The ordinal logit model results show that symbolic and affective factors play a statistically significant positive role in the willingness to buy a FEV or a PHEV for both conventional and hybrid car owners. This finding is beneficial especially for FEV sales as car buyers might compensate the limited functional performance of FEVs by their positive symbolic and affective aspects. In addition, a positive perception of a PHEV's or FEV's flexibility and reliability increases the respondents willingness to buy. For the FEV specifically, this also yields for a respondent's perception of the FEV's environmental performance. Hybrid car owners and conventional car owners differ on these points. Hybrid car owners find environmental performance more important, whereas conventional car owners find flexibility and reliability more important. Of the four personal identity factors, a pro-environmental attitude is shown to have a positive influence on the willingness to buy either a FEV or a PHEV for both conventional and hybrid car owners. Finally, none of the socio-economic variables was found statistically significantly influencing the willingness-to-buy an EV. This is not line line with literature expectations, that argue people of young to middle age and with a high socio-economic status have a higher willingness-to-buy an EV.

Exploratory results PHEV owner preferences The data set of the Dutch National Survey Electric Driving 2014 (NSED) will be used to explore the preferences of PHEV drivers for FEVs. The NSED is an annual survey into the experiences and preferences of Dutch FEV and PHEV owners. The limited response on the survey, being 69 PHEV owner respondents, only allowed for exploratory analysis. Three parts of the data set were examined for this research. First, the socio-economic profile of PHEV drivers was compared to the socio-economic profile of the conventional car owners in the data set of Hoen and Koetse's stated preference survey with independent samples t-tests. PHEV drivers are shown to match FEV early adopter characteristics of being younger, more highly educated and having more cars in the household than conventional car owners. Furthermore, it is shown that PHEV driver's car use pattern does not differ statistically

significant from FEV drivers car use pattern. Current car and infrastructure evaluation of PHEV drivers was found unrelated to future FEV choice.
Fuel costs are shown to be the most important monetary factor for PHEV drivers to buy their current car, rather than purchase price. This is beneficial for FEV adoption, as electricity costs of FEVs are lower than the fuel costs of conventional cars. Emissions of a car a perceived as the most important non-monetary factor for PHEV owners. Independent sample t-tests on the preferences of PHEV and FEV drivers showed that PHEV drivers find purchase price relatively more important than FEV drivers. This is unfavorable for future FEV choice of PHEV owners as FEVs generally have a higher purchase price than PHEVs.

Policy implications As this research was performed for PBL, the implications of the research findings are addressed to policy makers. In order to increase EV sales further, the results of this research advocate financial measures to compensate for the negative intrinsic preference for EVs compared to conventional cars, by either subsidizing EVs or penalizing conventional cars. In addition to vehicle tax measures, the willingness-to-pay results for additional range and reduced recharge times call for further stimulation of EV technological improvement programs. Finally, the positive role of symbolic and affective factors suggest positive effects for policy measures that affect the symbolic and affective aspects of driving, like EV-experience programs.
Furthermore this research highlighted differences in preferences between conventional car owners and hybrid car owners. Less financial measures are needed for FEV and PHEV stimulation among hybrid car owners compared to conventional car drivers due to higher intrinsic preferences for FEVs and PHEVs of hybrid car owners. On the other hand, the effects of technological improvements of EVs in terms of range and recharge times are expected to be lower for hybrid car owners, based on their lower willingness-to-pay for longer range and reduced recharge times. Finally, FEV experience programs are suggested to be less effective for hybrid car owners than for conventional car owners, as hybrid car owners find flexibility and reliability of a car less important than conventional car owners.
The results of this research call for financial measures to increase EV sales. This is partially reflected in the proposed changes in the Dutch vehicle tax scheme till 2020. FEV subsidies remain on the current level in the near future, whereas the discontinuation of the PHEV subsidies will have strong negative implications for future PHEV sales in the Netherlands. The results of this research support the Dutch project-based subsidies mainly aiming to improve the public charging network. Direct subsidies for improving vehicle technologies, on the other hand, are absent in the current Dutch EV stimulating policies. However, these subsidies are ought to be more appropriate and effective on a European level.

Discussion Several weaknesses are identified that could affect the results and the implications of this research. First, the research approach of this study left the interdependence of instrumental, symbolic and affective factors out of consideration. Previous research has shown this is an oversimplification. It is argued that symbolic and affective factors can influence a choice maker's perception of the instrumental factors. These interactions and their effects on EV preferences could not be addressed in this research as the first two data-sets did not contain enough overlapping hybrid car owners for a combined analysis with a hybrid choice model. The hybrid

choice model approach is a recommendation for further research as it allows for simultaneous estimation of instrumental attribute preferences by a choice model and the role of symbolic and affective factors by a latent variable model.
Secondly, the use of stated preference data limits the real world implications of the research findings: what people say they will do, is often not the same as what they actually do. Moreover, socially desirable response might also play a role at this research, as AFV preferences are an environmentally related topic.
Thirdly, the preferences of company car drivers are not addressed in this research. As the cost structures of private car ownership and company car use are very differ, the preferences of private and company car drivers are also likely to differ. Company cars account for almost half of the Dutch new car sales. This makes the preferences of company car drivers segment also important for research into AFV preferences.

Acknowledgements

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Gerke Feitsma
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Abbreviations

NSED	**N**ational **S**urvey **E**lectric **D**riving
PHEV	**P**lug-in **H**ybrid **E**lectric **V**ehicle
FEV	**F**ull **E**lectric **V**ehicle
FC	**F**uel **C**ell vehicle
DCM	**D**iscrete **C**hoice **M**odel
TCO	**T**otal **C**ost of **O**wnership
MNL	**M**ulti**N**omial **L**ogit model
WTP	**W**illingness **T**o **P**ay
WTA	**W**illingness **T**o **A**ccept
WTB	**W**illingness **T**o **B**uy

Chapter 1

Introduction

Forthcoming global climate change signals and fossil fuel depletion have induced a multitude of emission reduction policies on all governmental levels in the world. The European Commission announced that European countries should strive for a 60% reduction of transport-related CO_2 emissions in 2050 compared to 2000 [3]. As passenger cars are responsible for roughly 50% of the transport-related CO_2 emissions in Europe [4], the adoption of alternative fuel vehicles has received many attention in the light of reducing transport-related CO_2 emissions.

Alternative fuel vehicles (AFVs) are a promising means of CO_2 emission reduction as they emit only a fraction of the emissions of a conventionally powered car with an internal combustion engine. AFVs come in several forms, of which (partially) electric cars are currently the most common type on the Dutch roads. The high efficiency of electric engines makes them favorable to internal combustion engines [5]. In addition, electric energy can be produced from energy sources like solar and wind energy. Several forms of (partially) electric cars are present on the Dutch car market today. In hybrid electric vehicles (HEVs), an electric engine assists the conventional engine and braking energy is stored in a small battery. Plug-in hybrid vehicles (PHEVs), for example the Volkswagen Golf GTE, can drive fully on electric power for typically 50 km, after which the combustion engine takes over. Additionally, they are able to charge from the grid. Full electric vehicles (FEVs), like the Volkswagen eGolf, only have electric engines and rely fully on the electric energy stored in the battery. Due to current limitations in battery (capacity) technology and charging technology, electric cars currently have a typical range of 150 km [1].

The Dutch government stimulates consumer and company purchase of hybrid cars, PHEVs and FEVs cars by offering a range of tax benefits. These tax schemes intent to make these car types financially more attractive as their purchase prices are generally higher compared to comparable conventional cars due to their new drive-train technologies. These benefits range from purchase tax bonuses and road tax exemption to lower monthly contribution for company car users [6]. From a sole environmental view, these financial incentives have shown to be successful: the fleet of new cars sold in 2013 in the Netherlands has the lowest CO2 emissions Europe [7]. However, recent research has shown that the environmental benefits of PHEVs in practice are substantially lower than theoretically assumed [8], as their electric mode is used a lot less than expected. Consequently, the Dutch government will phase out their PHEV stimulating tax policies in the upcoming five years [9].

As AFVs are different from conventional cars in both cost and use, consumer preferences for AFVs may be very different from what is know about their conventional car preferences. AFV preferences has been the subject of many researches in the past fifteen years. See Hoen and Koetse [1] and Dimitropoulos [10] for an overview of the major works on this topic. However, none of the studies specifically addressed the role of current car type ownership. Hybrid car owners and plug-in hybrid car owners are interesting car owner segments as they already bought a more environmental-friendly car before and consequently have experience with partially electric driving. Therefore, this research will examine consumer preferences for FEVs and PHEVs with the specific objective of quantifying the differences in preferences between hybrid car owners and conventional car owners.

This thesis starts with a literature review in Chapter 2 to get understanding of the consumer car choice process and to become familiar with previous research results on this topic. The research objective and the research approach are described in Chapter 3. The next three chapters form the analysis part of this research. Chapter 4 describes consumer preferences for instrumental attributes of AFVs. Additionally, Chapter 5 shows the role of symbolic and affective factors in consumer willingness to buy a FEV or PHEV. Chapter 6 completes the analysis by exploring PHEV drivers' preferences for FEVs. Conclusions and policy implicates of the analysis results are described in Chapter 7. Finally, the validity of the research results is discussed in Chapter 8, as well as directions for further research.

Chapter 2

Literature study

The literature study of this research is divided into two parts. First, a theoretical framework for (PH)EV adoption is deduced from research on material possession, car use and ownership behavior and previous studies on AFV adoption. Subsequently, the different parts of the theoretical framework are further specified.

2.1 Theoretical framework development

The first part of the literature study deduces a theoretical framework and the validity of this model is assess, based on previous research on this topic.

2.1.1 The general consumer decision making process

Consumer research consistently discovers the search process before car purchase is rather limited [11, 12]. This finding is contrary to what one would expect in buying a good with a high purchase price. Apparently, consumer choice strategy is not solely determined by the purchase price of a good. Olshavsky [13] showed that the form of the decision process depends on the complexity of the choice task, predominantly determined by the number of available alternatives. It is apparent that car choice can be regarded as a complex choice task, as over 50 car brands is available in the Netherlands. A consistent finding in literature argues that choice makers use a multistage strategy in order to cope with complex choice tasks [13]. A practical formulation of such a multi-stage strategy is the two-step decision model proposed by Mueller and de Haan [14], see Figure 2.1. This model divides the choice into two steps: the elimination step, in which the universal choice set is reduced to the individual choice set and the appraisal step, which arrives at the final choice. The first phase is often dictated by basal, single-attribute considerations and

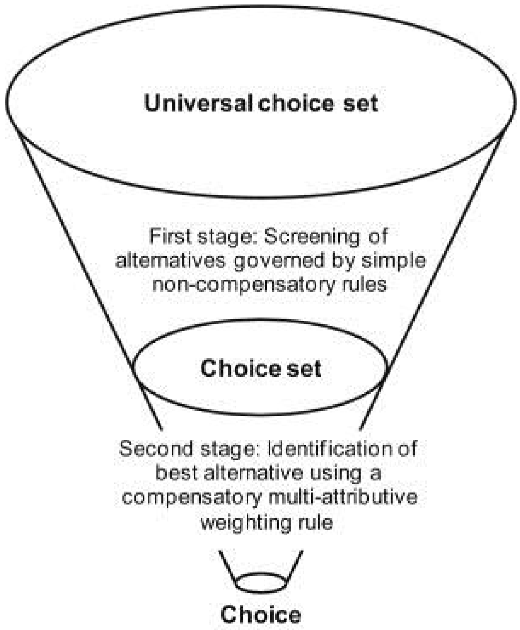


Figure 2.1: Conceptual two-stage model of consumer decision making, derived from Mueller and de Haan, 2009

driven by intuition [15, 16]. The resulting individual choice set consists of a set of alternatives that meet the choice makers basic requirements. Note the difference between the choice sets of step one and two: the universal choice set is the same for all choice makers, the individual choice set is personal. The second phase is usually more resource-intensive: the choice maker identifies the best alternative using a compensatory multi-attribute weighting rule. Compensatory, here, means that high performance on one attribute can compensate low performance on another attribute in assessing the overall utility of an alternative. Weighting means that not all attributes are perceived to be equally important to the choice maker in assessing the overall utility.

2.1.2 Reasons for car use and ownership

The model from the previous paragraph is indicative for the chronological phasing of consumer decision making. Additional theoretical work provides the required insights on the influential factors during this process. Two widely acclaimed theories on this subject are Dittmars Theory of Material Possession [17] and Ajzens Theory of Planned Behavior [18], that are surprisingly in line with each other. Dittmars theory deals with the reasons why people desire to have material possessions. In Figure 2.2 a schematic representation of Dittmar's Theory of Material Possession is shown. Apart from the obvious instrumental reasons of material possession (i.e. cars enable people to engage in activities that are spatially separated from them), Dittmar emphasizes on the symbolic and hedonic incentives for material possession. Symbolic reasons refer to the identity of a person. These symbolic reasons are twofold: one can use material possessions for self-expression, but also for assigning oneself to social categories. Remaining at the example of

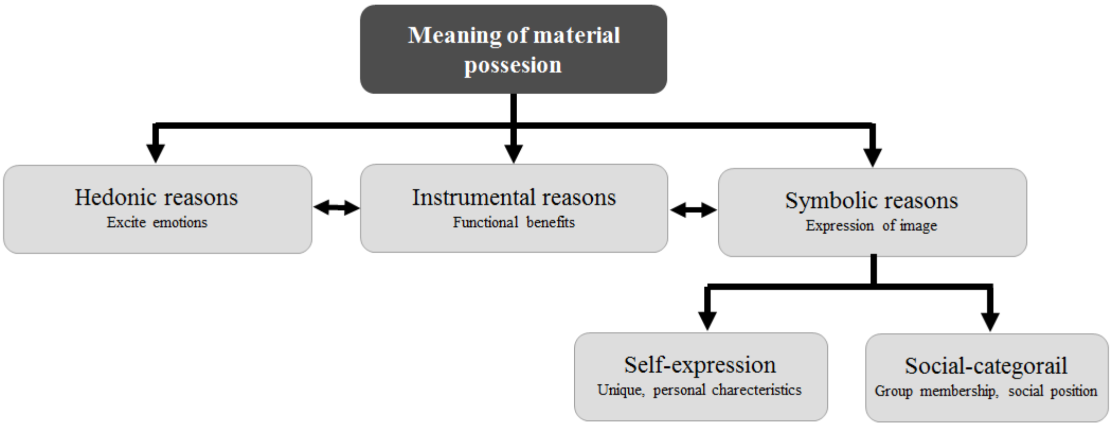


FIGURE 2.2: Schematic representation of Dittmar's Theory of Material Possession

cars: one can acquire and express a certain image possessing a certain brand or model of a car. Moreover, car ownership in general already expresses a certain image. The third and final type of reasons for material possession are hedonic/affective motives: intentions to excite emotions by material possessions. In the light of car ownership: some people experience a feeling of freedom when owning and using a car. Also, people have indicated they enjoy the sole activity of driving a car.

In line with Dittmars Theory of Material Possession is Ajzens Theory of Planned Behavior. In short, the Theory of Planned Behavior dictates that human behavior can mainly be predicted by the intentions to perform certain behavior: the stronger a person has the intention to perform certain behavior, the higher the likelihood a person will indeed perform that behavior. Consequently, these intentions have three determinants: the persons attitudes towards the behavior, the subjective norms and the perceived behavioral control. Attitudes refer to the degree of which a person has a favorable evaluation or appraisal of the behavior in question [18, p. 188]; it involves a certain self-reflection. Subjective norms refer to the perceived social pressure to perform or not to perform the behavior in question [18, p. 188]. The final determinant, perceived behavioral control, refers to the perceived ease of performing the behavior. Especially the first two determinants are closely related to Dittmars theory: symbolic and affective reasons for material possession are largely dictated by attitudes and norms. For example: when a person has the intention to buy a certain type of car, he reflects on what he thinks of the purchase and what others will think about it. However, it should be noted that this model only predicts the behavior a person is likely to perform, not the actual behavior itself. Ajzen stresses to study the underlying beliefs of people, as he argues that beliefs are the most basic level of explanation of reasons to certain behavior [18, p. 189].

In conclusion, the theoretical framework for this research is summarized in Figure 2.3. Material possession choice behavior is not only driven by their instrumental benefits. Symbolic and affective motives also play a key role. These symbolic and affective motives are shaped by

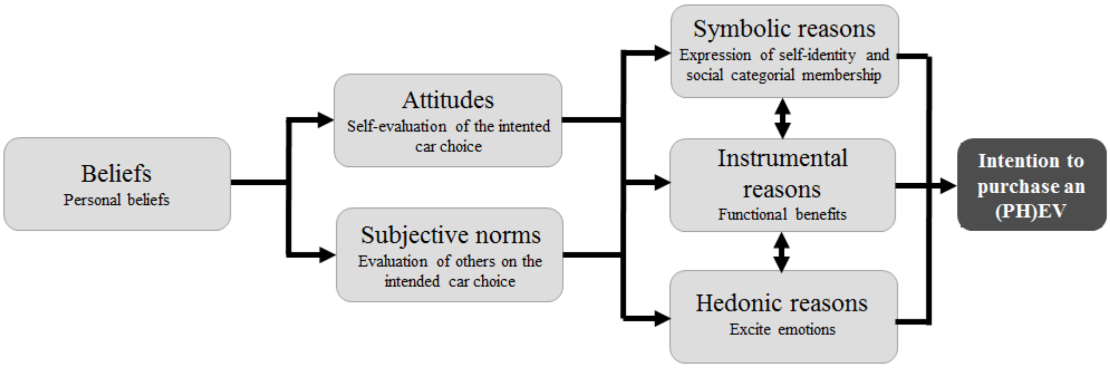


FIGURE 2.3: Theoretical framework

subjective social norms and the choice makers own attitude towards the purchase of a product. Norms and attitudes, in their turn, are shaped and explained by a persons beliefs.

2.1.3 Framework validity for electric vehicle purchase intention

Several researchers have demonstrated the validity of this theoretical framework for car-related research. Steg successfully proved that this framework is able to explain car use in general [19]. She also stressed the importance of symbolic and affective motives. Next, Schuitema [20] showed the usefulness of this theoretical framework regarding the intention to adopt a (PH)EV. She stressed the importance of symbolic and affective factors besides instrumental factors. However, she warned for the interdependence of the three types of factors. Following Dittmar's [17] argumentation, she argues that an independent distinction between the three factors is an over-simplification. Schuitema showed that the mediating effect of instrumental factors on symbolic and affective motives for AFV adoption may sometimes be larger than its own direct effect. A practical example: recently a more powerful, dual-engine Tesla Model S P85D is launched. It can be assumed that the direct effect of the 700 horsepower (reaching ones destination faster) is negligible, but the effect on the affective factor fun-to-drive can be substantial. In conclusion, the studies of Steg and Schuitema show, that the theoretical framework, showed in Figure 3 is valid for use at PH(EV) adoption studies. Findings during this research shall be explained with this theoretical framework.

2.2 Description theoretical framework

This second part of the literature study will go into detail about the various parts of the theoretical framework, presented in Figure 2.3. Our research here takes a unique approach. None of the literature reviewed in this chapter differentiates their results on AFV preferences to current car ownership of the respondents. Consequently, no prior results are available about the differences in EV preferences between hybrid car owners and conventional car owners. The literature study will be used as a guide for model development. It provides a comprehensive overview of instrumental, symbolic, affective and attitudinal factors that are used by other studies to quantify AFV preferences. In addition it provides a overview of the socio-economic and car use variables that are shown to have an influence on AFV preferences. Furthermore, an FEV early adopter profile was developed based on previous literature findings on socio-economic variables and car use variables.

2.2.1 Beliefs, attitudes and norms

People's beliefs are argued to be the basic information on which they form attitudes and subjective norms. Insights in ones beliefs can explain (the intention to perform) certain behavior [18]. Two types of beliefs are relevant for research into intentions to purchase a (PH)EV: behavioral beliefs as antecedents of attitudes and normative beliefs as antecedents of subjective norms. Both types will be discussed in the following pages.

2.2.1.1 Behavioural beliefs and attitudes

Three attitudes have been associated to a higher intention to buying an AFV in previous research: a pro-environmental attitude, high technological interest and high consumer innovativeness. The following paragraphs list these attitudes together with a description and statements, representing beliefs, to measure the presence of the attitudes at respondents.

Pro environmental attitude Both AFV vehicle ownership and high intention to adopt an AFV are associated with persons that state to have a pro-environmental attitude [21–25]. People having a pro-environmental attitude are actively concerned about the environment or state having a green lifestyle.

Schuitema [20] deduced four statements from the results of Graham-Rowe et al. [26]:

- Being environmentally responsible is an important part of who I am.
- I am not the type of person to worry about being green.
- Reducing my cars environmental impact would make me feel good.
- I would not buy a more efficient car just because it is environmental friendly.

Jensen[23] developed a set of statements:

- Employment is more important than the environment.
- The authorities should introduce legislation that forces citizens and companies to protect the environment.
- EVs should play an important role in our mobility system.

Technological interest Electric vehicles are packed with innovative, technical solutions. It could be that people with great technological interest will also find EVs more attractive than less technology-oriented people [23]. These people are often familiar with the newest technologies and therefore better able to compare and oversee the many differences between EVs and conventional vehicles [27].
Roehrich [28], assessed that Roehrich's scale has the highest validity for product consumption among several consumer innovativeness scales perceived. Roerich's scale has two distinct dimensions: the need for stimulation, referred to as hedonistic innovativeness and the need for uniqueness, called social innovativeness. These dimensions can be measured by the following statements.

Hedonistic innovativeness

- I am more interested in buying new than known products.
- I like to buy new and different products.
- New products excite me.

Social innovativeness

- I am usually among the first to try new products.
- I know more than others on latest new products.
- I try new products before my friends and neighbors.

2.2.1.2 Normative beliefs and subjective norms

The second determinant within Ajzens Theory of Planned behavior is subjective norm [18]. This phenomenon relates to the perceived social pressure to perform certain behavior. According to Ajzen, a persons subjective norm is the outcome of a weighted sum of normative beliefs of important others regarding the behavior in question. The subjective social norm SN of person i based on important others j is calculated by the strength of j's normative belief and person i's motivation to comply with j's normative belief, see Equation 2.1.
For example, a person considers purchasing a FEV. He has two important others: his best friend and his girlfriend. To construct the subjective social norm one can first ask the person to rate the degree to which his best friend and his girlfriend would approve or disapprove buying a FEV. Second, the person is asked to rate the degree to which he cares whether his best friend and his girlfriend would approve or disapprove his car purchase decision.

$$SN_{i,j} = \sum_j n_j \times m_j \tag{2.1}$$

2.2.2 Factors influencing the car purchase decision

Arguing from Figure 2.3, the attitudes and subjective norms shape the factors predicting the intention to buy and AFV: instrumental, affective and instrumental factors. This section goes into these three types of factors in more detail.

2.2.2.1 Symbolic and affective factors

Many authors have stressed the importance of symbolic and affective factors related to car use and purchase decisions; especially the work of Linda Steg is extensive [19, 29, 30]. First, symbolic factors are twofold: material possessions like cars can both serve self-expression and categorization. For example: young car-owners sometimes modify their factory-standard car to personalize it, which is called tuning. This is a sign of self-expression. Frequently, these people are also member of a tuning club: a group of people with modified cars, sometimes of the same brand and model. This reflects the social-categorical part of symbolic factors in car ownership behavior. Schuitema [20] measured the prevalence of symbolic attributes in AFV adoption intention by three statements:

- Compared to a normal car, PHEV/FEV cars are not suitable for my lifestyle.
- I would feel proud of having a PHEV/FEV outside my house.
- I would feel embarrassed to drive a PHEV/FEV.

Affective factors are often bracketed together with symbolic factors, but these factors are fundamentally different. Symbolic factors are aimed at the social aspect: the individual and his relation to other (groups) of individuals. Affective factors, on the other hand, mainly concern the individual and his emotions. Steg [29] summarized a list of emotional aspects of car use, derived from an extensive literature study. Note that the following summary of affective factors consists of both positive and negative emotions:

- Sense of speed
- Excitement
- Driving fun
- Stress
- Risk-taking
- Aggression
- Annoyance

Schuitema [20], measured affective factors by three statements:

- Compared to a normal car, PHEV/FEVs are very pleasant to drive
- Compared to a normal car, PHEV/FEVs are very exciting new technology
- I would prefer to drive a PHEV/FEV over a normal car

2.2.2.2 Instrumental factors

The previous sections focused on the social and psychological factors influencing car purchase behavior. However, up till now the largest body of alternative vehicle adoption mainly focused on the instrumental attributes of cars and the main instrumental function it fulfills: enabling people to engage in activities. As already mentioned, it is shown that instrumental factors influence car purchase directly as well as indirectly by influencing the symbolic and affective factors. This sections provides an overview of relevant car characteristics in car choice making including AFVs. This overview is derived from the substantial body of peer-reviewed literature on AFV preferences and summarized by Hoen and Koetse [1].

Purchase price The purchase price of an AFV, including vehicle sales tax, is a commonly used attribute in studies on AFV adoption studies. As AFV technology is relatively new vehicle technology, AFVs have significantly higher purchase prices than conventional cars. As this higher purchase price is assumed to depend on the vehicle's battery capacity and range consequently, some stated preference studies make the purchase price range-dependent (see for example Hoen and Koetse [1]). As for all cost-related attributes, the purchase price has a negative effect on the preference of a choice alternative. Several countries all over the world, as a response on the high AFV purchase prices, offer substantial tax rebates in various forms [31]. These tax rebates are promising in increasing AFV market shares, especially in countries with high vehicle sales taxes [32]. However, it must be stressed that both technological and political future developments are unknown. Political policies have shown to have significant effects of vehicle sales [6] and technological developments are difficult to predict [1].

Fuel cost Fuel costs of AFVs are substantially lower than for conventional cars. Not surprisingly, almost all studies listed by Hoen and Koetse include fuel cost or a related formulation (i.e. fuel efficiency, fuel consumption) in their study for AFV preferences. Hidrue et al [22] found that peoples hypothetical choice for an AFV would be driven largely by fuel savings, opposed to the environmental benefit.

Operation and maintenance costs Operation and maintenance costs involve the costs of keeping the car operational, for instance lubricants, replacement of wearing parts and repair of failures. As AFV technology is a relatively new technology, limited information is available for predicting AFV operation and maintenance costs. However, experts predict them to be lower than for conventional vehicles as AFVs contain less wearing parts. Regarding FEVs, skepticism exists on the part of substantial battery degradation on the long run. Although it is shown that this is no longer an issue, potential buyers may see still see this as a long-term risk for FEVs [23].

Range The range of a vehicle indicates the distance the vehicle can drive on a full battery or fuel tank. The range of a conventional vehicle varies between 500 and over 1000 km. The total range of a PHEV is approximately the same, consisting of around 50 km electric range before it switches to fuel. However, the current typical range of a FEV is a mere 150 km on average. Not surprisingly, the larger part of the studies conclude the range of a FEV is perceived as the major limitation hindering mass adoption, see for example Hidrue et al [22], Mau et al. [33] and Train [34].
Regarding FEV range, range anxiety is a frequently studied phenomenon in literature. Most research definitions of range anxiety define it as the perception or experience of drivers regarding the fear of not reaching their destination in an EV [35]. In other words: people, used to conventional cars with ranges up to 1000 km, perceive the much lower range performance of FEVs as a major limitation as they think the range is not sufficient for their travel behavior. Recent studies indeed indicate this range anxiety is indeed reasonable: only 5% of the one-car households in the Netherlands can fully substitute their car with an EV under current travel behavior [36]. Also, range anxiety has been found during the use of a FEV. People's trust in the vehicle-estimated range often lacks. Consequently, drivers are not comfortable at using the vehicle's full range and are reported to keep a range buffer of around 20% [35].

Recharge and refuel time The recharge/refuel time is the time involved to fully charge or refuel the cars fuel tank or battery. Refueling conventional cars takes a few minutes. Recharge times of PHEVs and FEVs are much longer and are dependent of the battery capacity and the type of charger. PHEVs have a recharge time of a few hours, due to the small battery. FEV charge cycles can take over 12 hours when charging from a wall socket. Chargers can be divided into normal chargers, meant for home and destination charging (public places and work), and rapid chargers, meant for on-trip charging at highway locations. Rapid chargers can charge a nearly empty battery to nearly full in 30 minutes [37]. Studies on AFV preferences like the research of Hidrue et al. [22] find rather large willingness-to-pay figures for shorter charging times. These figures indicate that potential AFV buyers are willing to make substantial investments in a vehicle with faster charging times.

Fuel availability Fuel availability refers to the network of places to refuel or recharge the vehicle. Refueling conventional cars takes place at a relatively dense network of commercial fuel stations. Recharge locations of electric vehicles are more diverse and currently less dense. The recharge locations range from private chargers at home and semi-public chargers at work, to public chargers at points-of-interest and rapid chargers at highway locations. Moreover, not all drivers have access to the same charging options. Not all drivers have a charger at home and/or at work, especially in urbanized areas. This diversity and dispersion has influence on the above mentioned range anxiety, as it can cause uncertainty of being able to recharge the vehicle at the

destination or during the trip.
Research has shown that the charging infrastructure is important in the intention to adopt an AFV, as it increases the compatibility of the EV with current travel behavior of drivers and can compensate for the limited range of EVs [38]. The importance indicated by Petschnig et al. is supported by others, that conclude that high fuel availability influences AFV choice positively [33, 39], including the possibility to charge at home [1].
Regarding the roll-out of the electric charging infrastructure, the chicken-and-egg problem seems present. It is shown that an extensive charging infrastructure is important for EV adoption, but on the other hand the business case of developing a charging infrastructure with few EVs is very weak.

Emission reduction Reduced (tailpipe) emissions are seen as the major advantage of AFV cars compared to conventional cars. It is shown that lower tailpipe emissions are valuated positively in choice experiments [40] and relatively large willingness-to-pay figures are found [1]. But Hoen and Koetse stress that these results should be interpreted cautiously as people tend to give socially desirable answers in choice experiments as reduced emissions largely contribute to social welfare rather than individual welfare. Second, the emission reduction of electric vehicles is not without dispute. Research into attitudes and perceptions of consumers regarding EVs showed that the majority of the respondents remains uncertain about sustainability of EVs, as the majority of electricity is generated in gas or coal power plants, and thus the emissions basically are transferred from the car to the power plant [27].

Number of available models Studies into buyer preferences for a car have shown that individual preferences widely vary [41]. With this information, Hoen and Koetse [1] included the number of available models in their study on AFV preferences, as they assumed that the likelihood for the individual in finding a suitable model is higher with more models available to choose from. They found that a higher number of available models indeed contributes to AFV adoption. Currently, 15 FEV and 20 PHEV models are available in the Netherlands [42]. This is a small number of models compared to the more than a hundred conventional car models available. This attribute can be related to the two-stage choice process of Figure 1: the number of available models on the market can be seen as the universal choice set. As individual preferences widely vary, it is likely, that for some individuals none of the PH(EV) models meets their non-compensatory preferences and thus does not end up in the individual choice set.

2.2.3 Influence of socioeconomic and travel-related variables

Besides the social, psychological and instrumental factors influencing the purchase decision of a car, most researches on this topic also related socioeconomic characteristics and travel behavior characteristics of the choice maker to his preferences. This section therefore indicates a number of socioeconomic variables and travel behavior related variables that have a relation with AFV adoption.

2.2.3.1 Socioeconomic variables

Age Several studies consistently find a relation between age and the likelihood of adopting an AFV: people of a higher age generally have a lower intention to adopting an AFV [21, 22, 40, 43]. A reasonable explanation of this finding can be found in the perspective of an AFV being a new technology, as suggested earlier this chapter (see Section 2.2.1). The relation between age and AFV adoption is in line with research on general new technology adoption and innovativeness: lower age is associated with a higher intention to adopt new technologies [44].

Education level Research shows that people with a higher education level have a higher intention of buying an hybrid vehicle [40] or an electric vehicle [22]. However, an explanation for this finding cannot be linked to general new technology adoption, as some studies could not proof a correlation [45].

Income Research into the effect of income on the intention to adopt an AFV shows somewhat mixed results. Some research indicates high income individuals have a higher intention to buy an AFV [46] and have higher willingness-to-pay for better performing cars [40]. Other researchers conclude that income is not important [22]. It should also be noted that income and education levels are correlated, which clouds the effects of either variable.

Gender Several researchers found that females have significantly higher stated preference for electric vehicles and hybrid vehicles [32]. This finding follows Morris finding, that the old stereotype of new technologies being a male-oriented domain seem to disappear [44].

2.2.3.2 Travel behavior

Besides socioeconomic variables, a driver/familys travel behavior can be of influence on the intention of adopting an AFV. For example, Van Meerkerk et al. already concluded that current travel behavior of the main part of Dutch households is not 100% compatible with the range of an electric vehicle [36]. Certain travel behavior related aspects can therefore lower the likelihood of adopting an AFV or exclude them on beforehand.

Annual mileage and commuting behavior Drivers with a high annual mileage have a more negative preference for full electric vehicles [1]. Hoen and Koetse relate this to the limited drive range as the effect of high mileage is also observed in the higher willingness-to-pay for extra driving range for people with high annual mileage. Correlated with a high annual mileage is a driver's commuting behavior. People that commute to work by car every day or with long commuting distances have stronger negative preferences for AFVs [1, 40].

(current) Car size It is shown that people, intending to buy a small/medium car increases the likelihood of buying an EV [22, 23]. Tendency to buy a small/medium car increases the propensity of buying an EV [22]. A possible explanation is that these people probably have a low mileage, as frequent drivers often drive larger cars. Regarding a driver's current car, Hoen and Koetse [1] found that the fuel type of the current car has only marginal influence on the preference for an AFV.

Number of vehicles Research generally finds multivehicle households have higher intention to adopt an AFV than households with only one car available [46–48]. An explanation of this finding is that the importance of the AFV's driving range decreases significantly when respondents have a second (conventional) car available [24]. These households can choose their car depending on the nature of the trip. For example, in the Dutch situation the number of households that can maintain their current travel behavior rises to 12% when a multicar household changes one of their cars to an FEV, compared to 5% for a single-car household [36].

Holiday behavior Car use for holidays abroad decreases the preference for an electric vehicle. Obviously, the long distances covered during holidays make limited range FEVs not suitable for these trips. The results for drivers using the car for towing a caravan are in line with this: it decreases the preference for AFVs. Power and range uncertainty are assumed to be the reasons for this [1]. Although holiday trips usually only take place a few times per year, drivers, especially in single-car households, have only one car available to make all their trips. Holiday behavior is assumed to be one of the reasons behind the results. Van Meerkerk et al. [36] found: only 5% of the Dutch households can maintain their current travel behavior with a FEV.

Company or private car ownership The cost structure of owning a lease car vs a private car is very different. In the Dutch context, company car owners pay a monthly all-inclusive fee for their cars, whereas private car owners pay separately for all car-related costs. Related to the cost structure is the tax structure, which is also very different between the two types of car ownership. Car choice behavior consequently may be different as well. Hoen and Koetse [1] showed that, arguing from differences in willingness-to-pay figures, indeed private and company car owners have different preferences. They show that in the short run, private AFV sales can profit most from technological improvements, whereas company AFV sales are likely to profit more from longer run investments like charging infrastructure improvements.

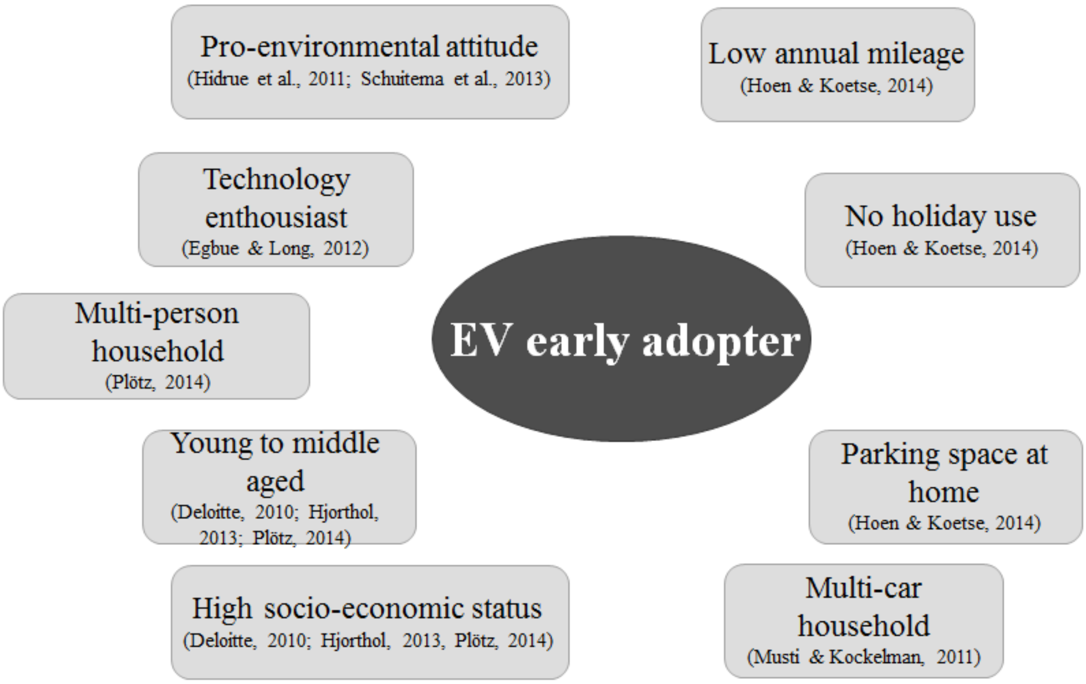


FIGURE 2.4: Characteristics of EV early adopters

2.2.4 FEV early adopters profile

Hoen and Koetse [1] found that preferences for AFVs are considerably heterogeneous. Nevertheless, several previous researches have tried to elicit early adopter characteristics: personal characteristics of groups of people that have a high likelihood of adopting an EV. Figure 2.4 provides an overview of FEV early adopter characteristics.

2.3 Overview Dutch EV stimulating polices

This section describes the current Dutch vehicle tax scheme [6] and the intended changes for 2017-2020 [9] for both private car ownership and company car use. In addition, several non-tax related policies are mentioned.

2.3.1 Current Dutch vehicle tax scheme

The Dutch vehicle tax scheme applies three types of taxes to private car ownership: vehicle sales tax, annual road tax and fuel taxes. Company car use is taxed by a fixed monthly fee.

Table 2.1: Dutch vehicle sales tax scheme 2015

Threshold	Threshold (g/km CO_2)	Price per g/km CO_2 per threshold[1)]
Fixed fee	< 1	€175
Threshold 0	< 83	€6
Threshold 1	< 111	€69
Threshold 2	< 161	€112
Threshold 3	< 181	€217
Threshold 4	> 180	€434

1) A additional charge of €86 per g/km CO_2 is levied for diesel cars > 70 g/km CO_2

Vehicle sales tax The Dutch vehicle sales tax is a one-time payment when the consumer purchases a new car. The Dutch vehicle sales tax dependents on the g/km CO_2 emitted by the vehicle. It consists of a fixed amount plus an amount per g/km CO_2 emitted. Higher amounts per g/km CO_2 are charged for diesel vehicles, for which EURO6-rated diesel engines receive a discount. Table 2.1 shows the exact amounts. In practice, FEVs are only charged the negligible fixed fee of €175. PHEVs are charged €6 per g/km CO_2 as they all emit < 83 g/km CO_2.

Annual road tax The base amount of annual road tax depends on the weight of the vehicle and is constituted by the Dutch government, increased by a province-dependent surcharge. Higher amounts are charged for diesel and LPG vehicles. Vehicles that emit < 50 g/km CO_2 are exempted from annual road taxes. As a result, FEVs and PHEVs are exempted from road taxes in 2015.

Fuel tax Fuel tax is charged by a fixed surcharge per liter, that is already included in the fuel price the consumer pays at the fuel station. The amount of tax charged depends on the fuel type. Electricity taxes are regulated in different legislation. A numeric example of the Volkswagen eGolf (energy consumption 12.7 kWh/100km) and the Volkswagen Golf 1.2 TSi petrol version (fuel consumption: 5 L/100km) and the tax levels below, demonstrates an EV tax benefit of €2.33 per 100 km.

The taxes for fuel and electricity in 2015 are:

- Petrol: €0.77 per liter
- Diesel: €0.48 per liter
- LPG: €0.33 per liter
- Electricity €0.1196 per kWh

Private contribution for company car use The tax scheme for company car use consists of one tax type: an annual contribution fee. A percentage of the vehicle sales price (including sales tax and VAT) is added to the taxable income of the user if the user uses the company car for

TABLE 2.2: Private contribution percentages for company car use

Percentage	CO_2 emission in g/km
4%	0
7%	1 – 50
14%	51 – 81
20%	82 – 110
25%	> 110

private purposes. As a result, the company car user pays for company car use by being charged higher income tax. The percentage of the vehicle sales price that is added to the taxable income depends on the vehicle's g/km CO_2 emission. Table 2.2 shows the percentages and corresponding emission thresholds. This scheme implicates 4% contribution for FEVs and 7% contribution for PHEVs. This scheme makes FEVs and PHEVs attractive for company car drivers as the benefits of the low contribution percentages in most cases compensate more than the higher FEV and PHEV sales prices.

2.3.2 2017-2020 changes in the Dutch vehicle tax scheme

The Dutch government has been trying to stimulate the transition to electric mobility by fiscal policy measures since 2007. Dutch car drivers have shown to be sensitive to these policy measures and as a result, the Dutch car fleet has on average the lowest CO_2 emission in g/km per car in Europe [7]. However, the policy measures induced several undesired side effects, including tax revenue deficits, disturbance of the vehicle sales market and policy execution complexity. Moreover, studies of the Court of Auditors, the Environmental Assessment Agency Netherlands and TNO have shown that the costs of the policy measures are disproportional to the environmental benefits. Several changes are proposed by the Ministry of Finance in order to generate a stable income from vehicle taxes and actual contribution to environmental goals by proportional fiscal stimulation [9].

Implications for FEVs The vehicle sales tax for FEVs remains negligible. Although the fixed fee will increase from €175 to €350, this amount is negligible relative to their purchase price and vehicle sales taxes of conventional cars. Furthermore, annual road tax exemption for FEVs remains as well. The largest policy change regarding FEVs is for company car users. To balance the tax benefit of luxurious FEVs, the 4% contribution will be capped to a purchase price of €50,000. A percentage of 22% will be applied to the amount that the sales price is over €50,000.

Implications for PHEVs The policy changes have thorough implications for PHEVs as research has shown that, in practice, PHEVs drive a lot less kilometers in electric mode than the

Table 2.3: Dutch vehicle sales tax scheme 2020

Threshold	Non-PHEVs Threshold ($g/km\ CO_2$)	Non-PHEVs Price per $g/km\ CO_2$	PHEVs [1)] Threshold ($g/km\ CO_2$)	PHEVs Price per $g/km\ CO_2$
Fixed fee	< 1	€350	< 1	€0
Threshold 0	< 83	€2	$1 - 30$	€30
Threshold 1	< 111	€66	$31 - 50$	€125
Threshold 2	< 161	€145	> 50	€300
Threshold 3	< 181	€238		
Threshold 4	> 180	€476		

1) An additional charge is levied for diesel cars

New European Driving Cycle (NEDC) accounts for when determining a car's CO_2 emissions [8]. As a result, PHEVs will be treated more as a conventional car in the future tax scheme. Firstly, PHEVs will have dedicated thresholds for the vehicle sales tax. The resulting vehicle sales taxes are substantially higher than the current €6 per g/km CO_2 for PHEVs. Table 2.3 shows the vehicle sales tax scheme for non-PHEVs and PHEVs in 2020. Secondly, the annual road tax exemption of PHEVs will gradually disappear from 2017-2020. After 2018, PHEVs are threaded similar to conventional cars for the annual road tax, albeit with a weight correction of -300 kg to compensate for the extra weight of the electric drive train and batteries. Finally, the attractiveness of PHEVs as a company car will gradually disappear from 2017-2020. The system of the current five percentage categories, shown in Table 2.2, will gradually be converted in a two categories system: 4% for 0 gr/km CO_2 vehicles (FEVs) and 22% for all other vehicles. As a result, PHEV versions of car models will become less attractive than their conventionally powered versions due to the combination of an equal contribution percentage and a higher sales price.

Implications for conventional cars Implications of the intended policy changes are small for conventional cars. The vehicle sales tax will be slightly lower due to the smaller CO_2 dependency. Furthermore, the annual road tax will be slightly (2%) lower, except for old diesel vehicles. For company car users, the highest private contribution percentage is lowered from 25% to 22%, which is the category most currently available cars belong to.

2.3.3 Non-tax oriented EV stimulating programs

The Dutch national government focuses its EV stimulating programs on tax measures. However, in addition to the vehicle tax scheme, the Dutch national government also developed non-tax related stimulation programs. The majority of the non-tax related project are currently organised as 'Green Deals' [49]. Green Deals are project-based subsidies. The projects are bottom-up initiatives of regional governments, companies or NGOs. The national government facilitates

the Green Deals by subidies and necessary adjustments in legislation.
The current Green Deals aiming to stimulate EV sales are mainly projects initiated by regional government to develop the public charging infrastructure further [50]. Other Green Deals include EV experience programs. An overview of all Green Deals can be found on the web page of Ondernemend Groen [51].

2.4 Conclusion

Car use and ownership is driven by instrumental, affective and symbolic factors. Additionally, a choice maker's perception of the instrumental, symbolic and affective performance of a car are affected by the choice maker's own attitude towards the intended car of choice and the subjective norm of choice maker's important relatives about the intended car of choice. This theoretical framework for consumer car buying behavior is derived from Dittmar's Theory of Material Possession and Ajzen's Theory of Planned Behavior, two widely acclaimed theories on general material possession. Previous research on EV preferences demonstrated the validity of this framework for EV purchase intentions.

The main part of the studies into AFV preferences focuses on the importance of their instrumental attributes. Instrumental factors deal with the functional benefits of using a car: taking the driver from A to B. First, cost attributes are examined in many studies. Costs have a negative effect on the attractiveness of cars. As AFV technology is relatively new, the purchase price of AFVs is higher than comparable conventional cars. Fuel costs and operation and maintenance costs, on the other hand, are substantially lower for AFVs than for conventional cars.
In addition to the difference in costs, AFVs are different from conventional cars during everyday use. Especially FEVs have far less range than conventional cars and much longer recharge times. Furthermore, the current fuel availability of conventional fuels is higher than for alternative fuels. The limited range of AFVs is argued to be the main barrier for AFV adoption. Previous studies have shown that a dense network of charge points and rapid charging technology are important attributes to increase consumer adoption of AFVs as they increase the compliance of the (limited range) AFVs with current travel behavior.
Furthermore, reduced emissions of AFVs compared to conventional cars, are argued to positively affect the attractiveness of AFVs. Finally, the limited number of available AFV models is argued to negatively influence the attractiveness of AFVs, as it is shown that car owner's individual preferences for car models in terms of design, size and et cetera widely varies.

Besides instrumental factors, car ownership is influenced by symbolic and affective factors. Symbolic factors concern the identity a car owner wants express with his car. In addition, cars can provide social categorization for the owner. The affective factors describe the emotions car use

can excite at the owner, like joy and excitement but also stress and aggression. Previous research has shown that a simple dichotomy between instrumental, affective and symbolic factors of car use is an oversimplification. The valuation of cars on instrumental factors is shown to influence the perception of their affective and symbolic factors and vice versa.
A car owner's perception of the instrumental, symbolic and affective performance of cars depends on his perceived personal identity. Car owners with a pro-environmental identity or a high technological interest are shown to find AFVs more attractive less pro-environmental or technologically oriented car owners.

Several socio-economic and car use characteristics are shown to be related to AFV preferences. Car owners with a high likelihood of buying AFVs are found to be younger or middle aged and often highly educated. Car use also affects the preferences for AFVs. Drivers with a high annual mileage or a high daily commuting distance are shown to have a more negative preference for AFVs. Furthermore, car owners that drive a smaller car show a higher likelihood of buying AFVs, as well as car owners with multiple cars in the household. Finally, car owners' holiday behavior plays a role at his AFV preferences. Car owners that use their cars for holidays have lower preferences for AFVs, as AFVs are generally not suitable for towing and their limited range hinders long-distance drives.

Chapter 3

Research Approach

This research concerns conventional and hybrid car owners' preferences for FEVs and PHEVs. This chapter first describes the motivation to perform this study. Secondly, the research objective and research questions are posed. Finally, the research design is described.

3.1 Motivation

The literature study of Chapter 2 has shown that AFV adoption by car owners received ample attention from scientific research. This research will add to this body of research by examining the influence of current car type ownership on AFV preferences. More specifically, looking for differences between hybrid car owners and conventional car owners in their preference for FEVs and PHEVs will form the main objective of this research. This approach to EV adoption is chosen with the idea that hybrid car technology is a stepping stone in the transition from conventionally powered cars to electric cars. Owning a partially electric car makes hybrid car owners an interesting car owners segment. These car owners already chose to buy a more environmental-friendly car instead of a conventional car before. In addition, they have experience with (partially) electric driving. The questions rises whether their previous choice for a more environmental-friendly car and current experiences also lead to higher preferences for full electric cars. The literature study concluded that car purchase behavior in influenced by instrumental, symbolic and affective factors. These three types of factors will be used as the indicators describing FEV and PHEV preferences of conventional and hybrid car owners.

3.2 Research questions

The main research objective is formulated as follows:

"To quantify the differences in preferences between conventional and hybrid car owners for instrumental FEV and PHEV attributes and the role of symbolic and affective factors at their FEV and PHEV willingness-to-buy."

1. How do the preferences of private hybrid car owners and conventional car about instrumental attributes of FEVs and PHEV differ?
2. What symbolic factors, affective factors and personal identities influence the willingness to buy a FEV or a PHEV?
3. How does the importance of symbolic factors, affective factors and personal identifies differ between conventional and hybrid car owners?
4. Which exploratory indications can be found at PHEV owners that are beneficial of possible FEV purchase in the future?

The following section will describe on the over-all approach of this research and continues to detail on the data sets and model types used to answer each research question.

3.3 Research design

As a result of being a relatively new technology, hybrid cars and PHEV cars are a minority in the Dutch car fleet. In 2014, 156.000 hybrid cars and 40.000 PHEVs were owned in the Netherlands, on a total car fleet of 8 million cars [52, 53]. Being such a small population, data collection on the preferences of hybrid car and PHEV owners is costly. This research opted for using existing databases over new data collection for resource reasons (time frame, costs and supervision). Three different data sets were made available for this research. These data sets originate from surveys already fielded by Hoen and Koetse [1] and Accenture et al. [2].

The chosen research approach was adapted to the data sets available for this research. As a result, the influence of instrumental attributes (research questions 1) and the role of symbolic and affective attributes (research question 2 and 3) was examined separately. Ideally, a hybrid choice model would have been estimated to answer research question 1 to 3 with one model. Hybrid choice models allow for simultaneous estimation of a choice model (on the instrumental attributes) and a latent variable model on the symbolic and affective factors. By doing so, the relative importance of instrumental, symbolic and affective factors can be assessed. This, however, requires response on all three aspects from the same respondents. This was not the

Table 3.1: Survey response

Segment	Instrumental attributes	Symbolic and affective attributes	Both survey completes
Conventional car owners	1899	1203	1203
Hybrid car owners	128	199*	26

* New respondents were recruited to increase the number of hybrid car owner respondents.

case with the available data sets. Table 3.1 shows that the number of hybrid car owners that are present in both data sets is too low ($n = 26$) to estimate a hybrid choice model. Table 3.1 also shows that the number of observations for the hybrid car owners segment in both data sets individually ($n = 128$ and $n = 199$ respectively) is just sufficient for separate model estimation. A number of around 150 respondents is generally used as a rule of thumb of minimum amount of respondents needed for discrete choice modelling.

3.3.1 Instrumental attribute influence on FEV and PHEV preferences

The influence of instrumental attributes on the preference of FEVs and PHEVs, following research question 1, will be answered with a data set from Hoen and Koetse's stated preference survey on instrumental attribute preferences of private car owners. The analysis is described in Chapter 4. The data set contains the results of a stated choice experiment for five AFV types: hybrid cars, PHEVs, FEVs, flexifuel cars and fuel cell cars. Mixed logit models will be estimated to examine the influence of instrumental attributes on the perceived utility of FEVs and PHEVs. These models also allow for quantification of the differences between conventional car owners and hybrid car owners.

The data set is well suitable for answering research question 1, as it includes nearly all instrumental attributes mentioned in the literature study of Chapter 2. Table 3.2 shows the instrumental attributes present in the data set and their corresponding descriptions. Hoen and Koetse used a specific approach for defining the attributes 'variable costs' and 'fuel availability'. First, the attributes fuel costs, maintenance cost and road taxes are merged to one single attribute: monthly costs. Second, fuel availability as and attribute was defined as additional detour time to reach a suitable fuel station rather the number or density of fuel stations. Thirdly, emission reduction is often used as instrumental attribute in other research, but not present in the data set here.

Finally, it should be emphasized that this data set only contains data of Dutch private car owners for the instrumental attributes. Company car usage in the Netherlands features a very different cost structure, as described in Section 2.3. Consequently, preferences for monetary instrumental attributes of company car users are very different from private car owners and thus cannot be estimated in one model. For time reasons, the research is therefore limited to private car owners. For the same reason, assessment of interaction effects between instrumental attributes

Table 3.2: Attributes in the stated choice experiment

Attribute	Description
Purchase price	The purchase price of the vehicle, dependent on the respondent's usual car purchase price. Mark-ups per AFV were used to reflect higher purchase price of AFVs.
Monthly cost	A combination of fuel costs (tailored to respondent's mileage, maintenance costs and, if applicable, road taxes.
Driving range	The number of kilometers to be driven on a full tank or fully charged batteries, depending on the car type.
Recharge/refuelling time	The time it takes to fully charge or refuel the car, depending on the car type.
Additional detour time	The additional detour time to reach a fuel station that has the required AFV fuel/electricity compared to a gas station, depending on the AFV type.
Number of brands/models	The number of different car brands and models available for that car type, AFV type dependent.
Policy measures	Beneficial policy measures for AFVs like urban bus lane use and free parking.

and car use characteristics (annual mileage, commuting distance, and etc.) was excluded from the research scope. Hoen and Koetse examined these interaction effects in their paper on AFV preferences [1].

3.3.2 The role of symbolic and affective factors

Research questions 2 and 3 will be examined by a second data set, which originates from a follow-up survey of PBL to the stated choice experiment described in the previous paragraph. The analysis is described in Chapter 5. The data set consists of Likert scale response to qualitative statements on symbolic and affective factors and car use in general. Ordinal logit models will be used to quantify the role of symbolic, affective and personal identity factors in the respondents willingness-to-buy and FEV or PHEV as a next car. This willingness-to-buy serves as the dependent variable in the model and was measured by the question: "Rank your likelihood of buying a [FEV/PHEV] as a next car on a $0 - 100\%$-scale.". The ordinal logit model is an appropriate model type to incorporate the ordinal nature of the dependent variable [54].
Table 3.3 provides an overview of the data set contents. PBL derived its formulation of the symbolic and affective statements from statements used in previous studies on the roles of affective and symbolic factors. A respondent's perception of his personal identity was measured by 20 statements about car use in general. A factor analysis will be performed to construct latent personal identities from the response on the 20 statements. In addition, the role of four socio-economic variables will be tested: gender, age, social class (a construct of income and education level) and urbanisation level of the respondent's place of residence. The first three variables are commonly used variables in other research on this topic (see Section 2.2.3.1) and

Table 3.3: Contents attitudes survey

Data set parts	Measurement method	Scale
Symbolic and affective factors at car choice	4 symbolic and 5 affective statements	7-point Likert scale
Personal identity perception	20 statements	7-point Likert scale
Current AFV performance perception	4 statements	7-point Likert scale
Willingness to buy (WTB) an AFV type as next car	1 WTB percentage per AFV type	11-point Likert scale

the fourth was included to test the hypothesis that residents of highly urbanised area's have a higher willingness-to-buy a FEV or PHEV.

3.3.3 Exploratory analysis PHEV driver experiences with electric driving

A data set of the Dutch National Survey Electric Driving 2014 (NSED) will be used to answer research question 4. The analysis is described in Chapter 6. The NSED is an annual survey into the experiences and preferences of Dutch FEV and PHEV owners. The limited response of the survey, being 69 PHEV owners and 140 FEV owners, only allows for exploratory analysis of PHEV driver preferences for FEVs. Moreover, as focus of the NSED questions was mainly on the current experiences of PHEV drivers, with emphasis on the charging infrastructure, rather than on future car preferences. Thorough understanding on the preferences of current PHEV drivers besides current hybrid drivers would be of great interest for this research, as the plug-in hybrid car technology is seen as 'the next step' in vehicle transition to FEVs. This is advised as a direction for further research that has resources available for own data collection.

The data set of the 2014 NSED will be used to search for indications that suggest PHEV drivers have a high likelihood of buying a FEV as a next car. First, the socio-economic profile of the PHEV drivers will be compared to the FEV drivers in the data set and to the socio-economic characteristics of early FEV adopters, mentioned in literature (see Figure 2.4). Table 3.4 shows the socio-economic characteristics examined in this research. The early adopter characteristics 'multi-person household', 'parking space at home' and 'holiday use' could not be examined as there was no data available on these variables. Secondly, correlations will be examined between the respondent's evaluation of his current car and charging infrastructure and his preference for a next car. The data set only contains evaluation data of the current car on instrumental (ie. range experience) and affective aspects (ie. comfort), none on the symbolic aspects. This evaluation will be related to the response on the question "What will be your next car type?". Thirdly, data about the respondent's decisive factors in the car purchase phase will be explored to examine whether some (non-)monetary factors are more important for drivers that a likely

Table 3.4: Socio-economic and travel-related variables used for analysis

Variable
Age
Gender
Highest followed education
Private/company car ownership
Annual mileage
Commuting distance
No. cars in household

to buy a FEV in the future. Differences in importance of several monetary and non-monetary factors will be examined with independent sample t-test between respondents that indicated to buy a FEV as a next car and respondents that indicated to stay with a PHEV.

3.4 Delimination

This research targets current owners of either hybrid electric vehicles or plug-in hybrid electric vehicles. Some data is gathered on the preferences of owners of a full electric vehicle, but this will be for comparison only. Furthermore, only the preferences for two types of alternative fuel vehicle as next car will be considered: a plug-in hybrid vehicle and a full electric vehicle. Other types of alternative fuel vehicles, sometimes present in other studies, are hydrogen vehicles or biofuel vehicles. These vehicles are beyond the scope of this research.
Another condition for interpreting the results of this research is, that it will be based on Dutch respondent data. Regional geographical and demographic differences, but also national car tax schemes often make transferability of transportation research results troublesome. Besides caution for spatial transferability, it should also be noted that this research subject is likely to be influenced by the current tax scheme. Results and predictions from this research are made under the assumption that the current car tax scheme in the Netherlands will not change rigorously, as people are likely to have other preferences at considerably different tax schemes like kilometer charging.

Chapter 4

Instrumental car preferences of hybrid car owners

Instrumental factors like purchase price, monthly costs, range and recharge options are widely perceived to be important in explaining consumer AFV preferences. This research builds upon a large body of research into consumer preferences on instrumental attributes of AFVs, see Section 2.2.2.2. Our research here contributes to this research by explicitly aiming for preferences between current owners of a hybrid car compared to current owners of a conventional car. The hypothesis here is that hybrid car owners have AFV preferences that are beneficial for future FEV adoption, as they already own a partially electric vehicle. The line of reasoning here is that consumers, having chosen to buy a partially electric car instead of a conventional car before, suggests they are more open for FEVs than conventional car drivers. Moreover, they already have experience with the characteristics of partially electric drive trains.

Data of a stated choice experiment was used to quantify the preferences for instrumental AFV attributes. The data was gathered by Hoen and Koetse [1] for their own research into AFV preferences and was made available for our research. The study of Hoen and Koetse examined the preferences of private car owners for more AFV types than just the FEV and the PHEV; also the fuel cell car, flexifuel car and the hybrid car were considered. Their study concludes that negative preferences for AFVs are large, especially for the FEV, mostly as a result of their limited driving range and long recharge time. They showed that improvements in AFV characteristics can improve the preference of AFVs substantially, but a negative WTP of €10.000 - €20.000 per AFV remains. Our analysis here adds to their study by specifically examining the role of current car type ownership. The data set contains information about the currently owned car type: conventional or hybrid car. The analysis aims to quantify the differences in preferences for AFVs of conventional versus hybrid car owners.

TABLE 4.1: Attributes in the stated choice experiment

Attribute	Description
Purchase price	The purchase price of the vehicle, dependent on the respondent's usual car purchase price. Mark-ups per AFV were used to reflect higher purchase price of AFVs.
Monthly cost	A combination of fuel costs (tailored to respondent's mileage, maintenance costs and, if applicable, road taxes.
Driving range	The number of kilometers to be driven on a full tank or fully charged batteries, depending on the car type.
Recharge/refuelling time	The time it takes to fully charge or refuel the car, depending on the car type.
Additional detour time	The additional detour time to reach a fuel station that has the required AFV fuel/electricity compared to a gas station, depending on the AFV type.
Number of brands/models	The number of different car brands and models available for that car type, AFV type dependent.
Policy measures	Beneficial policy measures for AFVs like urban bus lane use and free parking.

4.1 Data set contents and data collection

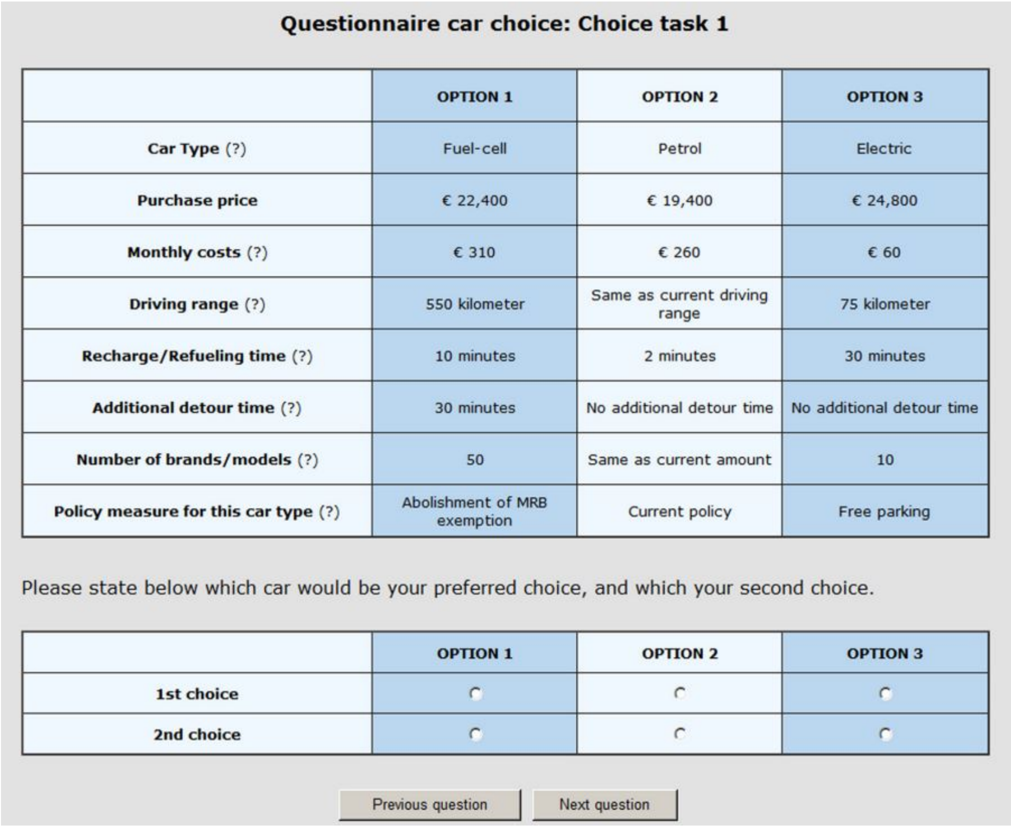
Data of a stated choice experiment was used to quantify the respondent's preference for instrumental attributes for five AFV car types: hybrid car, plug-in hybrid car, full electric car, flexifuel car and the hydrogen fuel cell car. This research focuses on the results for the (plug-in) hybrid and the full electric car.

4.1.1 Data set contents

The data set consisted of three parts. First, information about the car use and ownership of the respondent was asked, like annual mileage and current car type. Second, the stated choice experiment was presented by 8 choice cards. Figure 4.1 shows an example of a choice card. Stated choice experiments should be designed carefully on the part of attribute choice and attribute levels definition. Table 4.1 shows an overview of the attributes used in the experiment and their corresponding descriptions. A detailed description of the stated choice experiment design can be found in Appendix B. Thirdly, the respondents were asked to rate the performance of each AFV type on environmental impact and safety by indicating level of agreement to statements on a 7-point Likert scale. For example: 'Driving an [*AFV type*] is [*worse-better*] for the environment compared to my current car'.

4.1.2 Data collection and respondent characteristics

Respondents were recruited from a dedicated automotive panel, managed by TNS-NIPO. Using a specific automotive panel features several advantages. First, many car-related characteristics



Questionnaire car choice: Choice task 1

	OPTION 1	OPTION 2	OPTION 3
Car Type (?)	Fuel-cell	Petrol	Electric
Purchase price	€ 22,400	€ 19,400	€ 24,800
Monthly costs (?)	€ 310	€ 260	€ 60
Driving range (?)	550 kilometer	Same as current driving range	75 kilometer
Recharge/Refueling time (?)	10 minutes	2 minutes	30 minutes
Additional detour time (?)	30 minutes	No additional detour time	No additional detour time
Number of brands/models (?)	50	Same as current amount	10
Policy measure for this car type (?)	Abolishment of MRB exemption	Current policy	Free parking

Please state below which car would be your preferred choice, and which your second choice.

	OPTION 1	OPTION 2	OPTION 3
1st choice	○	○	○
2nd choice	○	○	○

Previous question | Next question

FIGURE 4.1: Choice card example (respondent values used: km/year: 15.000-25.000; Tax exemption: no; Weight: 1200kg; Next car: New; Fuel type next car: Petrol; Purchase price next car: €21.000-€24.000).

are known on beforehand and secondly, respondents are familiar with car-related questionnaires. Respondents of the TNS-NIPO panel are paid for filling in their surveys. Only the response data of private car users will be used here as this sample has the highest number of observations. Hoen and Koetse gathered data for both private car owners and company car drivers, albeit with two different stated choice experiments as it is shown that the tax schemes of the two car ownership types, and thus consumer preferences, differ greatly, see also Section 2.2.3.1. Table 4.2 shows the background characteristics of both the conventional car drivers segment and the hybrid car drivers segment. There is a substantial difference in number of respondents between the conventional car owners and hybrid car owners: 1899 versus 128. This poses limitations to the extent to which the two segments can be compared.

Both segments feature a strong over-representation of male respondents. This can be explained by the presence of a selection question that asked the respondent whether they were the person that drove the car most frequently. In the Netherlands, men drive twice as much kilometres as women and women are twice as likely to be the passenger of a car [55]. Consequently, males are over-represented in the sample. Age is distributed fairly evenly over all categories for the conventional car owners, except for under-representation of the youngest category. For the segment of hybrid car owners, the Dutch population is less resembled in the sample. The segment

Table 4.2: Background characteristics of the 2027 respondents

Variable	Conventional car owners ($N = 1899$) Percentage share (%)	Hybrid car owners ($N = 128$) Percentage share (%)
Gender		
Male	80	91
Female	20	9
Age category		
18-25	0	0
26-35	10	3
36-45	21	8
46-55	25	15
56-65	24	38
65 and older	19	36
Household size		
1 Person	9	10
2 Persons	44	69
3 Persons	16	10
4 Persons or more	31	11
Highest finished education		
Primary school	2	2
Secondary school (level 1)	13	11
Secondary school (level 2)	9	13
Secondary school (level 3)	27	25
Secondary school (level 4)	10	11
Bachelor	27	27
Master/PhD	11	9
Do not know/no response	1	2

is dominated by respondents of the two oldest categories (56 and older). The data set will be weighted according to the Dutch population on age and gender to increase the representativeness of the model results for the Dutch population.

4.1.3 Choice frequencies

Table 4.3 shows the amount of times the vehicle types were chosen by the respondents. The conventional technology is chosen every one out of two times by conventional car owners. Moreover, choice sets at which the conventional technology was absent, are also included in this figure. When looking only at the choice sets with the conventional technology included, the percentage share of conventional technology increases to around 75%[1]. In addition, Hoen and Koetse noted that almost half of the respondents systematically chose the conventional technology when it was present in the choice set. As this indeed may reflect their preferences, they are not excluded from the sample. A sensitivity analysis will be performed to assess the influence of this segment.

[1]Figures not included in this report, See Hoen and Koetse, (2014).

TABLE 4.3: AFV choice frequencies from the choice experiment

Car type	Conventional car owners		Hybrid car owners	
	Count	Percentage (%)	Count	Percentage (%)
Conventional	7119	47	290	28
Hybrid	1009	7	118	12
Electric	1866	12	174	17
Plug-in hybrid	1002	7	129	13
Flexifuel	1667	11	106	10
Fuel cell	2526	17	207	20

For the hybrid car owners, the conventional car type also has the largest choice frequency. This was contrary to expectations as it was expected that the hybrid car type would serve as their reference situation instead of the conventional car type.

4.2 Data analysis

The analysis of the survey data aimed to answer the question whether hybrid car owners have different preferences for instrumental attributes of AFV than conventional car owners.

4.2.1 Research method

The differences in preferences between hybrid car owners and conventional car owners are quantified by estimating a mixed logit model for each segment. As parameter estimates between two mixed logit models cannot be compared in absolute sense, willingness-to-pay figures for instrumental attributes are calculated and used for segment comparison.

4.2.1.1 Mixed logit model theory

Two distinctive works in the light of modeling travel behavior are Louviere, Hensher, and Swait [56] and Train [54]. This section is derived from their introductions to choice modeling. The commonly used models for travel behavior are based on utility theory. Utility theory dictates that consumers assess the perceived utility of all choice options and maximize the utility of the choice by choosing the alternative with the highest perceived utility. Mathematically, decision maker n determines his perceived utility U_{ni} for each alternative i and chooses i if:

$$U_{in} > U_{jn} \forall j \neq i \tag{4.1}$$

However, from a researchers perspective, the situation is different as he does not and cannot know decision maker n's exact perceived utility. For this purpose, utility theory is extended to random utility theory, where a decision maker n's utility for alternative i consists of two parts: a deterministic component V_{in}, which is based on observable characteristics of person n and alternative i and a stochastic error component ϵ_{in} that represents the factors that affect n's utility but are not included in the deterministic part V_{in}. This results in the following choice:

$$(V_{in} + \epsilon_{in}) > (V_{jn} + \epsilon_{jn}) \forall j \neq i \tag{4.2}$$

By observing more choices of individual n, one is able to estimate his sensibility to the parts of the deterministic component V_{in}. The family of logit models is the most commonly used model to assess these preferences of a group of respondents regarding attributes of the utility V_{in}. By assuming the error terms ϵ_{in} are independently and identically Gumbel distributed (IID), the probability of decision maker n choosing alternative i over other alternatives j can be calculated by:

$$P_{in} = \frac{\exp V_{in}}{\sum_j \exp V_{jn}} \forall j \neq i \tag{4.3}$$

As mentioned, this model is able to represent taste variations between parts of the deterministic utility V_{in} of alternative i for choice maker n. This deterministic utility consists of several attributes that influence the utility, negatively or positively and relative to each other determined by its own weighting coefficient. In formula, the systematic utility for alternative i to person n is determined by i's characteristics $x_{(1,2\ldots k)}$ and (optionally) n's socioeconomic characteristics $s_{(1,2\ldots k)}$, each with their own weighting factor β:

$$V_{in} = \beta_1 x_1 + \beta_2 x_2 + \beta_k x_k + \beta_{s1} s_1 + \beta_{s2} s_2 + \beta_{sk} s_k \tag{4.4}$$

The formulations here are general formulations, both for the logit model and the utility function. Logit models can take numerous shapes and the utility function can consist of many different attributes. The attributes considered in this research are covered in Table 4.1.

Mixed logit models The standard logit formulation of Equation 4.3 assumes IIA (Indepence of Irrelevant Alternatives). This assumption does not hold when using panel data for model estimation. Stated choice experiment data is a form of panel data as it consists of multiple choices per respondent. Consequently, there is a correlation between multiple entries of the database. A mixed logit model relaxes the IIA assumption by adding an error component to the model. This error component is a parameter distributed $N(0, \sigma)$, which is estimated over the respondent unique IDs. This enables the model to account for the correlation between the choices of a unique respondent.

4.2.2 Model estimation

This section describes the model estimation procedure. A discrete choice model is estimated to represent the choice behavior of the respondents at the stated preference survey. Open source software package BIOGEME 2.3 is used for estimating the model [57].

4.2.2.1 Data preparation

The data gathered from the stated choice survey needed preparation prior to use in BIOGEME. Hoen and Koetse [1] estimated their choice model in NLOGIT 4.0.1, which uses a different input format than BIOGEME. The main adjustment was the configuration of the choice alternatives from one choice alternative per row (NLOGIT) to one choice alternative in columns (BIOGEME). Furthermore, the database was cleared from missing entries.

4.2.2.2 Model development

It is good model practice to start with a basic model specification and stepwise include additional factors. As comparison between hybrid car drivers and conventional car drivers is the main objective, model specifications were estimated for both samples. The list below shows the model developments that were tested before arriving to the final model specification and are further described in the remainder of this section.

- Estimation of a basic MNL model
- Testing alternative specific attributes
- Implementation of attitudinal information
- Testing panel effects
- Testing preference heterogeneity
- Weighed responses
- Sensitivity analysis random choice strategy respondents
- Sensitivity analysis systematic conventional car choosers
- Simulated market shares

Basic MNL model A standard multinomial logit (MNL) model is estimated to serve as reference scenario for model development. At this MNL model, each attribute mentioned in Table 4.1, served as an explanatory variable. An alternative specific constant (ASC) was assigned to each car type to assess the respondent's intrinsic preferences per car type. A scale factor λ_{2nd} was estimated to account for the difference in preferences between new and second-hand car owners. Research has shown that this characteristic has a substantial influence on car choice [1], most importantly regarding price sensitivity. The interpretation of λ_{2nd} is shown in Equation

4.5.

The first and third column of Table C.1 of Appendix C show the results of the generic attribute models for conventional car owners and hybrid car owners respectively. The results showed expected signs on all attribute coefficients. Cost attributes (purchase price and monthly cost) were valued negatively, as well as time attributes (detour time and recharge times). Policy measures as an attribute were removed from the model as they had very little effect on the utility, reflected in the parameter value close to zero. Furthermore, the number of available models was removed from the model as the parameter value estimate was close to zero (little effect on the utility) and highly insignificant. Finally, these first results show that the preferences of new car owners and second-hand car owners differ for conventional car owners ($\lambda_{2nd} = 1.14, t = 4.55$) and not for hybrid car owners ($\lambda_{2nd} = 0.979, t = -0.11$).

$$\beta_{n,2nd} = \lambda_{2nd} * \beta_{n,new} \tag{4.5}$$

Testing alternative specific attributes In the basic MNL model, general attribute parameters are estimated. General attribute parameters assume that attributes are valued equally for each car type. This assumption is challenged as instrumental attribute preferences are expected to be car type dependent. Consequently, models with alternative specific attribute parameters have been estimated for both the conventional car owners sample and the hybrid car owners sample.

Table C.1 shows the model results of the alternative specific attribute models. Alternative specific parameters with similar parameter values were merged again to reduce the number of parameters, for example the purchase price of the FEV and the FC car. The results show that majority of the alternative specific attributes was significant, implicating that instrumental attribute preferences are indeed car type dependent. Based on these results, it was decided to continue with the alternative specific attributes models rather than the generic attributes models. The alternative specific attributes model accounts for the differences in preferences between different car types, but cannot account for non-linearity in preferences. Other studies have found evidence that preferences for instrumental attributes are non-linear, but the majority of the studies still opts for a linear approach [10]: one parameter per instrumental attribute.

Implementation of attitudinal information In the research approach, it was explained that data availability did not allow for estimating a discrete choice model on both instrumental and symbolic/affect factors. These so-called latent variable models, are therefore beyond the scope of this research. However, Hoen and Koetse [1] included two questions in the stated preference survey that provide attitudinal information of the respondent. Although these two questions do not provide sufficient data to specify a latent variable model, they are directly included in the utility function, as discussed by Walker [58]. The perception on the environmental performance is included as an attribute and was made alternative specific for the full electric car and plug-in hybrid car, as these car types are the main subjects of this research. Safety perception was excluded as the literature study did not indicate this factor being influential for AFV preferences. The environmental performance parameter of the FEV was statistically significant for the conventional car owners segment. The parameter for the PHEV was only statistically significant for the conventional car drivers sample.

Estimating a full sample scaled model Table C.1 shows the performance of the alternative specific attributes model for the hybrid car owners sample is $\rho^2 = 0.073$. According to Louviere et al., ρ^2-values between 0.2 and 0.4 are considered to indicate a good model fit for discrete choice models [56]. Consequently, a $\rho^2 = 0.073$ implicates a poor model fit. This could be the result of an over-specified model in relation to the limited number of observations. However, the model performance of the simpler generic attribute model ($\rho^2 = 0.091$) is also poor. Estimating a model with a scale factor between the conventional car owners and hybrid car owners offers the advantage of using the full sample, but quantifies the difference between the segments more generally than separate models for each segment. Separate model estimations quantify the difference per parameter, whereas a scaled model only quantifies the overall difference in utility between the two groups by a single scale factor λ.
Table C.2 of Appendix C shows the results of the separate segment models and the joint scaled model side-by-side. As the segments were already scaled according to new or second-hand car ownership, the scaled model results show four scale factors: conventional new car owners, conventional second-hand car owners, hybrid new car owners and hybrid second-hand car owners. The results show that model performance is on par with the conventional car owners segment model. In addition, the scale factors are found statistically significant. This implicates that hybrid car drivers have different preferences than conventional car owners and also maintains the previous finding that second-hand car owners have different preferences than new car owners. Finally, as both the segment-specific models and the full sample scaled model offer specific advantages, both approaches are continued in further model development.

Test for panel effects An error component was added to the model to account for panel effects. This overcomes the limitation of the MNL model's assumption of independence between choices. This assumption does not hold for stated choice experiments with multiple choices per respondent. The error component is a parameter distributed $N(0, \sigma)$, of which BIOGEME estimates the value of σ over the respondent unique IDs. As mixed logit models draw probabilities from a distribution, the number of draws needs to be specified. Large numbers of pseudo-random draws (> 1000) are often recommended in literature. This substantially increases computation times of the model. Train, however, argues that 125 Halton draws provide the same accuracy of

2000 pseudo-random draws [59]. Therefore, 125 Halton draws are used for estimating the mixed logit model. As each choice in the choice experiment comprised of three alternatives, three error components were added. For balance reasons, the error component with the lowest parameter value should be fixed, which, in this case, is the error component of the second choice alternative. The results show that error components for the conventional car owners segment and the scaled full sample were statistically significant and insignificant for the hybrid car owners segment. The interim results of adding the error components are not specifically addressed in an appendix, but shown in the final model results of Table 4.4.

Testing preference heterogeneity To overcome another limitation of the MNL model, random components were added to attribute parameters to account for preference heterogeneity between respondents. The MNL model estimates a fixed parameter value for each attribute. As a result, the parameter value represents the average preference of all respondents for an attribute. The MNL model therefore does not account for heterogeneity in preferences on one attribute between the respondents. A mixed logit model specification is able to overcome this limitation of the MNL model by estimating a density function $f(\beta)$ rather than a fixed β. This function $f(\beta)$ is distributed (β, σ_β).

It is known that mixed logit model specifications require large numbers of observations for reliable model estimations. Therefore, tests with random components were undertaken with the statistically most significant results of the previous steps: purchase price and monthly cost. Unfortunately, these model specifications lead to highly insignificant results. It was therefore decided to omit random components in the model specification.

Weighted responses Section 4.1.2 discussed that the data sample was over-represented by male respondents compared to the Dutch population. In addition, the hybrid car drivers sample was also over-represented by higher age categories. Survey responses were weighted to correct for these over-representations on age and gender and to let the model results represent the population better. Age and gender distributions of the Dutch population in 2014 were obtained from Statistics Netherlands [60].

Table C.3 shows the weights that are needed to represent the Dutch population. Several weights for the hybrid car owners segment are high: 35.91 and 16.30 for the two youngest female categories. The results of Table C.4 consequently show large differences in the weighted and unweighted results of the hybrid car owners model. It was decided to continue with the unweighted hybrid car owners sample as the required weights and the resulting estimations are found too large for valid weighting. The weights of the conventional car owners sample are smaller. Therefore, it was decided to continue with the weighted sample for the conventional car owners.

Sensitivity analysis random choice strategy respondents The data set contained information about the choice strategy of the respondent at the choice experiment. Out of 2027 respondents, 102 respondents stated they randomly choose the alternatives at the choice experiment. Underlying reasons are unknown, but possible reasons could be that respondents did not understand the choice task. Random choice behavior might influence the validity of the results as the discrete choice model assumes that the respondent based his choice on one or more attributes. A comparison of the model results with and without the 102 respondents revealed small differences between the sample with and without the stated random choosers. Table C.5 in Appendix C shows the detailed results of both models. Based on these results, it is decided to keep the 102 respondents in the sample.

Sensitivity analysis systematic conventional car choosers Section 4.1.3 argued that almost half of the respondents systematically chose the conventional car when it was present in the choice set. These 'non-traders' are an interesting sub sample as they apparently always perceive the highest utility for the conventional car compared to the AFVs presented to them. This sub sample cannot be excluded from the sample, as this choice behavior is likely to reflect their real world preferences. However, a sensitivity analysis was performed to examine the preferences of *traders*, respondents that chose an AFV over the conventional car at at least one choice card, versus *non-traders*.

Table C.5 shows that large preference differences exist between *traders* and *non-traders*. The negative intrinsic preference of the *traders* for FEVs and PHEVs is only half the value of that of the full sample (*traders* and *non-traders* combined). This finding brings up the hypothesis that *non-traders* may be less sensitive for financial stimulation of EVs. Consequently, they might be more sensible to technological improvements of EVs and thus should reveal a higher WTP for additional range and reduced charging times. The results in Table C.5 cannot confirm this hypothesis. The differences on the WTP for additional range and reduced charging times are less out-spoken than the results on the intrinsic preference. This finding is in line with Hoen and Koetse, who also conclude that the results on including or excluding the conventional car type in choice cards in not evident [1, p. 208]. This leaves the underlying reasons of the non-trading behavior as a suggestion for further analysis.

Simulating market shares Choice probabilities for the six car types were simulated with the model results of Table 4.4. The resulting market shares, shown in Table 4.5, demonstrate the stated willingness to buy a certain car type of the conventional car owners and hybrid car owners. Besides, the new vehicle sales in 2014 at the Dutch car market are included to serve as revealed preference. [52, 61–63].

TABLE 4.4: Overview segment-specific models and a full sample scaled model

	Conventional car owners Weighted				Hybrid car owners Unweighted				Full sample, scaled Weighted			
Parameter	β-value	Std. err.	t-test	WTP	β-value	Std. err.	t-test	WTP	β-value	Std. err.	t-test	WTP
ASC Conv.	0.00	fixed		€0	0.00	fixed		€0	0.00	fixed		€0
ASC Hybrid	-1.09	0.0483	-22.51**	€-10,999	0.885	0.187	4.58**	€10,714	-1.06	0.0472	-22.56**	€-10,392
ASC FEV	-2.25	0.142	-15.86**	€-18,908	-1.80	0.584	-3.07**	€21,201	-2.23	0.139	-16.07**	€-18,279
ASC PHEV	-1.82	0.170	-10.74**	€-18,365	-0.661	0.529	-1.25	insign.	-1.79	1.66	-10.79**	€-17,549
ASC FC	-0.759	0.0846	-8.97**		1.01	0.479	2.11**		-0.733	0.083	-8.82**	
ASC Flexifuel	-1.77	0.107	-16.50**		-0.819	0.388	-2.111**		-1.77	0.105	-16.83**	
Purchase price FEV/FC[1]	-0.119	0.00480	-24.74**		-0.0849	0.0129	-6.56**		-0.122	0.00475	-25.67**	
Purchase price other[1]	-0.0991	0.00530	-18.70**		-0.0798	0.0152	-5.26**		-0.102	0.00524	-19.46**	
Monthly cost FEV[2]	-0.442	0.0381	-11.62**		-0.441	0.166	-2.66**		-0.445	0.0374	-11.89**	
Monthly cost Flexi.[2]	-0.217	0.0265	-8.19**		-0.670	0.193	-3.47**		-0.226	0.0262	-8.61**	
Monthly cost other[2]	-0.142	0.0103	-13.81**		-0.201	0.0552	-3.65**		-0.145	0.0101	-14.35**	
Range FEV[3]	0.00307	0.000251	12.25**	€25.80/km	0.00235	0.000928	2.53**	€27.68/km	0.00306	0.000246	12.45**	€25.08/km
Range FC[3]	0.00220	0.000198	11.14**		0.00182	0.000751	2.43*		0.00224	0.000194	11.53**	
Recharge time FEV[4]	-0.000719	0.000172	-4.17**	€-6.04/min	-0.000860	0.000624	-1.38	insign.	-0.000692	0.000169	-4.10**	€-5.67/min
Recharge time PHEV[4]	-0.00281	0.000585	-4.80**	€-28.36/min	0.000118	0.00179	0.07	insign.	-0.00280	0.000572	-4.90**	€-22.95/min
Recharge time FC[4]	-0.00721	0.00251	-2.87**		-0.00794	0.00981	-0.81		-0.00717	0.00246	-2.92**	
Detour time FEV[4]	-0.00426	0.00267	-1.60	insign.	-0.00772	0.0100	-0.77	insign.	-0.00423	0.00262	-1.62	insign.
Detour time Flexi[4]	-0.0136	0.00257	-5.30**		-0.0191	0.0107	-1.79		-0.0140	0.00252	-5.56**	
Detour time FC[4]	-0.0160	0.00194	-8.24**		-0.0123	0.00733	-1.68		-0.0160	0.00190	-8.40**	
Environ. FEV	0.131	0.0196	6.70**		0.243	0.0820	2.96**		0.132	0.0192	6.87**	
Environ. PHEV	0.0659	0.0294	2.24*		0.151	0.0965	1.57		0.0634	0.0288	2.20*	
Sigma alt. 1	-0.507	0.0326	-15.55**		-0.293	0.157	-1.87		-0.509	0.0314	-16.20**	
Sigma alt. 2	0.00	fixed			0.00	fixed			0.00	fixed		
Sigma alt. 3	-0.278	0.0424	-6.55**		-0.0123	0.187	-0.07		-0.288	0.0393	-7.32	
λ_{new}	1.00	fixed			1.00	fixed						
λ_{2nd}	1.29	0.0391	7.42**		1.18	0.293	0.73					
$\lambda_{conv,new}$									1.00	fixed		
$\lambda_{conv,2nd}$									1.31	0.0391	7.82**	
$\lambda_{hyb,new}$									0.439	0.0558	-10.07**	
$\lambda_{hyb,2nd}$									0.336	0.0932	-7.12**	
Model performance												
nOBS	15189				1024				16213			
Final log-likelihood	-12308.534				1021.202				-13260.477			
Adjusted Rho-square	0.261				0.072				0.254			

* Statistically significant at 95% confidence level ** Statistically significant at 99% confidence level 1) in €1000 2) in €100 3) per km 4) per min

Table 4.5: Simulated stated choice and real world sales shares per vehicle type

Car type	Conv. car owners sample % share	Hybrid car owners sample % share	2014 new car sales in NL % share
Conventional	48.2	30.4	92.5
Hybrid	6.2	10.9	3.0
FEV	12.0	20.2	0.7
PHEV	6.1	9.1	3.1
Flexifuel	10.6	15.2	0.8
Fuel-cell	17.0	14.2	0.0

$$WTP_{\beta_1} = \frac{\beta_1}{[\beta_{cost}]} \tag{4.6}$$

4.2.2.3 Model results

Table 4.4 shows the results of the final model specification for the conventional car owners sample, the hybrid car owners sample and the scaled full sample model. As parameter estimates between two logit models cannot be compared in absolute sense, willingness-to-pay figures for instrumental attributes were calculated by dividing the non-monetary parameter estimates by the absolute value of the purchase price estimate, see Equation 4.6.

Model performance The bottom rows of Table 4.4 indicate model performance. The adjusted ρ^2 indicates the goodness-of-fit of the model to the data. Higher ρ^2-values indicate a better fit of the model to the data, however interpretation of this figure is not straightforward. According to Louviere et al., ρ^2-values between 0.2 and 0.4 are considered to indicate a acceptable model fit for discrete choice models [56]. The model estimation for conventional car drivers sample has an adjusted ρ^2 of 0.261, which is thus considered to be an acceptable fit. For the smaller hybrid car drivers sample, the adjusted ρ^2 is much lower: 0.072. This model estimation is assessed as a poor fit to the data. Finally, the scaled full sample model also has an acceptable fit of $\rho^2 = 0.254$. As the model performance of the hybrid car owners model is very poor, it is decided to mainly consider the results of the scaled model for conclusions about hybrid car owners.
Furthermore, choice probabilities were simulated with the model estimation results. Comparison of the choice frequencies in the data set and the choice probabilities from simulation show a similar pattern as the ρ^2 indicators, see Table C.6. Choice probabilities of the models with acceptable fit, the conventional car owners and full sample model, are closely resembling the choice frequencies of the data samples. On the other hand, the hybrid car owners model choice probabilities show deviations of 50% from the choice frequencies in the data set.

Scale factors full sample scaled model The previous paragraphs argued that insignificant parameter values at the hybrid car owners sample make it difficult to reach the research objective: quantifying differences between conventional and hybrid car owners. Therefore, the full sample scaled model has been developed. Table 4.4 shows that the scale parameters for hybrid car owners are statistically significant, t-test$= -10.07$ and t-test$= -7.12$. The parameter values of $\lambda_{hyb,new} = 0.439$ and $\lambda_{hyb,2nd} = 0.336$ implicate that the β values for hybrid car owners are on average 60% lower than for conventional car owners. This suggest that hybrid car owners experience 60% less disutility for AFVs. With a scale factor < 1, negative alternative specific constants (ASCs) decreases in magnitude, implicating less disutility.

ASCs The values of the ASCs support the hypothesis that hybrid car owners have a higher preference for FEVs than conventional car owners. The intrinsic preference of a FEV is €-18,908 for conventional car owners and €-17,549 for the full sample scaled model. As the scaled model is the combination of conventional and hybrid car owners, the WTP_{FEV} for hybrid car owners logically needs to be less negative than €-17,549. The hybrid car owners model contradicts this finding with a more negative FEV preference of €21,204, but model performance of this model is too low to draw conclusions from.
The results for the intrinsic preference for the PHEV were also in line with expectations. The hybrid car owners have a less negative intrinsic preferences, as the WTP for a PHEV for the full sample is smaller than the conventional car owners segment. The preference difference between hybrid car owners and conventional car owners is also reflected in the simulated market shares. Table 4.5 shows that the FEV market share is higher for the hybrid car owners than for conventional car owners.

Instrumental attributes The parameter signs for instrumental attributes are in line with expectations. Cost parameters are valued negatively, whereas additional range and reduced charging and detour times are valued positively. The relative importance between monthly costs and purchase price differs from other studies in this field. Table 4.4 shows that purchase price is valued at around $\beta = -0.1$ per €1,000, whereas monthly costs are valued in the range of $\beta = -0.142$ to $\beta = -0.442$ per €100 depending on the car type. Calculating the parameters to values per €1 results in -0.0001 per €purchase price and -0.00142 to -0.00442 per €monthly costs. De Jong, Kouwenhoven, Geurs et al. [64], however, argued that €1 in purchase price is valued more important than €1 in variable cost, implying that purchase price is more important than variable cost in car preferences.
Results on the differences between hybrid car owners and conventional car owners are derived from the scaled full sample model. The results show that hybrid car owners have a lower willingness-to-pay for extra FEV range than conventional car owners. Extra FEV range is valued at €25.08 per km in the scaled full sample and €25.80 per km in the conventional car drivers

sample. As the full sample combines the conventional and hybrid car owners, this implicates that the willingness-to-pay for hybrid car owners is lower than €25.08/km and lower than for conventional car owners consequently. The same line of reasoning yields for reduced FEV and PHEV recharge time, with a WTP in the conventional sample versus the full sample of €28.36 versus €22.95 and €6.04 and €5.67 per minute reduced charging time. As the WTPs of the full sample are lower than for the conventional sample, the WTP for reduced recharge time for FEV and PHEV have to be lower than €22.95 and €6.04 respectively for hybrid car owners.

Attitudinal perception The results show that a positive perception of a PHEV's environmental performance is increases the PHEV's utility for both conventional and hybrid car owners, indicated by $\beta = 0.0659$ and $\beta = 0.476$ respectively. Also, for the FEV, a positive perception of the environmental performance of a FEV is also beneficial for its utility, in the case of conventional car owners and the full sample model. For hybrid car owners, the parameter estimate was insignificant. Arguing from the scaled full sample model, it is suggested that hybrid drivers show the same behavior as the conventional car drivers, as the scaled model estimate for environmental performance perception is similar to that for the conventional sample, $\beta = 0.132$ versus $\beta = 0.131$. As attitudinal parameters are not suitable for WTP calculations, direct comparison of the parameter values between models is not possible. Comparison of the relative magnitude of the environmental performance perception parameters indicates that environmental performance perception influences the utility of FEV stronger than for the PHEV at both the conventional car sample as the full sample (ie. the full sample: $\beta_{FEV} = 0.132$ and $\beta_{PHEV} = 0.0634$).

Impact of technological improvements Electric vehicle technology is still a new type of car technology. Substantial technological improvements are likely to be made in the near future. The impact of these upcoming technological improvements is assessed by calculating the remaining negative intrinsic preference for a vehicle type, in the hypothetical situation of the vehicle having maximum values on all instrumental attributes. The scaled full sample results estimate a negative intrinsic preference for a FEV of €-18,279. This is the situation where the FEV has lowest attribute levels on all instrumental attributes: range=75km, recharge time=480min. If, due to technological developments, the FEV improves to the maximum attribute values used in the choice experiment, that is: range=350km and recharge time=30min, the negative intrinsic preference for the FEV lowers. Table 4.6 shows that, despite technological improvements in terms of range and recharge times, a negative intrinsic preference of €-8,917 for FEVs remains. Note that the additional detour time as an attribute could not be taken into account at this calculation due to the insignificant parameter estimate. The result implicates that realistic technological improvements alone are not sufficient to overcome the current negative intrinsic preference of FEVs.

TABLE 4.6: Impact of technological improvements on intrinsic preference for the FEV.

	Change	WTP for change[1]	Residual WTP
Current WTA			€-18,365
Range	75-350 km	€6,897	€-11,468
Recharge time	480-30 min	€2,552	€-8,917

1 WTP-values originate from Table 4.4

Simulated market shares Table 4.5 shows the simulated market shares of the six vehicle types together with the 2014 Dutch new car sales. The figures show that hybrid car owners have a higher preference for all AFV types addressed in the data set compared to conventional car owners. The FEV has a significantly higher market share for the hybrid car owners than the conventional car owners, 20.2% versus 12.0%. Furthermore, the PHEV also has a higher market share at the hybrid car owners sample than the conventional car owners sample, 9.1% versus 6.1%. The market shares from the stated preference data (from 2011) are not reflected in the new car sales figures of 2014 in the Netherlands. The actual vehicle sales figures show the conventional car still dominates new car sales nowadays, although our stated preference results suggest that FEV and PHEV sales should account for around 20% of the car sales instead of the revealed 4%.

4.3 Conclusion

The model estimation results showed mainly expected parameter signs. Cost parameters (purchase price and monthly costs) were valued negatively. In addition, longer range and reduced charging times and detour times were valued positively for the utility of the AFVs.
Concerning the alternative specific constants (ASCs), the conventional car owners model showed results expected from literature. PHEVs and FEVs are valued negatively compared to conventional cars, in line with findings of Ziegler [43]. Moreover, the FEV is perceived more negatively than the PHEV by conventional car owners. This finding is in line with the studies of Schuitema [20], who concludes that car owners generally have a more negative perception of FEVs than for FEVs and the research of Ewing [65], who also found a lower ASC for FEVs than conventional cars.

Intrinsic preference for AFVs It was expected that hybrid car owners would have a higher intrinsic preference for both FEVs and PHEVs as they are already familiar with (partial) electric driving and already chose a more environmental friendly car before. The results of this research confirm this expectation. Hybrid car owners are shown to have a higher intrinsic preference for FEVs than conventional car owners, albeit still negative. In addition, hybrid car owners revealed a less negative intrinsic preference for the PHEV than conventional car owners. The simulated market shares indicate a higher FEV and PHEV market share for hybrid car owners than for conventional car owners, in line with expectations.

The negative willingness-to-pay for a FEV of €-18,279 in the scaled model is more negative than the findings of similar studies. Hidrue et al. [22] found a negative intrinsic WTP of €10,000 for a FEV. In addition, the negative intrinsic preferences in the range of €18,000 are high for both the FEV and the PHEV compared to current average sales price of FEVs and PHEVs of €40,000 (FEV: BMW i3 and VW eGolf, PHEV: VW Golf GTE, Audi eTron). Moreover, as current EV purchase subsidies are already included in these sales prices, which are around €4,000 for a mid-size car like a VW Golf.

It should be noted that the differences in purchase price and monthly cost between conventional cars and FEVs or PHEVs are not included in these figures. These figures are derived from the ASCs, which reflect the variation in preferences when the car types have equal attribute values. At this moment FEVs are more expensive than conventional cars, but have lower monthly cost (fuel savings, less maintenance cost). Consequently, the negative WTP for a FEV increases by the price difference between a FEV and a conventional car. This price difference is around €10.000 (for example: VW eGolf versus VW Golf 1.2 TSi) minus an aggregated monthly cost difference over a number of years. Again, this negative WTP already includes the current fiscal subsidies in the Netherlands, as these are included in the sales price difference of €10,000 between current FEVs and conventional cars.

The results have shown the intrinsic negative preference of the FEV can be halved by technological improvements in range and recharge times to around €9,000. This results does not take the purchase price and monthly cost difference into account, as discussed. Nevertheless, it shows that substantial financial measures are needed to bridge the gap between FEVs and conventional cars on top of the currently existing policies described in Section 2.3).

Willingness to pay for instrumental attributes The results show hybrid car owners have a lower willingness-to-pay for additional FEV range than conventional car owners. In addition, they also value reduced charging times of the FEV and PHEV less than conventional car owners. This implicates that hybrid car owners are more satisfied with the current FEV and PHEV performance on range and recharge times than conventional car owners. The lower WTP for additional range and reduced charging times of hybrid car owners is likely related to their lower annual mileage compared to conventional car owners in the sample. The hybrid drivers in the sample driver drive about 16,000 km per year, whereas the conventional car owners driver approximately 21,000 km per year. The line of reasoning here is, that the lower car use of hybrid car owners makes them less likely to be troubled by the limited range or longer recharge times than conventional car owners with a higher car use.

The WTP figures for range and recharge time that are found in this study, are in between results of similar studies. The results here show a WTP for additional FEV range of around €25/km and a WTP for reduced FEV recharge time of €6. Hidrue et al. [22] found a WTP for additional range of approximately €40/km (originally $70/mile) and a WTP for reduced charging time of approximately €15/min (originally $1000 per hour). Batley et al., on the other hand report a willingness to pay of €16/km additional range (deduced from €2611 for 161 km) [66]. Mabit and Fosgerau have found a value of €14/km additional range [32].

Environmental performance perception The results show that respondents that have a positive perception about the environmental performance of a FEV or PHEV have a higher utility for FEVs and PHEVs. This is proven for the conventional car owners and likely for hybrid car owners. In addition, it is shown that the effect of the environmental performance perception is larger in the utility for a FEV than for a PHEV. Both results are in line with expectations that a positive perception of an EV's environmental performance is beneficial for its perceived utility.

Simulated market shares The market shares simulation results support the expectation that hybrid car owners have a higher likelihood of buying a FEV or a PHEV than conventional car owners. It is shown that the FEV has a higher market share of 20.2% for hybrid car owners versus 12.0% for the conventional car owners. In addition, the PHEV has a higher market share of 9.1% for hybrid car owners versus 6.1% for conventional car owners.
Furthermore, it is shown that the market shares from this research are not reflected in the current new car sales in the Netherlands. The actual vehicle sales show a 0.7% share of FEVs and a 3.1% PHEV share. With annual car sales of around 400.000 in the Netherlands, the calculated market shares of the conventional car owners would implicate that the number of FEVs in the Netherlands would increase from 7.000 to 54.000 FEVs after one year of car sales.

Chapter 5

The role of symbolic and affective factors at car choice for hybrid car owners

The previous chapter elaborated on the preferences for instrumental aspects of EVs, like driving range, charging times and costs. Two other types of aspects, however, are also perceived relevant in car choice: symbolic and affective aspects. Additional data was collected by the Dutch Environmental Assessment Agency (from now on: PBL) as a follow-up of Hoen and Koetse's study into the instrumental aspects of AFV preferences [1]. This chapter describes the analysis of the data from this follow-up survey and aims to find relationships between symbolic and affective factors for car choice and AFV preferences. This first section of the chapter describes the survey, as fielded by PBL. The second section details on the analyses performed with the data gathered from the survey

5.1 Data set contents and data collection

The questionnaire used Likert scale questions to assess respondents' agreement with qualitative statements regarding symbolic and affective factors. This is contrary to the first survey, described in Chapter 4, which used a stated choice experiment to assess the willingness-to-pay for instrumental attributes.

TABLE 5.1: Contents attitudes survey

Survey part	Measurement method	Scale
Symbolic and affective factors at car choice	4 symbolic and 5 affective statements	7-point Likert scale
Personal identity perception	20 statements	7-point Likert scale
Current AFV performance perception	4 statements	7-point Likert scale
Willingness to buy (WTB) an AFV type as next car	1 WTB percentage per AFV type	11-point Likert scale

TABLE 5.2: Symbolic and affective statements

Survey statement
Symbolic
I would buy a [PHEV, FEV] because it fits my personality.
A [PHEV, FEV] enables me to show who I am an represents my personal taste.
I would buy a [PHEV, FEV] because it allows me to differentiate myself from others.
I would buy a [PHEV, FEV] because it provides status.
Affective
I would buy a [PHEV, FEV] because I enjoy speeding.
Driving a [PHEV, FEV] is sporty and adventurous.
I would buy a [PHEV, FEV] because it looks good.
Driving a [PHEV, FEV] is a thrilling experience.
I would buy a [PHEV, FEV] because I enjoy driving a car.

5.1.1 Data set contents

The data set consisted of four parts, see Table 5.1. General socioeconomic data of the respondents was available from TNS-NIPO as the respondents originate from a periodically updated panel. Therefore, these are not questioned in the survey itself.

Symbolic and affective factors at car choice Literature shows symbolic and affective factors can play a role in the perception of AFVs, see Section 2.2.2.1. The roles of symbolic and affective factors at car choice were assessed by nine statements, of which the respondents had to indicate their level of agreements on a 7-point Likert scale. Table 5.2 shows the exact formulation of the statements.

Current AFV performance perception The current perception of AFVs relative to a respondent's current car on several aspects was questioned in the survey by four statements. These aspects, like flexibility and reliability, were classified as affective factors, based on the work of Schuitema [20]. Respondents were asked to indicate their level of agreement on a 7-point Likert scale. Table 5.3 shows the exact formulation of the statements.

Table 5.3: Current AFV perception statements

Survey statement
A [PHEV, FEV] is more reliable than my current car.
A [PHEV, FEV] accelerates slower than my current car.
A [PHEV, FEV] is more flexible to use than my current car.
A [PHEV, FEV] emits less greenhouse gasses than my current car.

Personal identity perception The survey presented the respondents 20 statements about their personal identity, for which they were asked to indicate their level of agreement on a 7-point Likert scale. For example: 'I really enjoy discovering new technological products or gadgets'. Table A.1 in Appendix A shows the exact formulation of the 20 statements.

Willingness-to-buy an AFV Respondents were asked to state their likelihood of buying five different AFV types as a next car on a 0% − 100%-scale. Response for two of the five AFV types is subject of this research: the FEV and the PHEV. This willingness to buy a FEV/PHEV is used as the indicator for AFV preference, which is the main subject of this research. Consequently, this stated willingness-to-buy served as the dependent variable in the data analysis.

5.1.2 Data collection and respondent characteristics

The survey was fielded as an internet questionnaire. Respondents were recruited from the group of respondents that had completed Hoen and Koetse's stated choice survey on instrumental attributes [1]. Consequently, the respondents originate from a dedicated automotive panel, managed by TNS-NIPO. As this second survey was fielded two years after the first survey, not all respondents of the first survey were able, or prepared to complete the second survey as well. For the hybrid car owners only 26 out of 127 respondents that completed the first survey, completed the second survey as well. To ensure sufficient response among hybrid car owners, hybrid car owners that had not completed the first survey, were invited to fill in the second survey as well.

Table 5.4 shows the background characteristics of both the conventional car drivers segment and the hybrid car drivers segment. Both segments feature a strong over-representation of male respondents. This can be explained by the presence of a selection question that asked the respondent whether they drove the car most frequently. In the Netherlands, men drive twice as much kilometres as women and women are twice as likely to be the passenger of a car [55]. Consequently, males are over-represented in the sample. Age is distributed fairly evenly over all categories for the conventional car owners, except for the youngest categories. These categories are underrepresented compared to the Dutch population.

TABLE 5.4: Background characteristics of the 1402 respondents

Variable	Conventional car owners ($N = 1203$) Percentage share (%)	Hybrid car owners ($N = 199$) Percentage share (%)
Gender		
Male	82	91
Female	19	9
Age category		
18-25	0	0
26-35	9	6
36-45	19	24
46-55	26	34
56-65	26	32
65 and older	20	8
Household size		
1 Person	10	11
2 Persons	46	36
3 Persons	16	14
4 Persons or more	29	40
Highest finished education		
Primary school	2	1
Secondary school (level 1)	13	6
Secondary school (level 2)	10	5
Secondary school (level 3)	27	28
Secondary school (level 4)	10	15
Bachelor	26	32
Master/PhD	11	14
Do not know/no response	1	1

5.2 Data analysis

The analysis of the survey data aimed to answer the question whether hybrid car owners have a higher likelihood of buying an EV than conventional car owners, and whether this can be explained by symbolic and affective factors.

5.2.1 Choice frequencies

Figure 5.1 and 5.2 show that hybrid car owners generally reported a higher WTB, arguing from the higher choice frequencies of high WTB categories (50% and higher). The difference between conventional car owners and hybrid car owners was found statistically significant as determined by one-way ANOVA for both the FEV ($F(1, 1400) = 32.635, p = 0.000$) and the PHEV ($F(1, 1400) = 85.023, p = 0.000$). This finding is in line with the findings of Chapter 4. In this previous chapter is shown the PHEV and FEV have larger simulated market shares at the hybrid car owners sample than the conventional car owners sample.

TABLE 5.5: Ratio of systematic AFV refusers

	Conventional car owners ($N = 1203$)	Hybrid car owners ($N = 199$)
Respondents that reported WTB=0% for all five AFV types.	247	6
Percentage share	20%	3%

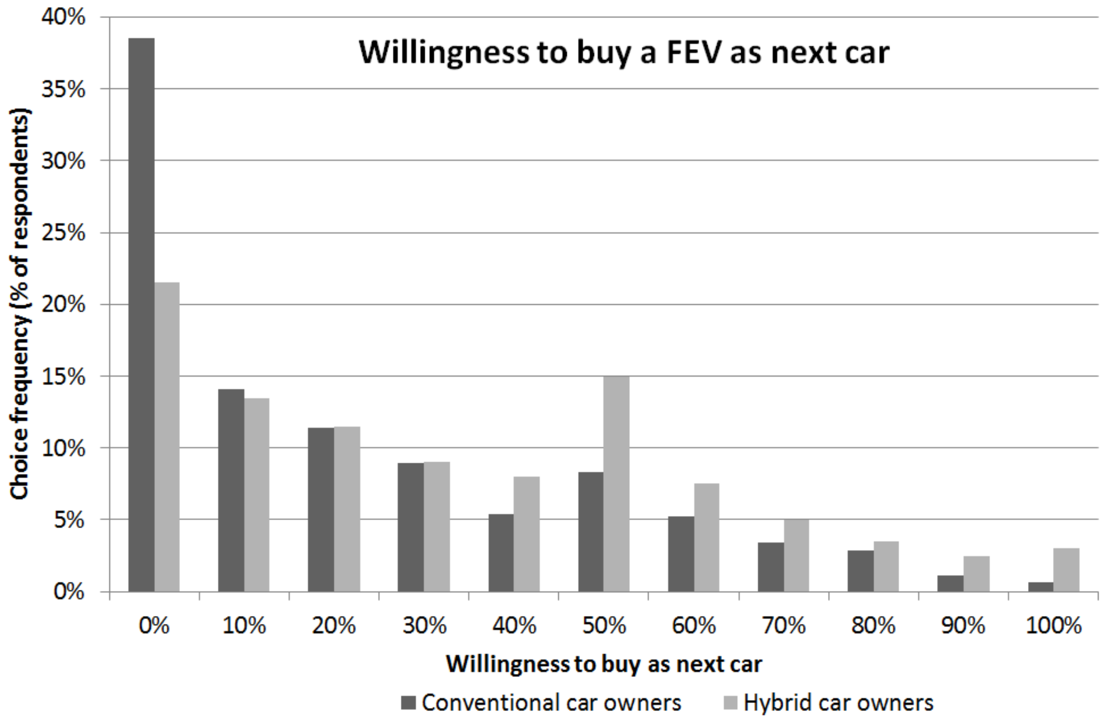


FIGURE 5.1: Willingness to buy a FEV as a next car

In addition, the amount of respondents that systematically rejects AFVs is larger for conventional car owners than for hybrid car owners. Table 5.5 shows that the proportion difference is 20% opposed to 3%. These respondents have the lowest likelihood of buying an AFV as a next car, as they do not consider any type of AFV as their next car.

5.2.2 Research method

The analysis examines whether the likelihood of buying an EV could be explained by symbolic and affective factors. The hypothesis here is that there are symbolic and affective factors that play a role in the likelihood of buying an EV. Finally, differences in the roles that symbolic and affective factors play were explored between conventional car owners and hybrid car owners. Ordinal logit models were estimated to test the hypothesis and to explore differences between conventional car owners and hybrid car owners.

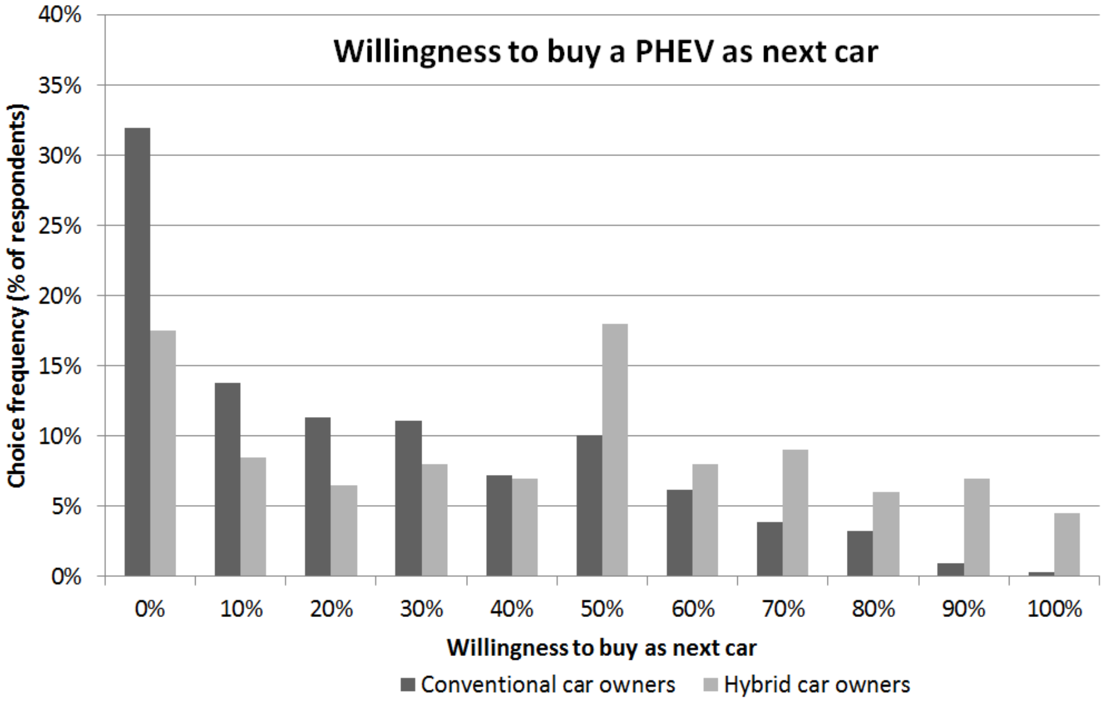


Figure 5.2: Willingness te buy a PHEV as a next car

5.2.2.1 Ordered and binary logit model theory

Willingness-to-buy of either a FEV or a PHEV served as the dependent variable in the regression analysis. This willingness-to-buy data features an ordinal scale. Respondents were asked to indicate their likelihood of buying an FEV or PHEV from 0% to 100%. This ordered type of response has implication for model estimation, as argued by Train [54]. The following section first describes the theory of ordered logit models, which is paraphrased from Train's book 'Discrete Choice Models with Simulations', pages 182-186. Additionally, a second approach of threading ordered response is described: the binary logit model.

Ordered logit model theory The ordered nature of the response on the willingness-to-buy violates the multinomial logit model's assumption of independence of alternatives. Suppose the response is aggregated to three categories: 0% – 20%, 30% – 50% and 60% – 100%. Consequently, it is not valid to define each of the three categories as an alternative. A more natural representation is to imagine the respondent having a utility/opinion about a FEV/PHEV and that his response on the willingness-to-buy question is a indicator of his perceived utility for that car type. Suppose this utility is defined as U, high levels of U indicate the respondent is more willing to buy a FEV than at lower levels of U. Although a respondent's utility can take many different levels, the question only allows for 3 pre-defined levels (0% – 20%, 30% – 50% and 60% – 100%). The respondent chooses the level that represents his utility U best. If this

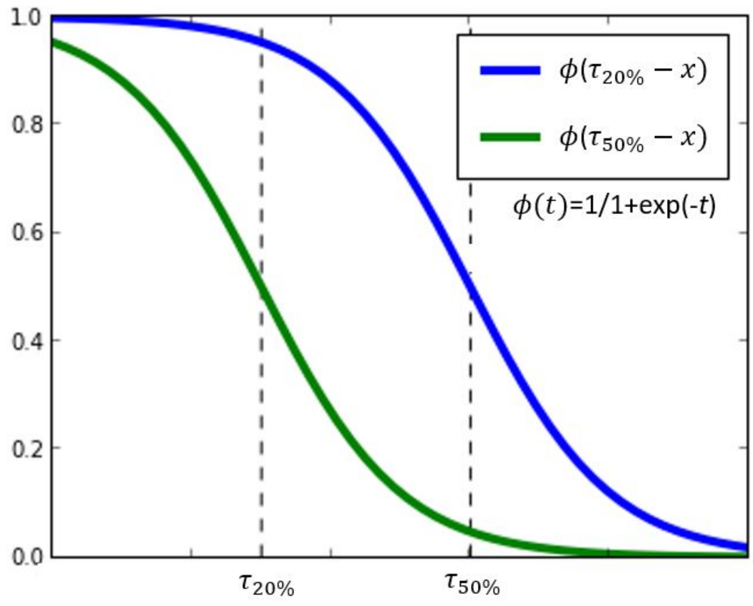


FIGURE 5.3: Distribution willingness-to-buy

U is above a cut-off level labeled $\tau_{50\%}$, the respondent answers '60% − 100%'. If his U is below $\tau_{50\%}$, but above $\tau_{20\%}$, he chooses '30% − 50%'. In summary:

- "60% − 100%" if $U > \tau_{50\%}$
- "30% − 50%" if $\tau_{50\%} > U > \tau_{20\%}$
- "0% − 20%" if $\tau_{20\%} > U$

Similar to regular logit model theory (Section 4.2.1.1), the researcher decomposes the perceived utility in observable attributes $\beta_{1,2...n}$ and an random error term ϵ representing unobserved factors.

$$U = \beta_1 x_1 + ... + \beta_n x_n + \epsilon \tag{5.1}$$

Figure 5.3 illustrates the distribution of ordered responses with respect to the utility U and the corresponding cut-off values τ_n.

When a logistic distribution for ϵ is assumed, the probability of the answer "$WTB = 0\% - 20\%$" is then:

$$\begin{aligned} Prob(\text{"0\%-20\%"}) &= Prob(U < \tau_{20\%}) \\ &= Prob(\beta x + \epsilon < \tau_{20\%}) \\ &= Prob(\epsilon < \tau_{20\%}) \\ &= \frac{e^{\tau_{20\%}-\beta x}}{1 + e^{\tau_{20\%}-\beta x}} \end{aligned}$$

And the probability of "$WTB = 30\% - 50\%$" is:

$$\begin{aligned} Prob(\text{"30\%-50\%"}) &= Prob(\tau_{20\%} < U < \tau_{50\%}) \\ &= Prob(\tau_{20\%} < \beta x + e < \tau_{50\%}) \\ &= Prob(\tau_{20\%} - \beta x < e < \tau_{50\%} - \beta x) \\ &= Prob(e < \tau_{50\%} - \beta x) - Prob(e < \tau_{20\%} - \beta x) \\ &= \frac{e^{\tau_{50\%}-\beta x}}{1 + e^{\tau_{50\%}-\beta x}} - \frac{e^{\tau_{20\%}-\beta x}}{1 + e^{\tau_{20\%}-\beta x}} \end{aligned}$$

The probabilities of the other choice options are calculated in the same way, with their corresponding τ's. Following from the equations, it should be noted that both the β's and the cut-off values τ's need to be estimated by the model.

Binary logit model theory A second approach to model the ordered response is the binary logit model. The binary logit model is a multinomial logit model with only two alternatives. The binary logit model features the advantage of using scale factors, which in their term enable us to use the combined sample of conventional and hybrid car owners in one model. Multinomial logit model theory is explained in Section 4.2.1.1 of Chapter 4 and scale factors are explained in Section 4.2.2.2. At the binary logit model, the choice variable, being the willingness-to-buy an AFV, is merged into a binary choice:

- High willingness-to-buy ($> K\%$)
- Low willingness-to-buy ($< K\%$)

The threshold level K between low and high willingness-to-buy can be chosen arbitrarily and the appropriate threshold level is determined through testing model performance with different threshold values.

5.2.3 Factor analysis personal identities

Previous research into the role of symbolic and affective factors also included the relation between self-identity and EV adoption. Schuitema [20] examined the role of two personal identities in the adoption of EVs: people seeing themselves as pro-environmental and seeing themselves as a car-authority. She found that people who identified themselves as a pro-environmental had more positive evaluations of the instrumental, affective and symbolic attributes of PHEVs and FEVs. Car authority, on the other hand, was found only weakly correlated with the perceive attributes of EVs.

Our analysis here will also try to examine the role of personal identities in the willingness to buy an EV. A factor analysis was performed to extract latent factors from the response on the 20 personal identity perception statements present in the data set. An elaborate description of the factor analysis performed can be found in Appendix A. The factor analysis resulted in the extraction of four personal identity factors. These factors are interpreted as follows:

- **Environmental norm** The normative beliefs of the respondent and important relatives about the environmental aspects of mobility.
- **Car authority** The extent to which the respondent beliefs he seeks new information about cars and influences others in their opinion about cars.
- **Technological interest** The extent to which the respondent enjoys discovering and using innovative and technological products.
- **Perceived behavioral control** The extent to which the respondent beliefs he can change car-related problems through his own behavior.

Two of these factors are in line with the personal identities used in the study of Schuitema [20]: environmental norm and car authority. Technological interest is also recognized in literature on AFV adoption. For example, Egbue and Long [27] argued that technological enthusiasts are likely to be early adopters of EVs as they are better equipped to sort out the many differences between EVs and conventional cars. Finally, perceived behavioral control is one of the three main components of Ajzen's Theory of Planned Behavior, which is used as the foundation of the theoretical framework of this study. This makes us conclude that the four factors resulting from the factor analysis are promising factors for input in the willingness-to-buy models. The four factors were saved as new variables an served as independent variables in the logit models.

5.2.4 The influence of symbolic and affective factors

In this section, the importance of symbolic and affective factors, current AFV perception, personal identity and socio-economic variables on the willingness-to-buy will be assessed with logit models.

Table 5.6: Scale reliability for symbolic and affective factors

Scale	Cronbach α	
	PHEV	FEV
Symbolic factors	0.920	0.864
Affective factors	0.905	0.859

5.2.4.1 Data preparation

This section describes the data preparation for the logit model estimation.

Dependent variable Respondents were asked to indicate their willingness-to-buy for five AFV types on an eleven-point scale (0% – 100%). To avoid low response for certain choice alternatives, response was aggregated into three categories:

- 0% – 20%
- 30% – 50%
- 60% – 100%

These aggregation thresholds were based on Figure 5.1 and Figure 5.2. These figures show choice frequencies for the lower categories are higher than for higher categories. To avoid low values, choice alternatives have not been aggregated uniformly. Instead, higher willingness-to-buy choice alternatives were aggregated in a broad category, whereas the lower willingness-to-buy choice alternatives were aggregated in two more narrow categories.

Symbolic and affective factors A symbolic scale and an affective scale were constructed by averaging the scores on the corresponding four and five statements from Table 5.2. Table 5.6 shows that the symbolic and affective scales are reliable scales, based on the Cronbach alpha estimates > 0.700 for all segments. Finally, the symbolic and affective scales are normalized to a [0,1] scale for correct comparison with other regression variables.

Current AFV perception The 7-point Likert scale response on the statements mentioned in Table 5.3 was normalized to a [0,1] scale for correct comparison with the other independent variables.

Socio-economic variables The literature review has shown that several socio-economic characteristics, like younger to middle age or high socio-economic status, are associated with a higher likelihood of buying an AFV, see Section 2.2.4. Therefore, several socio-economic characteristics are included as independent variable in the logit model estimations, see Table 5.7. The variable

Table 5.7: Socio-economic variables

Socio-economic variables
Gender
Age
Social class
Urbanization level of the residential area

'social class' is a construct variable combining job type and highest completed education of the household's breadwinner [67]. Social class levels range from D (low social class) to A (high social class). The socio-economic data was normalized to a [0,1] scale for correct comparison with other independent variables.

5.2.4.2 Ordinal logit model

To test the hypothesis of the role of symbolic and affective factors, ordinal logit models were developed including all variables mentioned in the previous section: personal identity factors, symbolic and affective reasons for car purchase, current AFV perception and socio-economic variables. As literature showed that preference for different AFV types varies (see Section 2.2.2.2), separate ordinal regression models were developed for FEV preferences and PHEV preferences. The data set contains separate data for FEVs and PHEVs on current AFV perception and the symbolic/affective factors. Socio-economic data and personal identity data is indepentent of the AFV type. Thus, for these variables, the same data is used for estimation of both regression models. In addition, the data sample is weighted to represent the Dutch population on gender and age class distribution. See Table D.1 in Appendix D for the applied weights per sample.

5.2.4.3 Model results

From Table 5.8 it can be observed that both symbolic and affective factors play a role in the decision to buy a FEV, indicated by the statistically significant parameter values $\beta = 1.49$ and $\beta = 1.44$. Only symbolic factors were found to play a role at the PHEV purchase decision ($\beta = 2.43$). Affective factors were not found to play a role at the purchase decision of a PHEV, ($\beta = 1.13$ with t-test$= -0.32$). These findings support the hypothesis that symbolic and affective factors play a role at FEV choice and partly for PHEV choice.

Furthermore, the current perception of AFV performance also has influence on the willingness-to-buy that car type. The results show significant parameter values for flexibility and reliability for both the FEV ($\beta = 0.962$ and $\beta = 0.974$) and the PHEV ($\beta = 1.45$ and $\beta = 1.13$). In addition, perception of the environmental performance was found significant for the FEV specifically ($\beta = 1.14$) and acceleration perception for the PHEV ($\beta = -0.803$, reverse coded). As these perceptional variables can be regarded as affective factors, this finding also supports the

TABLE 5.8: Influence of symbolic and affective factors on willingness-to-buy a FEV or PHEV

Parameter	FEV willingness-to-buy β-value	Std. err.	t-test	PHEV willingness-to-buy β-value	Std. err.	t-test
Symbolic and affective factors						
Symbolic factors	1.49	0.465	3.21**	2.43	0.498	4.87**
Affective factors	1.44	0.467	3.08**	-0.163	0.513	-0.32
Current AFV performance perception						
Acceleration	-0.365	0.238	-1.53	-0.803	0.263	-3.05**
Flexibility	0.962	0.229	4.20**	1.45	0.218	6.63**
Reliability	0.974	0.276	3.53**	1.13	0.273	6.63**
Environmental performance	1.14	0.277	4.12**	0.409	0.254	1.61
Personal identity factors						
Car authority	-0.0203	0.0673	0.76	0.192	0.0627	3.07**
Technological interest	0.159	0.0697	2.29*	0.180	0.0656	2.74**
Environmental norm	0.236	0.0652	3.61**	-0.00752	0.0619	-0.12
Perceived behavioral control	-0.0321	0.0617	-0.52	-0.00400	0.0584	-0.07
Socio-economic variables						
Age	0.243	0.264	0.92	0.796	0.259	3.07**
Gender	0.0270	0.124	0.22	-0.0539	0.119	-0.45
Social class	0.404	0.196	2.06*	0.179	0.188	0.95
Urb. level	-0.0737	0.187	-0.40	0.0713	0.181	0.39
Model specific parameters						
$\tau_{20\%}$	3.05	0.369	8.25**	2.34	0.334	7.01**
$\tau_{50\%}$	4.66	0.381	12.21**	4.05	0.346	11.71**
ASC	0.00	fixed		0.000	fixed	
Model performance						
nOBS	1402			1402		
Final log-likelihood	-1180.547			-1229.063		
Adjusted Rho-square	0.223			0.192		

* Statistically significant at 95% confidence level ** Statistically significant at 99% confidence level

hypothesis.

Of the personal identity factors, the results are less consistent. Only technological interest could be proven to affect the willingness-to-buy both a FEV and a PHEV, $\beta = 0.159$ and $\beta = 0.180$. In addition, environmental norm was found to be significant for the willingness to buy a FEV and car authority was found to play a role at the willingness to buy a PHEV.

A finding contrary to expectations from the literature study (see Section 2.2.3.1) was the insignificance of the majority of the socio-economic variables. Social class was found to play a significant role at the FEV willingness-to-buy and age was found to play a significant role at the PHEV willingness-to-buy.

Model performance Model performance for both the FEV and PHEV model are assessed as moderate fits to the data, with $\rho^2 = 0.223$ and $\rho^2 = 0.192$ respectively. A ρ^2 between 0.2 and 0.4 is considered to be an acceptable fit, see Section 4.2.2.3. In addition, the τ-values for both models are statistically significant. This implicates that the thresholds in the dependent variables, described in Section 5.2.4.1, are appropriately defined.

5.2.5 Differences between conventional car owners and hybrid car owners

The previous section showed that some symbolic and affective factors were proved to play a role at the willingness-to-buy an EV. This section will seek for differences in the role of symbolic and affective factors between conventional car owners and hybrid car owners. Different logit models were estimated for the conventional car owners and hybrid car owners for two reasons. First, because separate models deliver more detailed information on segment differences than one model with a scale parameter between the two groups. Secondly, the number of observations per segment is very different: 1203 observations for the conventional car owners sample and 199 observations for the hybrid car owners sample. In line with the analysis in the previous section, separate models were also estimated for FEV willingness-to-buy and PHEV willingness-to-buy. This results in a total of four different regression models.

5.2.5.1 Ordinal Logit models and binary mixed logit models

The four regression models were estimated using the stepwise forward selection method [68]. The stepwise forward selection method starts with no variables in the models and stepwise adds variables to the model, assessing model performance after each addition with a log-likelihood ratio test. Newly added variables are removed from the model if they do not improve model performance. By using this method, models mainly include statistically significant parameters.

Table 5.9 and 5.10 show, the models for the hybrid car owners segment only consist of a small number of variables and have low model performance ($\rho^2 = 0.099$ and $\rho^2 = 0.025$). Specifying the independent variables as dummy variables with a threshold rather than a continuous scale yielded no improvements in model performance. Alternatively, a binary logit model with a scale parameter for hybrid car drivers was estimated to seek for better model performance. The scaled binary logit model has the advantage of using the full sample.
To obtain a binary dependent variable, the willingness-to-buy was aggregated from three choice alternatives ($0\% - 20\%$, $30\% - 50\%$ and $60\% - 100\%$) to two alternatives:

- Alternative 1: Low willingness-to-buy ($0\% - 50\%$)
- Alternative 2: High willingness-to-buy ($60\% - 100\%$)

Model estimations with this aggregation method outperformed a different aggregation method ($0\% - 20\%$ and $30\% - 100\%$). Table D.2 of Appendix D shows the model performance of the model with the threshold at WTB=50% is substantially higher ($\rho^2 = 0.466$) than the model with the threshold at WTB=20% ($\rho^2 = 0.173$). The model performance of the scaled binary logit model performance is acceptable for both FEV willingness-to-buy and PHEV willingness-to-buy, arguing from their $\rho^2 = 0.466$ and $\rho^2 = 0.395$ respectively (see Tables 5.9 and 5.10).

5.2.5.2 Model results

Table 5.9 and 5.10 show the estimation results for the willingness-to-buy a FEV and willingness-to-buy a PHEV respectively.

Willingness to buy a FEV As only AFV performance perception factors and the symbolic factors were found significant in the model, the comparison between the conventional car owners and hybrid car owners on parameter-level is limited to these variables. The results show that the perception of the environmental performance of a FEV is more important for hybrid car owners than for conventional car owners. Moreover, environmental performance is the most important performance perception factor for hybrid car owners ($\beta = 1.69$), but the least important performance perception factor for conventional car owners ($\beta = 0.850$). A second result is that symbolic factors are relatively more important than AFV performance perception for hybrid car owners than for conventional car owners. For hybrid car owners the symbolic factors have $\beta = 2.53$ compared to FEV performance perception parameters in the range $\beta = 1.69 - 1.20$, whereas or conventional car owners the parameter values for FEV performance perception are in the range of $\beta = 0.850 - 1.46$, compared to $\beta = 0.560$ for symbolic factors. For these two models it is shown that the cut-off values have comparable values ($\tau_1 \approx 2.95$ and $\tau_2 \approx 4.50$) and are all statistically significant.
The scaled binary logit model performance is higher than the two ordered logit models, arguing from a $\rho^2 = 0.466$ versus a $\rho^2 = 0.281$ and $\rho^2 = 0.099$. Furthermore, the parameter estimates have the expected sign. The models shows hybrid car drivers perceive a lower utility for low willingness-to-buy. This implicates that they have a higher willingness to buy a FEV. This is argued from the combination $\lambda_{hybrid} < 1$ and $ASC_{lowWTB} = 5.04$. When the scale factor $\lambda_{hybrid} < 1$, the β's and $ASCs$ are lower for hybrid car owners than for conventional car owners, see Equation 4.5. This finding in is line with the suggestion of section 5.2.1 that hybrid car drivers indicate a higher willingness to buy a FEV more frequently.

Willingness to buy a PHEV Table 5.10 shows the model estimation results for the willingness to buy a PHEV. Model performance for the hybrid car owners segment is very low. The adjusted ρ^2 of 0.025 indicates that only 2.5% of the variance in the data set is explained by the estimated model. Due to the large difference in model performance between the conventional car owners model and the hybrid car owners model and the limited number of significant variables in the model, it was decided that a comparison between the two models is invalid. Therefore, only conclusions will be drawn from the scaled binary logit model. The scaled binary logit model performance is higher than the two ordered logit models, arguing from the $\rho^2 = 0.395$ versus a $\rho^2 = 0.212$ and $\rho^2 = 0.025$. Furthermore, the signs of parameter estimates are as expected, except for the negative $\beta_{flexibility}$. A more positive perception of EV flexibility should be favourable for high willingness-to-buy, whereas the negative estimate in the model reveals the relationship is negative. The conclusion for the willingness-to-buy a PHEV is similar to that of the FEV: hybrid car drivers perceive a lower intrinsic preference for a low willingness-to-buy, arguing from the $\lambda_{hybrid} < 1$ and the $ASC_{lowWTB} = 5.02$. This finding also supports the suggestion of section 5.2.1.

5.3 Conclusion

The results show several symbolic and affective factors play a statistically significant role in the willingness-to-buy an EV. Moreover, the roles are positive, meaning that if car owners find symbolic and affective aspects of cars important, their willingness-to-buy an EV is higher. This finding is in line with the work of Schuitema [20], who concluded that the intention to adopt an EV is stronger for people that have a more positive perception of the symbolic and affective attributes of EVs. This finding is beneficial for current EV sales as especially the FEV currently has less instrumental functionality than conventional cars. People who find symbolic and affective aspects of cars important are likely to base their car choice on these aspects as well, rather than solely on the car's functional aspects.

Of the affective aspects specifically, it is shown that the current perception of FEV and PHEV performance on flexibility and reliability is also important. In addition, the environmental performance perception of FEVs is also important for the respondents. This implies that EV stimulating policies and car manufacturer marketing strategies should also focus on consumer perception of non-instrumental car attributes like the flexibility, reliability and environmental friendliness. For example, stimulating EV car sharing programs [69] and events, at which consumers can try an EV for a short period, can influence the current perception of EVs.

A factor analysis resulted in four personal identity factors concerning mobility beliefs: environmental norm, car authority, technological interest and perceived behavioral norm. Of these factors, only pro-evironmental norm could be related to high willingness-to-buy a FEV or a PHEV. The results show that people with strong normative beliefs about the environmental effects of mobility are more likely to buy an FEV or PHEV in the future. This finding is in line with Schuitema's [20], Ziegler's [43] and Skippon's [70] finding that people with a pro-environmental identity have a more positive evaluation of FEVs and PHEVs. However, Schuitema debates this finding as it is shown that people with limited knowledge of environmental issues easily change their attitudes. As the environmental friendliness of PHEVs is currently under debate [8], this implies that car owners' perception of a PHEV's environmental performance is vulnerable. The

TABLE 5.9: Estimation results FEV preferences logit models

Parameter	Ordinal logit model Conventional car owners			Ordinal logit model Hybrid car owners			Binary logit model Full sample, scaled		
	β-value	Std. err.	t-test	β-value	Std. err.	t-test	β-value	Std. err.	t-test
Current FEV performance perception									
Flexibility	1.03	0.240	4.31**	1.20	0.558	2.15*	0.511	0.318	1.61
Reliability	1.46	0.308	4.76**	1.58	0.613	2.59**	1.85	0.399	4.63**
Environmental performance	0.850	0.294	2.89**	1.69	0.708	2.39*	1.33	0.444	3.00**
Personal identity factors									
Technological interest	0.229	0.0809	2.83**						
Environmental norm	0.255	0.0703	3.64**						
Perceived behavioral control	-0.203	0.0667	-3.04**				-0.299	0.0926	0.00**
Car purchase factors									
Symbolic factors	0.561	0.533	1.05	2.53	0.658	3.84**	1.27	0.610	2.08*
Affective factors	1.98	0.501	3.96**				1.88	0.664	2.84**
Model specific parameters									
$\tau_{20\%}$	2.97	0.297	10.01**	2.95	0.706	4.18**	not applicable		
$\tau_{50\%}$	4.50	0.314	14.32**	4.61	0.751	6.14**	not applicable		
λ_{hybrid}							0.792	0.106	-2.60**
ASC	0.00	fixed		0.000	fixed				
ASC_{lowWTB}							5.02	0.466	10.77**
$ASC_{highWTB}$							0.00	fixed	
Model performance									
nOBS	1203			199			1402		
Final log-likelihood	-940.147			-208.208			-510.161		
Adjusted Rho-square	0.281			0.099			0.466		

* Statistically insignificant at 95% confidence level ** Statistically significant at 99% confidence level

Table 5.10: Estimation results PHEV preferences ordinal logit regression models

	Ordinal logit model Conventional car owners			Ordinal logit model Hybrid car owners			Binary logit model Full sample, scaled		
Parameter	β-value	Std. err.	t-test	β-value	Std. err.	t-test	β-value	Std. err.	t-test
Current PHEV performance perception									
Acceleration	-0.913	0.281	-3.24**						
Flexibility	0.963	0.230	4.18**				-0.779	0.356	-2.19*
Reliability	1.170	0.302	3.87**	1.54	0.538	2.87**	1.30	0.406	3.21**
Environmental performance	0.604	0.265	2.28*				1.65	0.451	3.66**
Personal identity factors									
Car authority	0.153	0.0629	2.42*				0.187	0.0990	1.88
Technological interest	0.202	0.0756	2.67**	0.309	0.138	2.23*	0.349	0.0996	3.50**
Environmental norm	0.174	0.0646	2.69**	0.276	0.138	2.00*	0.198	0.0926	2.14*
Perceived behavioral control	-0.131	0.0621	-2.11*				-0.189	0.0911	-2.08*
Car purchase factors									
Symbolic factors	1.180	0.548	2.16*						
Affective factors	0.959	0.536	1.79				1.28	0.539	2.37*
Model specific parameters									
$\tau_{20\%}$	2.95	0.706	4.18**	-0.175	0.261	-0.67		not applicable	
$\tau_{50\%}$	4.61	0.751	6.14**	1.32	0.278	4.76**		not applicable	
λ_{hybrid}							0.394	0.0807	-7.51**
ASC	0.00	fixed		0.000	fixed				
ASC_{lowWTB}							4.03	0.495	8.15**
$ASC_{highWTB}$							0.00	fixed	
Model performance									
nOBS	1203			199			1402		
Final log-likelihood	-1029.577			-206.730			-573.936		
Adjusted Rho-square	0.212			0.025			0.395		

* Statistically insignificant at 95% confidence level ** Statistically significant at 99% confidence level

effects of respondents seeing themselves as a car authority are less outspoken. It was found significant for PHEV willingness-to-buy of the full sample, but only significant for conventional car drivers when distinguishing between conventional and hybrid car owners. This is in line with the weak correlation that Schuitema [20] found between seeing oneself as a car authority and the perception of EVs. This finding suggests that opinion leaders on the subject of car choice, are not convinced of the merits of EVs. Socio-economic variables, on the other hand were not found playing a role in the willingness to buy an EV. This is not in line with literature expectations of for example Plötz et al. [71], who concluded that people with a higher likelihood to buy an FEV are often young to middle aged and have a high socio-economic status (job and/or education level). Our findings implicate that policies and marketing strategies should define target audiences on personal identity characteristics rather than socio-economic characteristics.

Finally, it was explored whether differences in factor importance could be observed between hybrid car owners and conventional car owners. Conclusions on a parameter-level were drawn only on the willingness to buy a FEV. It was found that for hybrid car drivers, a respondent's perception of the environmental performance of a FEV compared to his current car is relatively more important than for conventional car drivers. This suggests that policies or marketing strategies that target hybrid car owners should emphasize more on the environmental performance of a FEV compared to marketing strategies targeting conventional car owners. For conventional car owners, the emphasize should be more on the flexibility and reliability of the FEV.

Chapter 6

Plug-in Hybrid Vehicle owners

Plug-in hybrid car (PHEV) drive-trains are very similar to FEV drive-trains. Both car types can drive solely on electric power and can be recharged by the grid. Consequently, current owners of a PHEV are familiar with the characteristics of electric driving, ie. battery range and charging times. In addition, they have knowledge of the charging infrastructure. Based on this knowledge and experience advantage, plus the fact that they already chosen to buy a partially electric vehicle over a conventional car, it is suggested that PHEV drivers should have a higher likelihood of buying a FEV in the future than current conventional car owners.

The exploratory analysis of this chapter searched for indications that suggest that PHEV drivers have a high likelihood of buying a FEV as a next car. First, the socio-economic profiles of PHEV drivers were examined to search for characteristics that are associated with a high likelihood of buying a FEV in literature. Secondly, the relationship between current car evaluation and future car preferences was examined to search for correlations between current car evaluation and future FEV preference. Thirdly, the importance of several monetary and non-monetary factors at the car choice process was considered. It was examined what factors are important to respondents that indicated to buy a FEV as a next car. After that, their preferences were compared to the preferences of respondents that indicated to stay at a PHEV for the next car.

6.1 Survey design and data collection

The data that was used for this analysis originated from the 2014 National Survey Electric Driving (NSED). The NSED was fielded by Accenture et al. between October 2014 and December 2014 [2] among current drivers of PHEVs and FEVs. The results of this survey were made available for this research. The data set mainly consists of information about respondents preferences

Table 6.1: Themes covered in the data set of the 2014 NSED, themes relevant for this research are underlined.

Theme
Socio-economic characteristics
Travel characteristics
EV stimulation policy of the company (only for company car drivers)
Travel behavior changes as a result of current EV purchase
Current EV evaluation
Car purchase process
Current charging behavior
Charging infrastructure preferences
Future car preferences

Table 6.2: Socio-economic and travel-related variables used for analysis

Variable
Age
Gender
Highest followed education
Private/company car ownership
Annual mileage
Commuting distance
No. cars in household

about the charging infrastructure and charging behavior. In addition, it consists of evaluation of respondent's current car, his car choice process and his future car preferences. Table 6.1 shows an overview of the NSED themes. The themes that were used in our analysis are underlined. The next section details on the relevant data set parts for this research.

6.1.1 Data set contents

Socio-economic and travel characteristics Previous research identified socio-economic and travel characteristics of car drivers that have a higher likelihood of adopting an EV. For example, younger to middle aged people or people with a low annual mileage. See Section 2.2.4 and Figure 2.4 for the complete list. Seven socio-economic and travel-related characteristics from the NSED were used for this research, see Table 6.2.

Evaluation of the currently owned EV and current infrastructure Current car experience is assumed to influence future car preferences. As PHEV owners already have experience with (partially) electric driving, their current experience with electric driving is an important to analyze. Respondents were asked to evaluate their car on both affective and instrumental aspects. In addition, the perception of the current infrastructure was asked. Five-point Likert scales were used for the assessment. Table 6.3 describes the exact survey questions.

TABLE 6.3: Survey questions evaluation current car experience and charging infrastructure

Survey question	Type of factor
Current car evaluation	
How do you experience the technical reliability of your EV?	Affective
How do you experience the ease of use of your EV?	Affective
How do you experience the sound level of your EV, compared to a conventional car?	Affective
How do you currently experience the range of your EV?	Instrumental
To what extent do you have insights in the cost savings of your EV, compared to a conventional car?	Instrumental
Infrastructure evaluation	
How much knowledge do you have of charging point locations?	Instrumental
How do you assess the charging point coverage in the Netherlands (excl. occupation by other cars)?	Instrumental
How often do you feel the need for reserving a charge point?	Instrumental
Do you have a charge point available at home?	Instrumental
Do you have a charge point available at work?	Instrumental

TABLE 6.4: Factors considered in the car choice process

Factor	Type of factor
I have considered the following monetary factors in the decision to drive an EV: (Provide your answer by assigning percentages, adding up to 100%)	
Purchase price	Instrumental
Maintenance cost	Instrumental
Fuel cost	Instrumental
Residual value	Instrumental
I have considered the following non-monetary factors in the decision to drive an EV: (Provide your answer by assigning percentages, adding up to 100%)	
Emissions	Instrumental
Sustainable image	Symbolic
Innovative image	Symbolic
Others (acceleration, design)	Affective

Car choice process The data set contains information about the car choice process of the respondents. The importance of four monetary and four non-monetary factors at the choice process for the current car is assessed by two constant-sum questions. At a constant-sum question, the respondent is asked to divide 100 points between four factors. Consequently, this type of question not only ranks the alternatives according to importance, but also reveals the relative importance of the attributes. Table 6.4 shows the exact formulation of the constant-sum questions. In addition, it should be noted that the eight factors are asked in two questions. Consequently, it is not possible to compare the relative importance of monetary versus non-monetary factors.

Future car preference Respondents were asked to indicate which car type their next car will be. The respondents were allowed to choose only one option from the following list:

- Conventional car

- Plug-in hybrid
- Full electric car
- Other, please specify

This choice situation indicates the EV preference of the respondent. Therefore, response on this question will be used as the dependent variable in the data analysis.

6.1.2 Data collection and respondent characteristics

The NSED was first held in 2012 and has been repeated annually thereafter. This research used the 2014 edition of the NSED, which was fielded by consultancy companies Accenture and Oranjewoud, e-mobility service provider GreenFlux and the Netherlands Enterprise Agency between October 2014 and December 2014 [2]. The survey was fielded as an internet questionnaire. The survey was publicly available on the internet and respondents were recruited through social media and websites of the responsible parties. Respondents were not paid for filling in the survey and it was not verified whether the respondent actually owned an EV. This voluntary nature of the survey posses questions to usability of the data for scientific research. It is decided to use the data for analysis, as this was the only suitable survey data available for the current Dutch population of 40.000 EV drivers [61].
Table 6.5 shows the respondent characteristics in the NSED sample. The sample features an overrepresentation of male and highly educated respondents. The main part of the sample is middle-aged. Furthermore, the FEV drivers sample has relatively more private car owners. Private car owners are argued to have different car preferences than company car drivers due to the different cost structures, see also Section 2.2.3.1. This has been taken into account when interpreting differences between the PHEV and FEV drivers on monetary aspects.

6.1.3 Choice frequencies

Table 6.6 shows future car type choice frequencies for the PHEV sample and the FEV sample. The table shows that there is sufficient variation in the dependent variable (future car choice) for the PHEV drivers sample to analyse differences based on future car type choice. The FEV drivers sample shows less variation with 83% of the respondents stating to buy the same car type as they currently own. This is unlikely to cause analysis issues as the main focus of the analysis will be on PHEV drivers.
In addition the choice frequencies reveal switching behavior of respondents between car types. It is promising to see that less than 5% of the respondents state to switch back to the conventional car type as a next car. Furthermore, one third of the PHEV respondents indicated they will ‘upgrade’ to a full electric vehicle. Finally, the majority of the FEV drivers indicates they will

Table 6.5: Background characteristics of the 209 respondents

Variable	Plug-in hybrid owners ($N = 69$) Percentage share (%)	Full electric vehicle owners ($N = 140$) Percentage share (%)
Gender		
Male	81.2	87.1
Female	18.8	12.9
Age category		
younger than 25	0	1.4
25-35	14.5	10.7
36-45	29.0	35.0
46-55	27.5	34.3
56-65	26.1	14.3
65 and older	2.9	4.3
Highest finished education		
Secondary school	2.9	2.1
Intermediate Vocational Education	7.2	14.3
Higher Vocational Education	42.0	35.7
Bachelor/Master/PhD	47.8	47.1
Other	0	2.1
Private or company car ownership		
Yes	46.4	25.7
No	46.4	64.3
No response	7.2	10.0

Table 6.6: Choice frequencies survey question on future car choice

	Current PHEV owners $N = 69$		Current FEV owners $N = 140$	
Future car type	Count	Percentage(%)	Count	Percentage(%)
PHEV	38	55	9	6
FEV	24	35	116	83
Conventional fuel	2	3	7	5
Do not know yet	5	7	8	6

keep driving a FEV as next car. However, a part of the effect of the 24 upgrading PHEV drivers is neutralized by the downgrading FEV drivers to either a PHEV (9 respondents) or a conventional car (7 respondents).

6.2 Data analysis

The analysis of the data set aimed to search for indications that suggest current PHEV drivers have characteristics or car preferences that are positively related to FEV adoption.

6.2.1 Research method

The analysis consists of three parts. First, data on annual mileage, commuting distance and number of cars in the household of the PHEV drivers were compared to those of the FEV drivers. The line of reasoning here is that similarities between the two sub-samples are beneficial for the likelihood of adopting a FEV in the future by PHEV drivers, as apparently the driving pattern of the PHEV drivers also seems possible with a FEV on these three indicators. Furthermore, the socio-economic and travel profile of the PHEV drivers was compared to the EV early adopters suggested by literature (see Figure 2.4). Second, correlations were analyzed between future car type preference and current car and infrastructure evaluation. Third, differences were analyzed between PHEV and FEV drivers at the importance of instrumental, symbolic and affective factors during the car purchase decision.

6.2.2 Socio-economic profiles

The first column of Table 6.7 shows the Pearson's χ^2 test values between the PHEV and FEV sample on the socio-economic and travel variables. Significant χ^2-test values indicate a statistically significant difference between the two samples. Only the ratio between private and company car ownership differs significantly: a PHEV is more frequently owned as a company car than a FEV, as can also be observed from Table 6.5. No statistically significant differences were found for the car use characteristics annual mileage, commuting distance and number of cars in the household. This result suggests that current car use patterns of PHEV drivers, indicated by annual mileage, commuting distance and number of cars in the household, can be maintained if they would switch to a FEV. This conclusion is posed mildly, as compliance of FEVs to current car use of non-FEV drivers is strongly questioned and often comes down to details rather than general indicators used here, see for instance Van Meerkerk et al [36].

Next, previous research on AFV adoption suggests people of younger to middle age and have a high socio-economic status. Furthermore, they have multiple cars and have a low annual mileage, see also Figure 2.4. These suggestions were tested by comparing the data of the NSEDs PHEV drivers with the data of conventional car drivers used for the analyses in the next two chapters. See Section 5.1.2 for details on this dataset. The second column of Table 6.7 shows that the PHEV sample differs significantly from the conventional car drivers sample on age, education level, annual mileage and number of cars in the household. Table 6.8 shows that PHEV drivers are younger and have more cars in the household than the conventional car drivers sample, but have a higher annual mileage. A comparison of Table 6.5 and 4.2 shows that PHEV drivers are also higher educated. Consequently, the PHEV drivers sample matches the early adopter characteristics from literature on age, education level and number of cars in the household, but not for annual mileage. This higher annual mileage of PHEV drivers is probably caused by the

Table 6.7: Comparison of socioeconomic characteristics

Variable	PHEV vs. FEV χ^2	p-value	PHEV vs. conv. χ^2	p-value	PHEV vs. hyb χ^2	p-value
Age	5.452	0.244	11.475	0.043*	43.963	0.000**
Gender	1.214	0.271	0.006	0.939	4.546	0.033*
Education level	2.407	0.300	104.962	0.000**	58.072	0.000**
Private or company car	6.216	0.013**	n.a.	n.a.	n.a.	n.a.
Annual mileage	8.716	0.121	31.772	0.000**	61.539	0.000**
Commuting distance	6.542	0.181	8.213	0.084	25.810	0.000**
No. cars in household	0.077	0.781	8.798	0.003**	27.090	0.000**

* statistically significant at 5%
** statistically significant at 1%

Table 6.8: Mean values of variables differing between PHEV and conventional samples

Variable	PHEV drivers mean value	Conventional car drivers mean value
Age	47.2	53.5
Annual mileage	27344	19677
No. cars in household	1.68	1.56

fact that the PHEV sample included both private and company car drivers and the conventional car drivers sample only private car drivers. It is known that company cars have higher annual mileage than privately owned cars [53].

6.2.3 Current car and infrastructure evaluation

In this part of the analysis, current car and infrastructure was related to future car preferences. The hypothesis here is that PHEV drivers are more likely to switch to a FEV as next car when they are more positive about their current (partially electric) plug-in hybrid and the current charging infrastructure. A series of correlations have been tested, using future car preference as the dependent variable and current car and infrastructure as dependent variables. Future car choice was coded “1” if future car choice was a FEV and coded “0” if future car choice was a not a FEV. Therefore, correlation values with a positive sign in the analysis are beneficial for future FEV choice.

Table 6.9 shows that charge point availability at work was significantly correlated to future car choice. The negative sign of the correlation however, was contrary to expectations. It was expected that charge point availability at work would be beneficial for future FEV adoption as the driver then has a charging point available at a frequently visited destination. If this finding indeed reflects the preferences of PHEV drivers, this would implicate that policy measures like subsidizing charge points at work by either the company or the government would have no effect on FEV adoption rates. No other significant correlations could be found between current car and infrastructure evaluation and future car choice for PHEVs. Possibly, there are other factors

TABLE 6.9: PHEV drivers sub-sample crosstab analysis results

Factor	PHEV drivers sample χ^2 (df)	p-value	R^2	Full sample (PHEV and FEV) χ^2 (df)	p-value	R^2
Current car evaluation						
Technical reliability[a]	2.971 (3)	0.396	0.219	7.523 (3)	0.057	0.202
Ease of use[a]	0.943 (3)	0.815	0.123	9.916 (3)	0.022*	0.232
Noise level inside car[a]	1.323 (2)	0.516	0.146	2.992 (3)	0.224	0.127
Current range evaluation[i]	8.431 (4)	0.077	0.303	52.550 (4)	0.000**	0.533
Current infrastructure evaluation						
Charge point awareness[i]	5.155 (4)	0.272	0.135	13.972 (4)	0.007**	0.273
Charge point reservation[i]	1.652 (4)	0.799	0.031	3.342 (4)	0.050*	0.134
Charge point at home[i]	0.230 (1)	0.631	0.154	4.361 (1)	0.037*	0.154
Charge point at work[i]	4.250 (1)	0.039*	-0.262	4.164 (1)	0.041*	-0.151
Charge point coverage NL[i]	6.720 (4)	0.151	0.016	18.069 (4)	0.001**	0.313
TCO insight[i]	5.849 (4)	0.211	0.178	18.958 (4)	0.001**	0.320

* statistically significant at 5% ** statistically significant at 1% [a] affective factor [i] instrumental factor

that are not assessed in this survey that play more important roles. But the small sample size ($N = 69$) could be of influence on the results. Therefore, the correlation analysis is also performed on the full sample, consisting of both PHEV and FEV drivers ($N = 209$).

The second column of Table 6.9 shows significant correlations for nearly all variables tested. The strongest correlations were found for current car range ($R^2 = 0.533$), total cost of ownership insight ($R^2 = 0.320$) and charge point coverage in the Netherlands ($R^2 = 0.313$). In addition, it is interesting to see that a significant correlation was found for an affective factor besides the instrumental factors. The correlation of $R^2 = 0.232$ implies that the ease of use of the current car (either a PHEV or a FEV) is positively correlated to future FEV choice.

6.2.4 Factors determining car purchase

The third part of the analysis details on the car choice decision. Respondents were asked how important a set of monetary and non-monetary factors were to them, when deciding to buy their current PHEV or FEV. Table 6.10 shows the descriptive statistics of the factor scores. The table shows that for the monetary cost, fuel cost is on average the most important attribute for both PHEV and FEV drivers. Of the non-monetary factors, the emissions of a car (an instrumental attribute) were on average more important than symbolic factors like a sustainable or innovative image and also more important than affective factors like comfort and design. Table 6.10 shows several differences between current PHEV drivers and current FEV drivers, for example on the importance of purchase price, maintenance costs and sustainable image. T-tests are performed to analyse whether these differences are statistically significant.

Table 6.11 shows the differences on purchase price and maintenance cost are statistically signficant. Current PHEV drivers find purchase price more important for car choice. On the other

Table 6.10: Means and standard deviations of the points assigned to each factor

Factor	PHEV drivers Mean	PHEV drivers St.dev.	FEV drivers Mean	FEV drivers St.dev.
Monetary factors				
Purchase price[i]	34.24	23.15	26.03	18.80
Maintenance cost[i]	15.00	11.46	25.13	15.44
Fuel cost[i]	44.24	24.88	42.09	18.31
Residual value[i]	6.52	9.40	6.75	9.58
Non-monetary factors				
Emissions[i]	35.80	22.99	35.47	25.81
Sustainable image[s]	26.60	14.63	21.35	16.14
Innovative image[s]	22.54	14.63	24.17	17.11
Other (i.e. comfort)[a]	18.06	23.71	19.01	20.83

[i] instrumental factor [s] symbolic factor [a] affective factor

Table 6.11: Independent sample t-test scores

Factor	Current PHEV vs. Current FEV t-value	σ (2-tailed)
Purchase price	2.000	0.048*
Maintenance cost	-3.423	0.001**
Fuel cost	0.518	0.605
Residual value	-0.119	0.906
Emissions	0.086	0.931
Sustainable image	0.938	0.349
Innovative image	-0.653	0.515
Other (i.e. comfort)	0.679	0.777

* statistically significant at 5%
** statistically significant at 1%

hand, FEV drivers find maintenance costs more important. Both results are in line with expectations. FEVs currently available on the market are more expensive than comparable conventional and (plug-in) hybrid cars. If one finds purchase price very important, a FEV is not an interesting alternative. On the other hand, FEVs are perceived to have lower maintenance costs due to less wearing parts. This makes it an interesting alternative for people that find maintenance costs important. However, it should be noted that a confirmation bias might play a role. It is general knowledge that FEVs are more expensive than PHEVs and that PHEVs have lower maintenance costs. Respondents might tend to confirm their current car choice in their response to these questions.

The finding that the differences between PHEV drivers and FEV drivers on the symbolic and affective factor were not found significant is contrary to expectations. As FEVs generally have lower instrumental performance than conventional cars (range, and et cetera) it was expected that a FEV purchase decision is made with more emphasis on symbolic and affective factors like sustainability and innovation. Our findings here suggest that current FEV drivers do not emphasize more on symbolic and affective factors than current PHEV drivers.

6.3 Exploratory conclusions

The analysis of this chapter sought for exploratory indications among PHEV drivers that are suggested to be beneficial for buying a FEV as a next car. The hypothesis was that PHEV drivers already chose a partially electric vehicle before and consequently already have experience with electric driving. Future FEV choice for them would be more based on experience than assumptions compared to conventional drivers' choice for a FEV. Arguing from the choice frequencies, it is shown that one-third of the PHEV respondents indicated to switch to a FEV as a next car. In addition, $< 5\%$ of the respondents indicates to downgrade to a conventional car. These findings suggest PHEV drivers are positive about the electric driving part of their EV. However, it should be noted that socially desirable response might play a role at this voluntary survey.

Car use patterns of PHEV and FEV drivers, based on annual mileage, commuting distance and number of cars in the household, are found similar between PHEV drivers and FEV drivers. This suggests that the car use pattern of PHEV drivers is also feasible with a FEV. This conclusion is posed midly, as FEV compliance to current non-FEV car use patterns often comes down to details rather than the general indicators used here. In addition, it is shown that PHEV drivers match the socio-economic profile of FEV early adopters. This implies that current PHEV drivers have a socio-economic profile that is suggested to have a higher likelihood of adopting a FEV as a future car.

Current car and infrastructure evaluation of PHEV drivers is not related to future FEV choice in our research. For the full sample (PHEV and FEV drivers combined), strong correlations were found for the instrumental factors range perception, charge point coverage and the affective factor ease of use in relation to future FEV choice. Further research should be undertaken to make the step from correlations to causality on this point, but this requires more data than is currently available.

Regarding the car purchase decision, fuel costs are on average the most important monetary factor. This is favourable for FEV adoption, as electricity costs per kilometer of FEVs is lower than petrol costs for conventional cars. It implies that EV buyers are especially sensitive for fuel cost savings. In addition, emissions of a car are the most important non-monetary factor for the NSED respondents. Furthermore, it was found that PHEV drivers find purchase price relatively more important that FEV drivers. Finally, contrary to expectations, FEV drivers give similar weight to symbolic and affective factors during the car purchase than PHEV drives. This implies that symbolic and affective factors do not play a larger role for FEV drivers, as often believed from the fact that FEVs generally have lower instrumental performance than conventional cars.

Chapter 7

Conclusions and policy implications

The main research objective was formulated as follows:

"To quantify the differences in preferences between conventional and hybrid car owners for instrumental FEV and PHEV attributes and the role of symbolic and affective factors at their FEV and PHEV willingness-to-buy."

1. How do the preferences of private hybrid car owners and conventional car about instrumental attributes of FEVs and PHEV differ?
2. What symbolic factors, affective factors and personal identities influence the willingness to buy a FEV or a PHEV?
3. How does the importance of symbolic factors, affective factors and personal identifies differ between conventional and hybrid car owners?
4. Which exploratory indications can be found at PHEV owners that are beneficial of possible FEV purchase in the future?

7.1 Preferences for the FEV and PHEV and their instrumental attributes

This section describes the results of Chapter 4 for research question 1 about the influence of instrumental attributes on the perceived utility of FEVs and PHEVs.

Instrinsic preference for AFVs Findings for the conventional car owners are in line with expectations from other research. FEVs and PHEVs are valued negatively compared to conventional cars 'ceteris paribus' by €-18.908 and €-18,365 respectively. This negative intrinsic preference excludes the cost difference between EVs and conventional cars. As EVs have a higher purchase price, the negative preference including the cost difference increases by €5,000 to €10,000 depending on the amount of monthly cost savings that are taken into account. This negative intrinsic preference for EVs is substantial with respect to their sales price of around €40,000. Moreover, as this €40,000 sales price already includes the vehicle tax subsidies of the Dutch government of around €4,000 compared to a mid-size conventional car. This implicates that substantial additional subsidies are needed to bridge the gap between conventional cars and EVs. The findings for the hybrid car owners show a higher preference for FEVs and PHEV, albeit still negative. Exact numbers could not be determined as a result of the model type used, but hybrid car owners negative intrinsic preference is smaller that €-18.279 and €-17.549 for the FEV and PHEV respectively.
In addition, it is shown that the negative intrinsic preference for the FEV can be reduced by technological improvements, like range improvements and recharge time reductions, to €-8,917. This result does not include the price difference between a FEV and a conventional of €5,000-€10,000 mentioned earlier, but nevertheless shows that substantial subsidies are needed on top of currently existing subsidies to make FEVs equally attractive as conventional cars.

Willingness to pay for instrumental attributes The willingness to pay for higher performance on instrumental attributes is lower than figures found in similar research [22]. Willingness to pay for additional range is valued €25.80/km by conventional car owners. Reduced charging times are valued €6.04/min and €28.36/min for FEVs and PHEVs respectively. The WTP figures of the hybrid car owners are lower than conventional car owners. The exact values for hybrid car owners could not be determined, as this conclusion is derived from a full sample model with a scale factor between conventional and hybrid car owners. As the results show hybrid drivers are less willing to pay for additional instrumental functionality, it is suggested that hybrid car owners are more satisfied with current EV performance on these attributes. A plausible explanation of the finding is the lower mileage of the hybrid car owners in the sample compared to the conventional car owners. Due to less car use, hybrid car owners are likely to experience the functional limitations of FEV less often. Another implication of the lower WTP of hybrid car owners also implies a lower marginal effect of future range and charging time improvements among hybrid car owners than for conventional car owners.

Simulated FEV and PHEV market shares Simulated market shares show higher market shares for FEVs and PHEVs for the hybrid car owners sample than for the conventional car owners sample. The market shares are simulated with the model outcomes and the data sets.

The results show a 20.2% FEV market share for hybrid car owners, compared to a 12.0% market share for conventional car owners. For PHEVs the market share is 9.1% versus 6.1% among conventional car owners. The higher market share of FEVs compared to PHEVs is contra-intuitive as FEVs have limited instrumental performance than conventional cars, whereas PHEVs combine some benefits of electric driving with the functionality of conventional cars. In addition, it is shown that market shares simulated on the stated choices are not reflected in recent real world sales figures. Actual vehicle sales show a 0.7% FEV market share and a 3.1% PHEV market share in the Dutch new vehicle sales of 2014. This indicates a rather large gap between stated preference and revealed choice.

7.2 The role of non-instrumental attributes in AFV preferences

This section concludes on research question 2 and 3 by discussing the results on the role of symbolic and affective attributes in the willingness-to-buy a FEV or PHEV, described in Chapter 5.

Symbolic and affective attributes The results show symbolic and affective factors play a statistically significant positive role in the willingness to buy a FEV or a PHEV. Respondents that indicated symbolic factors like status provision and personal identity expression are important reasons to buy an EV, have a higher likelihood to buy an EV. The same yields for hedonic affective factors like joy, thrill and adventure. This finding is beneficial for especially FEV sales as FEVs might compensate their limited functional performance by their symbolic and affective aspects in the minds of car buyers.

In addition, it is shown that a positive perception of both FEV and PHEV flexibility and reliability increases a respondent's willingness to buy. For the FEV specifically, this also yields for a respondent's perception of the FEV's environmental performance. This implies that the likelihood of buying an EV can also be increased by shaping car buyer's perception of EVs besides improving the car itself in terms of instrumental attributes like range and recharge times. Finally, the results reveal some differences between hybrid car owners and conventional car owners. For hybrid car owners, their perception of the environmental performance of a FEV is of greater importance in their willingness to buy a FEV than flexibility and reliability perception. For conventional car owners, the opposite holds.

Personal identity A factor analysis extracted four personal identity factors from data on personal identity perception: environmental norm, car authority, technological interest and perceived behavioral control. Only environmental norm could be related to the willingness to buy an EV. The results show that people with strong normative beliefs about the environmental effects of mobility state a higher willingness-to-buy a PHEV or FEV. This implies that, in line with previous literature findings, a pro-environmental attitude is beneficial of the likelihood of buying an EV. This finding suggests car buyers with a pro-environmental attitude are attracted to buying EVs, which is valuable information for creating a profile of EV early adopters. The influence of a pro-environmental attitude on the likelihood to buy a PHEV also affects the current debate about the environmental performance of PHEVs during actual use. As Schuitema argues that people with limited knowledge about environmental issues easily change their attitudes, the perception of the PHEV's environmental performance might be vulnerable in the future. The findings of this research suggest that the willingness-to-buy might drop considerably if the public attitude towards PHEV environmental performance changes negatively.

7.3 Exploratory results on PHEV driver preferences

This section describes the results of the exploratory analysis of Chapter 6 to address research question 4. The exploratory results on the characteristics and preferences of PHEV drivers show several indications that suggest PHEV drivers have a higher likelihood of buying a FEV as a next car. First, it is shown that PHEV drivers sample matches the socio-economic profile of early FEV adopters on being younger and have more cars in the household than conventional car owners sample. In addition, they are more highly educated than conventional car owners. The PHEV drivers did not match the early adopter characteristic of having a low annual mileage. Current PHEV and infrastructure evaluation of PHEV drivers was not related statistically significant to future FEV choice.

Regarding the car purchase decision, fuel costs are shown to be the most important monetary factor. This is a favourable finding for FEV adoption, as electricity costs per kilometer of FEVs is lower than petrol costs for conventional cars. Furthermore, a car's emissions are the most important non-monetary factor. This is also a favorable finding as FEVs are zero-emission vehicles, apart from the electricity production emissions at the power plant. In addition, it is shown that FEV drivers give similar weight to symbolic and affective factors during the car purchase decision than PHEV drivers. This implies that symbolic and affective factors doe not play a larger role for FEV drivers, as often believed from the fact that FEVs generally have lower instrumental performance than PHEVs and conventional cars. Finally, the results show that PHEV drivers find purchase price relatively more important than FEV drivers, whereas FEV drivers find maintenance cost more important. As FEVs currently have a higher purchase price, this finding implicates that FEVs are less attractive to PHEV drivers. However, it is likely that a confirmation bias is present in this data about car choice in the past.

7.4 Policy implications

The results of this research are interesting for all parties having an interest in stimulating FEV sales. Besides policy makers, this also includes FEV manufacturers and charging infrastructure service providers. As this research was performed on behalf of the Dutch Environmental Assessment Agency (PBL), the implications of this research are addressed to public policy makers.

7.4.1 General policy implications

In order to increase EV sales in the Netherlands, the results conclude that substantial financial measures are needed to bridge the gap between AFVs and current cars. This can be performed by either subsidizing EVs or penalise conventional cars. Subsidizing EVs will practically mean financial bonuses like current vehicle sales tax and annual road tax exemption. Penalising conventional cars can be performed by increasing the CO_2-variability of the sales tax, road tax or fuel tax. However, public and political support for penalising conventional cars is not unanimous. Moreover, as effects can be low, due to inelasticity of fuel prices, or effects can be undesirable like mobility reductions inducing welfare losses.

In addition to tax measurements, the results advocate government programs for technological development of EVs. The positive willingness-to-pay for additional EV range and reduced charging times implicate that EV sales are likely to increase when their performance on these instrumental attributes increases. However, (the speed of) technological developments in the near future is uncertain and implementation of government subsidies might be difficult in the competitive car market.

Furthermore, the results implicate that EV sales can also be stimulated by policy measures focusing on the symbolic and affective factors of car use in addition to taxes and technological improvement programs. For example, FEV-experience programs might convince car buyers of the flexibility and reliability of FEVs, rather than letting them base their attitude towards FEVs on perceptions. The duration of this program should be long enough to let the users develop stable preferences that go beyond the adaptation phase. In addition, promotional campaign stressing the environmental benefits of FEVs over conventional cars might increase EV sales as the results show, a positive perception of the environmental performance of a FEV increases the willingness to buy it. This yields especially for the pro-environmental car buyers, who are more likely than average to buy a FEV. Nevertheless, it should be noted that changing the public opinion on the environmental benefits of FEVs by promotional campaign is difficult, as a counter-narrative is still present. This counter-narrative argues that emissions are transferred from the tailpipe to the power plant and pose questions to the life cycle sustainability of battery resources. This skeptism, combined with vulnerable opinion of the average consumer makes it difficult to affect the public opinion.

7.4.2 Specific policy implications for hybrid car owners

This research highlighted several differences between hybrid car owners and conventional car owners. These differences have an affect on the policy implicated described previously. The results show hybrid car owners have a higher intrinsic preference for FEVs and PHEVs than conventional car owners. This implies that less financial measures are needed for hybrid car owners to make FEVs and PHEVs equally attractive as conventional cars. A trade-in program that offers a purchase subsidy for hybrid car owners who are buying a FEV as a next car is a policy measure that specifically stimulates FEV sales among this group of car owners. However, this conditional allowance to the subsidy program should only be established when the subsidy budget is limited. Otherwise, it would be beneficial for EV sales to allow all car users to the trade-in subsidy regardless of their current car.
In addition to taxes, government subsidies for technological development of EVs are proposed in the previous section. The results show that hybrid car owners have a positive, but lower willingness to pay for additional instrumental functionality of EVs than conventional car owners. Consequently, the effect of technological improvements of EVs will still be positive for hybrid car owners, but marginal effectiveness will be lower compared to conventional car owners. Finally, policies targeting the symbolic and affective factors of car use were proposed to stimulate EV sales. The results show that hybrid car owners attribute more importance to the environmental performance of a FEV than its flexibility and reliability, compared to conventional car owners. This suggests that the promotional campaigns emphasizing on the FEV environmental benefits are of greater importance to increase FEV sales specifically among hybrid car owners than the FEV experience program mentioned.

7.4.3 Discussion of current and future Dutch EV stimulation programs

Section 2.3 described the current Dutch EV stimulation programs and the upcoming changes in the car tax scheme. The results of this research call for fiscal stimulation of EVs like currently present policies. This is not fully reflected in the intended policy changes till 2020, which prescribes that the current level will only be maintained for FEVs. The results of this research show that, also for PHEVs, the fiscal benefits need to be in place to stimulate sales. The Dutch government however, sends a clear message about their negative perspective on the role of PHEVs in CO_2 reduction by discontinuing all fiscal benefits of PHEVs in the upcoming years.

Furthermore, the Dutch government stimulates EV sales with non-fiscal policies through project-based subsidies. The majority of the projects target the development of the public charging infrastructure. The results of this study support subsidizing the public charging network as it is shown that reduced charging times increase the preference for EVs. In addition, several EV experience programs are currently being subsidized. This research supports the need for these programs as they aim to improve car owners perception of EVs.

Finally, the research findings recommend improving car technology in terms of vehicle range and vehicle recharge times (a combination of charge point and car technology). The current Dutch EV stimulation programs lacks measures specifically aiming to improve car technologies. This is reasonable as governmental policies to improve car technology are more appropriate on the European level, due to the global nature of the car manufacturing industry. The need for additional car functionality in terms of range and charging times calls for government cooperation with car manufacturers specifically to speed up the technological developments in electric driving.

Chapter 8

Discussion and recommendations

This section discusses the validity of the results and weaknesses in the research methods. Consequently, directions for further research are described.

8.1 Discussion

Several points of discussion are described in the following section. This includes limitations to the experimental set-up of the stated choice data, model results validity and data limitations.

8.1.1 Stated choice experiment design

The choice sets and definition of attributes and levels are a vital part of stated choice experiments. This research uses data that was collected for a stated choice survey developed by Hoen and Koetse [1]. Although the data was well suited for answering the research questions of this research, some limitations were found during the analysis.

Validity of respondent-specific purchase price Hoen and Koetse's made the attribute 'purchase price' respondent-specific. It is common practice to make attribute values respondent-specific to present realistic choice sets that complement the choice makers personal situation. Hoen and Koetse followed this common practice by depending the purchase price attribute to the amount the respondent usually spends on a car. They use mark-ups for AFVs to reflect the higher purchase price. In addition, they use lower mark-ups for AFVs for respondents that buy second-hand cars. This however, affects the real-world realism of the choice situation. For example, respondents that usually buy second-hand cars worth €3,000 are presented FEV purchase prices of €8,000 at most. These sub-€10,000 purchase prices of cars are unrealistic in the near future.

Hoen and Koetse preferred respondent-realism over real-world realism because they preferred to measure the preferences of second-hand car buyers as well. This is a reasonable argumentation, but one should bear in mind that the choice situations presented to the second-hand car buyers have limited realism in the near future.

8.1.2 Model results

The models developed in this research are not without limitations. Besides, the use of stated preference data to estimate the models poses limitations to the real-world implications of the results. Finally, as consumer preferences change over time, preference data can become out-of-date rather quickly. These aspects, among other things, are discussed in the following section.

Desirable response The results in Chapter 4 show a substantial difference between simulated AFV market shares based on stated preferences and the actual shares in real world sales data. This brings up the discussion on one of the major limitations of stated preference data: what people say they will do, is often not the same as what they actually do. Possibly, people actually might not know what they will actually do if a hypothetical situation is real. However, socially desirable response might also play a role, especially about social issues like environmental preservation and sustainability. Ideally, stated preference data and revealed preference data (ie. real world sales data) would be combined in a choice model to utilize the benefits of both data types.

8.1.3 Data limitations

The number of observations for the hybrid car owners limited the specification of an advanced logit model. Model specifications like hybrid choice model specifications and mixed logit specifications were discarded during model development due to the limited number of observations. As a result, the models here represent the choice behavior of hybrid car owners in an appropriate, but simplified way.
The limited number of observations also played a role at the data set for PHEV drivers. I choose to limit the statistical analysis to correlations and sample differences tests. Alternatively, regression analyses or discrete choice models would have resulted in more explanatory conclusions rather correlations and statistically significant differences between samples. In addition, the absence of data on conventional car drivers in the National Survey did not allow for comparison of choice behavior between plug-in hybrid drivers and conventional car drivers. Some further limitations of the data sets are discussed in the following sections.

Interdependence of instrumental, symbolic and affective factors The stated choice data and attitudinal data did not provide enough overlapping observations to estimate a hybrid choice model, integrating both instrumental and symbolic plus affective factors. Consequently, the relative importance of instrumental, symbolic and affective factors could not be assessed. In addition, for example Schuitema [20] argued that a straightforward distinction between instrumental, symbolic and affective factors is an oversimplification of the actual choice process. She argued that symbolic and affective factors can influence a choice maker's perception of instrumental factors. These possible interactions were not taken into account in the models of this research. Furthermore, the research results implicate that besides policies targeting the instrumental aspects of car use, symbolic and affective factors should also be goal of public policies. However, as the relative importance of instrumental, symbolic and affective attributes in car choice is unknown, the relative importance of different policy measurements is also unknown. Consequently, this research cannot make recommendations about which policy measures will be most effective in increasing EV sales.

Preference differences between private and company car ownership It is known that different factors play a role at car choice for private car owners and conventional car owners. Especially the cost structures of private car ownership and company car ownership differ greatly. To limit the scope of the research, only private car owners were considered at researching car owners preferences. Consequently, readers should be aware that there is a second segment of company hybrid car drivers that are likely to have different preferences for FEVs than the preferences resulting from this research.

This preference difference also plays a role at PHEV preferences for FEVs. To avoid low response numbers, the private and company owned PHEVs are aggregated to one group of respondents: PHEV drivers. Given the fact that these two segment have different preferences, the research results reflect the aggregated preferences of two different segments. It is therefore likely that the results for the two discrete segments differ from the results found in this research.

Preference differences between new and second-hand car buyers Previous research has shown that the preferences of new and second-hand car buyers vary significantly, especially regarding cost sensitivity. It is shown that second-hand car buyers are twice as price-sensitive that new car buyers [1]. This difference in cost-sensitivity is likely to influence their preferences for FEVs. The distinction between new and secondhand car buyers is adressed in the models by applying a scale factor. This accounts for preference differences, but leaves few possibilities to examine the differences between the two groups further. Ideally, separate model results were calculated for the two segments separately. The limited data did not allow for this further segmentation into new and second-hand car buyers. As a result, the preferences of the two discrete segments are likely to differ from the aggregated results of this research.

8.2 Directions for further research

A discrete choice model for AFVs including instrumental, as well as symbolic and affective factors is able to assess the relative importance of these three types of factors. Hybrid choice models, which simultaneously estimate a latent variable model and a choice model, as described by Walker [58], are suitable for this purpose. See the study of La Paix Puello and Geurs [72] for an application of hybrid choice models to modeling modal choice behavior.

Stated choice experiments are widely used for quantitative research into travel behavior. Collection of stated choice experiment data combined with attitudinal data for PHEV owners allows to estimate discrete choice models on preference data of PHEVs similar to analyses proposed in the previous paragraph of this section.

Finally, it advised to define two a-priori segmentations when collecting new data on this subject: private versus company car drivers and new versus second-hand car buyers. As these segments are argued to have different preferences at car choice, sufficient data should be gathered for each of the segments. This will enable researchers to analyse the preferences of these four segments separately.

Appendix A

Exploratory Factor Analysis of personal identity factors

The survey presented the respondents 20 statements about their personal identity. This appendix shows the results of the exploratory factor analysis (EFA) that extracted four latent factors from the response on the 20 statements.

A.1 Survey statements

Respondents were presented 20 statements, for which they were asked to indicated their level of agreement on a 7-point Likert scale. The survey was originally fielded in Dutch; the statements in Table A.1 are translated from Dutch to English.

A.2 Factor analysis procedure

Factor analysis is a statistical method that identifies variables featuring similar variability and group them as one latent 'factor'. During the procedure of factor analysis, two factor extraction methods are available. First, factors can be extracted from the set of variables based on their Eigenvalues or secondly, a user-defined fixed number of components. Although arbitrary, a commonly used procedure in exploratory factor analysis is initially letting the software (in this case IBM SPSS v22) extract components based on an Eigenvalue > 1. The breaking point of the resulting scree plot provides a suggestion for the number of components to extract. Despite this suggestion, exploratory factor analysis remains a trail-and-error procedure to find a suitable number of latent factors that can be interpreted clearly.

Table A.1: Personal Identity statements

	Label	Survey question
1.	Gadgets	I really enjoy discovering new technological products or 'gadgets'.
2.	Innovations to impress	I like to use innovative products to impress others.
3.	Differentiation	I like owning new products that other people do not have yet, because I like to distinguish myself from others.
4.	Innovation use	I enjoy using innovative products.
5.	Good feeling innovative car	Buying an innovative car would give me a good feeling.
6.	Car magazines	I enjoy reading car magazines.
7.	Normative limit to car use	Certain values that are important to me, force myself to use my car as less as possible.
8.	Environmental-friendly modes	For principal reasons, I use environmental-friendly modes like public transport or the bike as much as possible.
9.	Role of the environment	Environmental-friendliness plays an important role in choosing my transport mode.
10.	Expectation relatives	Relatives that are important to me, expect me to use environmental friendly transport modes.
11.	Insinuations relatives	Important relatives insinuate I should take the environmental into account when choosing my transport mode.
12.	Support relatives	Important relatives support me when I choose a more environmental friendly transport mode that the car.
13.	Transport problems	I can contribute to solving car-related traffic problems by limiting my car use.
14.	Car use of others	Limiting my car use makes no sense, as others will keep driving their cars anyway.
15.	Implications car problems	I cannot see what I can change about the problems resulting from car use.
16.	Solution car problems	Issues resulting from car use cannot be solved.
17.	Car advise	People frequently ask me for advise when buying a new car.
18.	Car information	I frequently browse for information about cars.
19.	Opinion influence	I can influence other's opinion about cars.
20.	Car comparison effort	I tend to spend a lot of time comparing different models when I am buying a car for me or my family.

For the conventional car owners, the scree plot shape clearly shows a breaking point around 3 or 4 extracted components, see Figure A.1. This suggests extraction of 3 or 4 factors is a suitable starting point for extracting a fixed number of components. Several factor analyses have been performed, using different numbers of factors to be extracted and trying different rotation methods for easier interpretation of the results. An extraction of 4 factors, using Varimax rotation produced the most sensible results. A requirement for using Varimax rotation is orthogonality of the factors. This requirement was met as the values of factor correlation matrix with oblique rotation did not exceed 0.32, following the guideline of Brown[73].

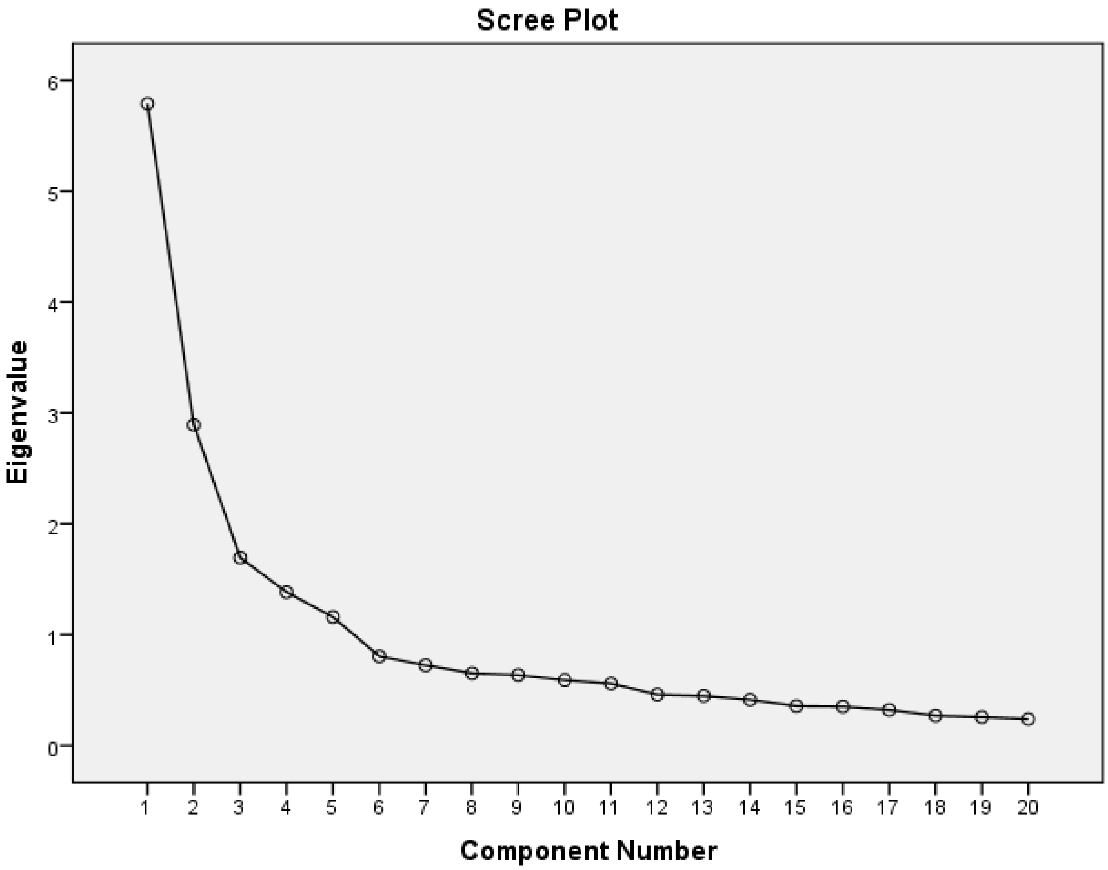


FIGURE A.1: Scree plot factor analysis conventional car owners

A.3 Factor analysis results

Table A.2 shows the result of the final factor analysis specification. Variables are regarded belonging to a factor when factor loadings are around 0.600 or higher in the component matrix and are indicated by underscores. The four extracted factors were interpreted as follows:

Environmental norm The normative beliefs of the respondent and important relatives about the environmental aspects of mobility.

Car authority The extent to which the respondent beliefs he seeks new information about cars and influences others.

Technological interest The extent to which the respondent enjoys in discovering and using innovative and technological products.

Perceived behavioral control The extent to which the respondent beliefs he can change car-related problems through his own behaviour.

Table A.2: Rotated component matrix using Varimax rotation, conventional car owners

Statement label	Component name			
	Tech. interest	Envir. norm	Car auth.	Beh. control
Gadgets	0.761	0.004	0.299	-0.034
Innovations to impress	0.815	0.108	0.173	0.120
Differentiation	0.802	0.025	0.144	0.129
Innovation use	0.765	0.140	0.231	-0.135
Good feeling innovative car	0.675	0.287	0.155	-0.078
Car magazines	0.222	-0.042	0.791	0.045
Normative limit to car use	0.015	0.727	0.007	-0.058
Environmental-friendly modes	-0.039	0.765	-0.013	0.062
Role of the environment	0.115	0.733	0.041	-0.097
Expectation relatives	0.435	0.599	0.101	0.067
Insinuations relatives	0.314	0.578	0.189	0.222
Support relatives	0.227	0.695	0.151	0.173
Transport problems	0.015	0.634	0.113	-0.205
Car use of others	0.119	-0.301	0.135	0.694
Implications car problems	-0.029	-0.048	0.127	0.707
Solution car problems	-0.033	0.134	0.015	0.722
Car advise	0.254	0.079	0.726	0.109
Car information	0.151	0.038	0.855	0.083
Opinion influence	0.352	0.249	0.582	0.068
Car comparison effort	0.078	0.126	0.603	0.058

Appendix B

Description of attributes and levels

The data set used for the analysis in Chapter 4 originates from a stated choice survey designed by Hoen and Koetse [1]. This appendix describes their definition of the attributes and levels used in their stated choice experiment. Hoen and Koetse chose the attributes as a result of an extensive literature study and consultations with government policy makers and the automotive industry.

Car type Six car types were included in the choice experiment: conventional technology (petrol, diesel or LPG), hybrid, plug-in hybrid, full electric, fuel cell and flexifuel car. Two car types are the main interest of this research: the plug-in hybrid car and full electric car.

Purchase price The attribute purchase price was made respondent specific, increasing choice task realism for the respondent. Based on the indicated purchase price level the purchase price of the conventional technology was determined. To add variation to this base price, a random factor between 0.9 and 1.1 was applied. Price mark-ups were used for each AFV type, to reflect the advanced technologies used in these car types. Table B.1 shows the exact definition of the purchase price levels per car type.

Monthly cost Hoen and Koetse opted to merge three car-related cost aspects in one attribute: monthly cost. Monthly costs consist of fuel cost, maintenance cost and road taxes. Each of these cost aspects varies between the car types. First, fuel cost were based on the respondent's monthly mileage, derived from their stated annual mileage. Fuel prices used for these calculations are shown in Table B.2. As hybrid cars run only on conventional fuels, their fuel costs are based on

Table B.1: Mark-up levels for AFV purchase price

Car type*	Mark-up level 1	Mark-up level 2	Mark-up level 3
Hybrid	€0	€2000	€6000
Plug-in hybrid	€0	€2000	€7000
Fuel-cell	€1000	€3000	€10,000
Full electric	€1000 × (range/140)	€3000 × (range/140)	€10,000 × (range/140)
Flexifuel	€500	€1200	€3000

* Mark-ups for secondhand car buyers are 50% of those for new car buyers

Table B.2: Fuel prices for the six car types

Fuel type*	Car type	Level 1	Level 2	Level 3
Petrol	Petrol	€1.55/l	-	-
Diesel	Diesel	€1.25/l	-	-
LPG	LPG	€0.65/l	-	-
Petrol + elec.	Plug-in	70% of petrol	90% of petrol	100% of petrol
Hydrogen	Fuel-cell	65% of petrol	100% of petrol	130% of petrol
Electricity	Electric	25% of petrol	40% of petrol	75% of petrol
Biofuels	Flexifuel	65% of petrol	100% of petrol	130% of petrol

* 2011 price level

conventional fuel prices. Alternative fuel prices are defined proportionally to the prices of conventional fuels. Regarding the maintenance costs, fixed levels were adopted for conventional cars (€50/month for petrol, €150/month for diesel and LPG), (plug-in) hybrid cars (€150/month) and flexifuel cars (€100/month). For full electric and fuel-cell vehicles three levels were adopted: €20, €30 and €50. These cost are substantially lower compared to the other car types, as these cars have less wearing parts and thus are expected to have low maintenance cost.

Driving range For hybrid and flexifuel cars, the range does not differ from conventional car range. Therefore, the range of these car types was fixed and defined 'same as current car range' in the choice card. This also yields for plug-in hybrid cars, although they can drive a short distance on electricity. For electric vehicles and fuel cell vehicles, four range levels were adopted. In 2011, the real-world driving range was around 75 km. This was adopted as the lowest level, together with 150 km, 250 km and 350 km. Driving range of fuel-cell cars is uncertain as only one model is available on the market in the Netherlands. This Hyundai ix35FCEV has an estimated real world driving range of 500 km (manufacturer: 594 km). In 2011, only prototypes existed and Hoen and Koetse adopted 250 km, 350 km, 450 km and 550 km as range attribute levels for the fuel-cell car.

Recharge/refuelling time Recharge and refuelling times of the car types widely differs. Table B.3 shows an overview of the recharge and refuelling time levels used. The refuelling time of a conventional car is defined at 2 minutes. The refuelling time of hybrid vehicles does not differ from conventional cars, as they cannot be charged from the grid. Plug-in hybrids, however,

TABLE B.3: Recharge/refuelling times for the six car types

Car type	Level 1	Level 2	Level 3	Level 4
Petrol/diesel/LPG	2 min	-	-	-
Hybrid	2 min	-	-	-
Plug-in hybrid	20 min	35 min	1 h	3 h
Fuel-cell	2 min	10 min	15 min	25 min
Electric	30 min	1 h	2.5 h	8 h
Flexifuel	2 min	-	-	-

can be charged by the grid. Four levels are adopted. Plug-in hybrids have substantially lower battery capacity than full electric cars. This explains the lower recharge time levels. Recharge time developments of full electric vehicles are highly uncertain as the EV industry mainly focuses its research and development on this aspect. Hoen and Koetse adopted a wide range of charging times to account for this uncertainty: from 30 minutes (currently perceived as fast charging) up to 8 hours for charging from charging point at home. Recharge times for fuel-cell vehicles are also uncertain as the technology is still in an experimental phase and different hydrogen recharge methods are considered (liquid, volatile and solid). Hoen and Koetse adopted four levels from market consultations: from 2 minutes to 25 minutes.

Additional detour time Conventional fuel is currently available through a well-developed, dense network of refuelling stations. To test respondent preference for fuel availability, a derivative of network density was used: additional detour time. This time represents the extra time spent to reach a fuel station of the required fuel type over time required to reach a conventional fuel station. As mentioned in Table B.2, electric cars, fuel-cell cars and flexifuel cars require other fuel types than conventional cars. Four levels of detour time were adopted: 0, 5, 15 and 30 minutes.

Number of available models Hoen and Koetse argued that there might be an imbalance in supply and demand for current AFVs as the availability of different models is not on par with the number of conventional car models. Therefore, they included an attribute that represented the number of AFV models available on the market. The four levels used were equal for each AFV type and defined as 1, 10, 50 and 200 models. For the conventional car type, it was fixed at 'same as current amount'.

Policy measures An attribute was added to test respondent sensitivity to beneficial policy measures that only yield for AFVs. Although these are not direct functional aspects of the car itself, they affect the functional aspects of the car directly. Three policy measures, that are expected to be attractive in the Dutch situation, were used: (1) free parking, (2) access to bus lanes within cities and (3) abolishment of road tax exemption.

Appendix C

Interim results instrumental attributes model

This appendix shows interim results of the instrumental attributes model from Chapter 4. The following tables are included:

- Table C.1: General attributes models versus alternative specific attributes models.
- Table C.2: Sub-sample models for conventional and hybrid car owners versus a scaled full sample model.
- Table C.3: Weights used to resemble population distribution of age and gender in the sample.
- Table C.4: Weighted response models versus unweighted response models for conventional and hybrid car owner segments.
- Table C.5: Sensitivity analysis for excluding not serious respondents and respondents that systematically chose the conventional car.
- Table C.6: Comparison of data set choice frequencies and simulated choice probabilities.

TABLE C.1: Generic attribute and alternative specific attribute models for conventional car owners and hybrid car owners

Parameter	Conventional car owners Generic attributes			Conventional car owners Alt. spec. attributes			Hybrid car owners Generic attributes			Hybrid car owners Alt. spec. attributes		
	β-value	Std. err.	t-test	β-value	Std. err.	t-test	β-value	Std. err.	t-test	β-value	Std. err.	t-test
ASC Conv.	0.00	fixed		0.00	fixed		0.00	fixed		0.00	fixed	
ASC Hybrid	-0.668	0.0750	-8.90**	-1.02	0.0457	-22.24**	1.49	0.318	4.68**	0.847	0.184	4.59**
ASC FEV	-1.02	0.0861	-11.83**	-2.32	0.143	-16.20**	0.240	0.371	0.65	-1.76	0.580	-3.03**
ASC PHEV	-1.21	0.0780	-15.54**	-2.04	0.164	-12.41**	0.778	0.294	2.64**	-0.667	0.525	-1.27
ASC FC	-0.665	0.0735	-9.04**	-0.736	0.0852	-8.63**	0.233	0.288	0.81	0.990	0.473	2.09*
ASC Flexifuel	-0.766	0.0755	-10.15**	-1.69	0.108	-15.67**	0.519	0.312	1.66	-0.832	0.386	-2.15*
Purchase price	-0.0867	0.00438	-19.78**				-0.0843	0.0130	-6.48**			
Purchase price FEV/FC				-0.0963	0.00444	-21.69**				-0.0832	0.0128	-6.49**
Purchase price other				-0.0774	0.00492	-15.75**				-0.0783	0.0150	-5.20**
Monthly cost	-0.395	0.0176	-22.44**				-0.717	0.107	-6.71**			
Monthly cost FEV				-0.380	0.0359	-10.60**				-0.449	0.165	-2.72**
Monthly cost Flexi.				-0.180	0.0253	-7.10**				-0.663	0.191	-3.48**
Monthly cost other				-0.113	0.0101	-11.13**				-0.201	0.0548	-3.66**
Range	0.00148	-0.000084	17.61**				0.00166	0.000434	3.82**			
Range FEV				0.00344	0.000254	13.56**				0.00183	0.000747	2.45**
Range FC				0.00208	0.000200	10.36**				0.00219	0.000909	2.41*
Recharge time	-0.00113	0.000166	-6.80**				-0.000921	0.000586	-1.57			
Recharge time FEV				-0.000951	0.000175	-5.43**				-0.000859	0.000638	-1.35
Recharge time PHEV				-0.00226	0.000566	-4.00**				0.000198	0.00178	0.11
Recharge time FC				-0.0106	0.00258	-4.11**				-0.00737	0.00973	-0.76
Detour time	-0.0139	0.00140	-9.98**				-0.0157	0.00544	-2.90**			
Detour time FEV				-0.00696	0.00274	-2.54**				-0.00669	0.00967	-0.69
Detour time Flexi				-0.0132	0.00255	-5.17**				-0.663	0.191	-3.48**
Detour time FC				-0.0160	0.00197	-8.10**				-0.0123	0.00728	-1.69
Environ. electric				0.134	0.0198	6.78**				0.235	0.0815	2.88**
Environ. plug-in				0.112	0.0288	3.89**				0.154	0.0957	1.60
λ_{new}	1.00	fixed		1.00	fixed		1.00	fixed		1.00	fixed	
λ_{2nd}	1.14	0.0309	4.55**	1.21	0.0352	5.97**	0.979	0.182	-0.11	1.16	0.237	0.70
Model performance												
nOBS	15189			15189			1024			1024		
Final log-likelihood	-12493.635			-12554.083			-1010.783			-1021.725		
Adjusted Rho-square	0.251			0.246			0.091			0.073		

* Statistically significant at 95% confidence level ** Statistically significant at 99% confidence level 1) in €1000 2) in €100 3) per km 4) per min

Table C.2: Overview segment-specific models and a full sample scaled model

Parameter	Conventional car owners β-value	Std. err.	t-test	Hybrid car owners β-value	Std. err.	t-test	Full sample, scaled β-value	Std. err.	t-test
ASC Conv.	0.00	fixed		0.00	fixed		0.00	fixed	
ASC Hybrid	-1.02	0.0457	-22.24**	0.847	0.184	4.59**	-0.983	0.0451	-21.81**
ASC FEV	-2.32	0.143	-16.20**	-1.76	0.580	-3.03**	-2.32	0.142	-16.29**
ASC PHEV	-2.04	0.164	-12.41**	-0.667	0.525	-1.27	-2.02	0.162	-12.47**
ASC FC	-0.736	0.0852	-8.63**	0.990	0.473	2.09*	-0.720	0.0846	-8.51**
ASC Flexifuel	-1.69	0.108	-15.67**	-0.832	0.386	-2.15*	-1.68	0.107	-15.73**
Purchase price FEV/FC	-0.0963	0.00444	-21.69**	-0.0832	0.0128	-6.49**	-0.0985	0.00441	-22.33**
Purchase price other	-0.0774	0.00492	-15.75**	-0.0783	0.0150	-5.20**	-0.0795	0.00489	-16.26**
Monthly cost FEV	-0.380	0.0359	-10.60**	-0.449	0.165	-2.72**	-0.384	0.0357	-10.75**
Monthly cost Flexi.	-0.180	0.0253	-7.10**	-0.663	0.191	-3.48**	-0.183	0.0252	-7.27**
Monthly cost other	-0.113	0.0101	-11.13**	-0.201	0.0548	-3.66**	-0.114	0.0100	-11.34**
Range FEV	0.00344	0.000254	13.56**	0.00183	0.000747	2.45**	0.00346	0.000252	13.76**
Range FC	0.00208	0.000200	10.36**	0.00219	0.000909	2.41*	0.00210	0.000199	10.56**
Recharge time FEV	-0.000951	0.000175	-5.43**	-0.000859	0.000638	-1.35	-0.000962	0.000174	-5.53**
Recharge time PHEV	-0.00226	0.000566	-4.00**	0.000198	0.00178	0.11	-0.00221	0.000557	-3.96**
Recharge time FC	-0.0106	0.00258	-4.11**	-0.00737	0.00973	-0.76	-0.0106	0.00255	-4.15**
Detour time FEV	-0.00696	0.00274	-2.54**	-0.00669	0.00967	-0.69	-0.00709	0.00272	-2.61**
Detour time Flexi	-0.0132	0.00255	-5.17**	-0.663	0.191	-3.48**	-0.0135	0.00254	-5.32**
Detour time FC	-0.0160	0.00197	-8.10**	-0.0123	0.00728	-1.69	-0.0161	0.00196	-8.23**
Environ. electric	0.134	0.0198	6.78**	0.235	0.0815	2.88**	0.138	0.0197	7.00**
Environ. plug-in	0.112	0.0288	3.89**	0.154	0.0957	1.60	0.113	0.0284	3.99**
λ_{new}	1.00	fixed		1.00	fixed				
λ_{2nd}	1.21	0.0352	5.97**	0.979	0.237	0.70			
$\lambda_{conv,new}$							1.00	fixed	
$\lambda_{conv,2nd}$							1.22	0.0355	6.15**
$\lambda_{hyb,new}$							0.378	0.0453	-13.74**
$\lambda_{hyb,2nd}$							0.433	0.0844	-6.72**
Model performance									
nOBS	15189			1024			16213		
Final log-likelihood	-12554.083			-1021.725			-13628.296		
Adjusted Rho-square	0.246			0.073			0.234		

* Statistically significant at 95% confidence level ** Statistically significant at 99% confidence level 1) in €1000 2) in €100
3) per km 4) per min

Table C.3: Weights used to resemble population distribution of age and gender in the sample

Class		Conventional car owners sample	Hybrid car owners sample	Full sample
Gender	Age	Weight	Weight	Weight
Male	26-35	1.18	3.42	1.50
Male	36-45	0.66	1.54	0.75
Male	46-55	0.60	0.89	0.60
Male	56-65	0.53	0.29	0.48
Male	>65	0.42	0.19	0.35
Female	26-35	4.73	35.91	2.84
Female	36-45	2.65	16.30	1.92
Female	46-55	2.38	9.34	2.34
Female	56-65	2.14	3.11	3.01
Female	>65	2.07	2.50	5.95

TABLE C.4: Overview segment-specific models and a full sample scaled model

	Conventional car owners Unweighted			Conventional car owners Weighted			Hybrid car owners Unweighted			Hybrid car owners Weighted		
Parameter	β-value	Std. err.	*t*-test	β-value	Std. err.	*t*-test	β-value	Std. err.	*t*-test	β-value	Std. err.	*t*-test
ASC Conv.	0.00	fixed		0.00	fixed		0.00	fixed		0.00	fixed	
ASC Hybrid	-1.04	0.0474	-21.93**	-1.09	0.0483	-22.51**	0.855	0.187	4.58**	0.645	0.142	4.55**
ASC FEV	-2.39	0.147	-16.27**	-2.25	0.142	-15.86**	-1.80	0.584	-3.07**	-0.394	0.338	-1.18
ASC PHEV	-2.11	0.169	-12.51**	-1.82	0.170	-10.74**	-0.661	0.529	-1.25	-2.64	0.527	-5.00**
ASC FC	-0.746	0.0878	-8.50**	-0.759	0.0846	-8.97**	1.01	0.479	2.11*	2.50	0.435	5.75**
ASC Flexifuel	-1.76	0.111	-3.80**	-1.77	0.107	-16.50**	-0.819	0.388	-2.11*	-1.44	0.342	-4.21**
Purchase price FEV/FC	-0.0992	0.00454	-21.87**	-0.119	0.00480	-24.74**	-0.0849	0.0129	-6.56**	-0.102	0.0153	-6.65**
Purchase price other	-0.0799	0.00503	-15.90**	-0.0991	0.00530	-18.70**	-0.0798	0.0152	-5.26**	-0.0774	0.0177	-4.39**
Monthly cost FEV	-0.391	0.0365	-10.70**	-0.442	0.0381	-11.62**	-0.441	0.166	-2.66**	-0.0725	0.0938	-0.77
Monthly cost Flexi.	-0.189	0.0259	-7.28**	-0.217	0.0265	-8.19**	-0.670	0.193	-3.47**	-1.01	0.182	-5.56**
Monthly cost other	-0.115	0.0104	-11.13**	-0.142	0.0103	-13.81**	-0.201	0.0552	-3.65**	-0.253	0.0477	-5.30**
Range FEV	0.00358	0.000260	13.80**	0.00307	0.000251	12.25**	0.00235	0.000928	2.53**	-0.000186	0.000691	-0.27
Range FC	0.00218	0.000206	10.60**	0.00220	0.000198	11.14**	0.00182	0.000751	2.43*	0.00357	0.000750	4.76**
Recharge time FEV	-0.000980	0.000178	-5.49**	-0.000719	0.000172	-4.17**	-0.000860	0.000624	-1.38	0.00171	0.000374	4.58**
Recharge time PHEV	-0.00219	0.000577	-3.80**	-0.00281	0.000585	-4.80**	0.000118	0.00179	0.07	-0.00104	0.00163	-0.63
Recharge time FC	-0.0111	0.00264	-4.22**	-0.00721	0.00251	-2.87**	-0.00794	0.00981	-0.81	-0.0272	0.00951	-2.86**
Detour time FEV	-0.00654	0.00279	-2.35*	-0.00426	0.00267	-1.60	-0.00772	0.0100	-0.77	-0.00721	0.00965	-0.75
Detour time Flexi	-0.0139	0.00262	-5.32**	-0.0136	0.00257	-5.30**	-0.0191	0.0107	-1.79	-0.0432	0.0101	-4.26**
Detour time FC	-0.0167	0.00202	-8.26**	-0.0160	0.00194	-8.24**	-0.0123	0.00733	-1.68	-0.0106	0.00601	-1.77
Environ. electric	0.136	0.0202	6.72**	0.131	0.0196	6.70**	0.243	0.0820	2.96**	0.0190	0.0458	0.42
Environ. plug-in	0.122	0.0294	3.82**	0.0659	0.0294	2.24*	0.151	0.0965	1.57	0.476	0.106	4.50**
Sigma alt. 1	-0.507	0.0334	-15.18**	-0.507	0.0326	-15.55**	-0.293	0.157	-1.87	-0.254	0.0954	-2.66**
Sigma alt. 2	0.00	fixed		0.00	fixed		0.00	fixed		0.00	fixed	
Sigma alt. 3	-0.269	0.0457	-5.90**	-0.278	0.0424	-6.55**	-0.0123	0.187	-0.07	-0.0196	0.0768	-0.25
λ_{new}	1.00	fixed		1.00	fixed		1.00	fixed		1.00	fixed	
λ_{2nd}	1.23	0.0375	6.19**	1.29	0.0391	7.42**	1.18	0.239	0.73	2.15	0.303	3.79**
Model performance												
nOBS	15189			15189			1024			1024		
Final log-likelihood	-12484.107			-12308.534			-1021.202			-881.054		
Adjusted Rho-square	0.250			0.261			0.072			0.196		

* Statistically significant at 95% confidence level ** Statistically significant at 99% confidence level 1) in €1000 2) in €100 3) per km 4) per min

TABLE C.5: Sensitivity analysis for excluding not serious respondents and respondents that systematically chose the conventional car

	Final model Full sample				Minus random choice respondents Full sample				Minus systematic conventional car choosers Full sample			
Parameter	β-value	Std. err.	*t*-test	WTP	β-value	Std. err.	*t*-test	WTP	β-value	Std. err.	*t*-test	WTP
ASC Conv.	0.00	fixed		€0	0.00	fixed		€0	0.00	fixed		€0
ASC Hybrid	-1.06	0.0472	-22.56**	€-10,392	-0.974	0.0477	-20.44**	€-9,990	-0.295	0.0427	-6.91**	€-3,145
ASC FEV	-2.23	0.139	-16.07**	€-18,279	-2.35	0.148	-15.89**	€-19,583	-1.02	0.134	-7.59**	€-9,273
ASC PHEV	-1.79	1.66	-10.79**	€-18,365	-1.93	0.177	-10.86**	€-19,795	-0.881	0.170	-5.18**	€-9,392
ASC FC	-0.733	0.083	-8.82**		-0.618	0.0849	-7.28**		0.0398	0.0817	0.49	
ASC Flexifuel	-1.77	0.105	-16.83**		-1.63	0.107	-15.15**		-0.830	0.101	-8.19**	
Purchase price FEV/FC[1]	-0.122	0.00475	-25.67**		-0.120	0.00482	-24.82**		-0.110	0.00533	-20.63**	
Purchase price other[1]	-0.102	0.00524	-19.46**		-0.0975	0.00531	-18.36**		-0.0938	0.00580	-16.18**	
Monthly cost FEV[2]	-0.445	0.0374	-11.89**		-0.465	0.0388	-12.01**		-0.404	0.0393	-10.29**	
Monthly cost Flexi.[2]	-0.226	0.0262	-8.61**		-0.244	0.0271	-9.02**		-0.217	0.0279	-7.78**	
Monthly cost other[2]	-0.145	0.0101	-14.35**		-0.136	0.0106	-12.84**		-0.128	0.0112	-11.45**	
Range FEV[3]	0.00306	0.000246	12.45**	€25.08	0.00329	0.000256	12.86**	€27.42	0.00306	0.000257	11.91**	€27.82
Range FC[3]	0.00224	0.000194	11.53**		0.00215	0.000200	-3.21**		0.00198	0.000203	9.75**	
Recharge time FEV[4]	-0.000692	0.000169	-4.10**	€-5.67	-0.000730	0.000176	-4.15**	€-6.08	-0.000861	0.000169	-5.08**	€-7.83
Recharge time PHEV[4]	-0.00280	0.000572	-4.90**	€-22.95	-0.00325	0.000612	-5.32**	€-33.33	-0.00213	0.000589	-3.62**	€-22.71
Recharge time FC[4]	-0.00717	0.00246	-2.92**		-0.00817	0.00254	-3.21**		-0.00729	0.00235	-3.11**	
Detour time FEV[4]	-0.00423	0.00262	-1.62	insign.	-0.00441	0.00273	-1.62	insign.	-0.00601	0.00251	-2.40*	€-54.64
Detour time Flexi[4]	-0.0140	0.00252	-5.56**		-0.0128	0.00259	-4.94**		-0.0125	0.00253	-4.94**	
Detour time FC[4]	-0.0160	0.00190	-8.40**		-0.0159	0.00196	-8.10**		-0.0129	0.00188	-6.87**	
Environ. electric	0.132	0.0192	6.87**		0.164	0.0205	7.97**		0.0782	0.0188	4.15**	
Environ. plug-in	0.0634	0.0288	2.20*		0.0951	0.0304	3.13**		0.0449	0.0293	1.53**	
Sigma alt. 1	-0.509	0.0314	-16.20**		-0.455	0.0341	-13.32**		-0.406	0.0337	-12.04**	
Sigma alt. 2	0.00	fixed			0.00	fixed			0.00	fixed		
Sigma alt. 3	-0.288	0.0393	-7.32		-0.245	0.0472	-5.20**		0.137	0.0592	2.31*	
$\lambda_{conv,new}$	1.00	fixed			1.00	fixed			1.00	fixed		
$\lambda_{conv,2nd}$	1.31	0.0391	7.82**		1.26	0.0389	6.60**		1.68	0.0882	7.68	
$\lambda_{hyb,new}$	0.439	0.0558	-10.07**		0.497	0.0556	-9.06**		0.617	0.0961	-3.99	
$\lambda_{hyb,2nd}$	0.336	0.0932	-7.12**		0.340	0.0963	-6.85**		0.506	0.177	-2.78	
Model performance												
nOBS	16213				15405				9613			
Final log-likelihood	-13260.477				-12857.246				-9164.394			
Adjusted Rho-square	0.254				0.239				0.130			

* Statistically significant at 95% confidence level ** Statistically significant at 99% confidence level 1) in €1000 2) in €100 3) per km 4) per min

Table C.6: Comparison of data set choice frequencies and simulated choice probabilities

Car type	Conventional car owners		Hybrid car owners		Full sample, scaled	
	Choice freq data set	Sim. choice prob.	Choice freq data set	Sim. choice prob.	Choice freq data set	Sim. choice prob.
Conv.	47%	48%	28%	30%	46%	47%
Hybrid	7%	6%	12%	11%	7%	6%
FEV	12%	12%	16%	20%	13%	12%
PHEV	7%	6%	12%	9%	7%	6%
Flexifuel	11%	11%	10%	15%	11%	11%
Fuel-cell	17%	17%	21%	14%	17%	17%

Appendix D

Interim results symbolic and affective attributes model

This appendix shows interim results of the instrumental attributes model from Chapter 5. The following tables are included:

- Table D.1: Weights used to resemble population distribution of age and gender in the sample.
- Table D.2: Comparison of models results for different threshold values.

Table D.1: Weights used to resemble population distribution of age and gender in the sample

Class		Conventional car owners sample	Hybrid car owners sample	Full sample
Gender	Age	Weight	Weight	Weight
Male	26-35	1.66	4.89	1.85
Male	36-45	0.82	0.51	0.75
Male	46-55	0.59	0.39	0.55
Male	56-65	0.44	0.35	0.42
Male	>65	0.34	0.90	0.38
Female	26-35	3.44	9.64	3.71
Female	36-45	2.03	5.47	2.23
Female	46-55	2.25	3.41	2.34
Female	56-65	3.53	4.10	3.53
Female	>65	4.83	15.46	5.52

Table D.2: Comparison of models results for different threshold values

	Threshold at 50% Binary logit model Full sample, scaled			Threshold at 20% Binary logit model Full sample, scaled		
Parameter	β-value	Std. err.	t-test	β-value	Std. err.	t-test
Current FEV performance perception						
Flexibility	0.511	0.318	1.61	-1.37	0.278	-4.91**
Reliability	1.85	0.399	4.63**	-1.42	0.337	-4.21**
Environmental performance	1.33	0.444	3.00**	-0.814	0.309	-2.63**
Personal identity factors						
Technological interest				-0.217	0.0922	-2.35*
Environmental norm				-0.289	0.0768	-3.76**
Perceived behavioral control	-0.299	0.0926	0.00**	0.184	0.0721	2.56**
Car purchase factors						
Symbolic factors	1.27	0.610	2.08*	-1.12	0.585	-1.92*
Affective factors	1.88	0.664	2.84**	-1.87	0.551	-3.39**
Random component parameters						
σ perc. beh. control	-0.366	0.290	-1.26	-0.0241	0.276	-0.09
σ env. norm				-0.0159	0.327	-0.05
σ tech. interest				-0.482	0.354	-1.36
Model specific parameters						
λ_{hybrid}	0.792	0.106	-2.60**	0.581	0.161	-2.60**
ASC_{lowWTB}	5.02	0.466	10.77**	3.11	0.361	8.59**
$ASC_{highWTB}$	0.00	fixed		0.00	fixed	
Model performance						
nOBS	1402			1402		
Final log-likelihood	-510.161			-790.889		
Adjusted Rho-square	0.466			0.173		

* Statistically insignificant at 95% confidence level ** Statistically significant at 99% confidence level

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