Master thesis

Quantifying consumer preferences for electric vehicles with the aim to stimulate its uptake in the Netherlands

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Abstract

The Dutch government aims that by 2030 all new passenger cars sold will be emission-free. In reaching this goal, electric vehicles (EVs) play an important role. The adoption of EVs is however lacking behind despite existing policy incentives. This study gained insight into Dutch consumer preferences for EVs. It is expected that a better understanding of consumer preferences allows to identify effective policy measures. Consumer preferences for an EV and a gasoline car were elicited using a Discrete Choice Experiment (DCE) with seven attributes: purchase price, monthly costs, driving range, additional detour time, fast-charging station density, CO_2 emissions, and the market share of the car among friends, relatives and colleagues. This study contributes to the academic literature by producing recent figures for Dutch consumers and knowledge about social influence, as recent studies in the Netherlands are lacking, as well as studies that measured the effect of social influence. Results showed that the preference for an EV is negative relative to a gasoline car. Preferences for EVs increase considerably with improvements in purchase price, monthly costs and driving range. Social influence is found to play a minor role in the decision-making process. Opportunities for the Dutch government lie in the direction of buyers who are younger, and have a higher income and level of education.

Foreword

In March 2021, I started this research challenge at TNO, where I became part of the project Flanking policy (Flankerend beleid in Dutch). It was a true pleasure working with a team from many different academic backgrounds.

I started this project with some basic knowledge regarding choice experiments, but absolutely no knowledge about the advanced statistical methods needed for data analysis and no experience with the software RStudio. In the end, I can proudly say that I have managed to create a Discrete Choice Experiment (DCE) and use RStudio to apply a Multinomial Logit (MNL) model to produce useful insights into consumer preferences for electric vehicles for TNO. Though, I experienced some difficulties along the way. Becoming part of a project while working at home due to the COVID19-pandemic resulted in difficulties regarding communication and eventually in delays in the project planning. It took me three extra months to deliver the thesis that now lies before you, although I did not mind these extra months since this project was a lot of fun.

In this process, I received a lot of support from Yashar Araghi regarding RStudio and the MNL model. I, therefore, want to thank him greatly. Furthermore, I worked on the design of the DCE together with Geerte Paradies and Kevin Broecks, who I would like to thank for their nice cooperation. In addition, I would like to thank Caroline van Ooij for peer-reviewing my master thesis and of course my VU supervisor Francisco Estrada for his overall support along the way. Finally, I would like to thank my parents, and especially my father for reviewing my master thesis, and friends for their mental support.

Please enjoy reading my master thesis, I enjoyed writing it.

Annemijn Huijboom

Amsterdam, 30 September 2021

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1. Introduction

This chapter introduces the research executed in cooperation with TNO. The problem underlying this research, the research objective and scope, the research question and sub-questions, and scientific relevance will be described. Finally, the outline of this paper will close off this chapter.

1.1 Background

Climate change is an ever growing problem, with the main cause being a sharp increase in global anthropogenic greenhouse gas (GHG) emissions. 197 countries, including the Netherlands, realised that making changes as a united front is necessary to combat climate change. Hence, in 2015, the Paris Agreement was created. The goal of this agreement is to:

> "… limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reach global peaking of greenhouse gas emissions as soon as possible to achieve a climate neutral world by mid-century." (UNFCCC, n.d.)

Consequently, the Netherlands also faces the major task of reducing its GHG emissions and has drawn up the Climate Agreement containing its goals to do so. It aims to reduce its GHG emissions by 49% by 2030, and 95% by 2050, compared to 1990 levels (Dutch government, 2020). In reaching these goals, emissions from the transport sector should also fall sharply.

The transport sector is namely, with 16.2%, a major contributor to global GHG emissions (Ritchie & Roser, 2020). This sector therefore plays a key role in lowering GHG emissions. In the Netherlands, transport is responsible for roughly 19% of total GHG emissions, of which half are caused by passenger cars, nearly a third by freight traffic and almost a tenth by mobile machinery used in the construction industry and agriculture (Centraal Bureau voor de Statistiek, 2020c). Besides emitting GHG emissions, transport is also a major source of air and noise pollution. Air pollutants like Nitrogen Dioxide (NO_2) and Particulate Matters (PMs) are not only detrimental for the environment, but also for human health (European Environment Agency, 2020).

Through electrification of transport, large GHG emission reductions can be achieved (IPCC, 2018). This is therefore central to the government's goals to make the transport sector more sustainable. In the Climate Agreement, the Dutch government has formulated the ambition that by 2030 all new passenger cars sold will be emission-free, meaning that no emissions are released while driving the car (Rijksoverheid, 2020). An electric vehicle (from now on referred to as EV) is an example of this.

1.2 The problem statement

In 2020, 20% of all new passenger cars sold were electric (Netherlands Enterprise Agency, 2021). A sharp increase in EV sales against a sharp decline in conventional car sales is required to achieve the ambitious goal of the government. However, a consumer research by the Royal Dutch Touring Club (ANWB) (2020b) revealed that a quarter of the Dutch citizens still have a negative attitude towards electric driving. On the other hand, about 40% is interested in driving an EV, but at the same time, this group does not yet drive electric. There is thus an important gap here between considering and actually buying an EV. Learning about why these groups do not want to drive electric is crucial to identify effective policy measures that enhance the uptake of EVs to decarbonise the transport sector.

Currently, TNO – an independent Dutch organisation for applied scientific research – is working on a modelling approach that supports policy makers to assess the effects of different kinds of policies that stimulate the uptake of EVs. TNO is carrying out this project for – and in close cooperation with – the Ministry of Infrastructure and Water Management. The model, called COnsumer DEcisions Comprehended (CODEC), forecasts the adoption rate of an innovation by quantifying the decision-making process of consumers (see Appendix A for an overview of CODEC). Simply said, it estimates how many new EVs will be bought in a given year by modelling consumer behaviour. In order to gather input for CODEC as well as to find out what drives Dutch consumers in buying an EV or not, a Discrete Choice Experiment (DCE) will have to be conducted. This method enables eliciting consumer preferences for selected attributes of EVs. This is crucial to identify effective policy measures that drive the uptake of EVs in the Netherlands.

1.2 Research objective

There is an increasing need for clean mobility like EVs. However, the current adoption rate of EVs in the Netherlands is relatively low. This is despite existing policy incentives of the Dutch government, such as exemptions from vehicle tax (MRB in Dutch) and tax on cars and motorcycles (BPM in Dutch), a lower tax addition, a subsidy, and emission zones for diesel cars (Rijksoverheid, 2021). Other policy measures in the pipeline are increasing the charging infrastructure, providing more information about Total Cost of Ownership (TCO) as well as going on holiday with an EV, and a national communication campaign (Berveling et al., 2020).

Without the appropriate policy incentives, gasoline cars will remain dominant on the streets because consumers will stick to their existing purchase behaviour. The main objective of this study is to gain insight into Dutch consumer preferences for EVs. This will help to formulate effective policy measures that stimulate the adoption of EVs. This contribution is made by reviewing the literature about relevant DCEs executed to decide on the alternatives, attributes and attribute levels to include in the DCE, and finally analysing the choice data collected.

1.3 Research scope

In order to efficiently achieve the research objective, four important boundaries are formulated that define the scope of this research. First, the results of the data analysis will be used as the main input for CODEC, but processing these results into CODEC is out of the scope for this research. On the other hand, the research results will be used to understand consumer preferences so that policy measures can be identified and translated into recommendations for the Ministry of Infrastructure and Water Management. Second, CODEC predicts new car sales separately from second-hand car sales. In this study, the focus therefore lies on the new car market only. Third, the target group of this study are Dutch citizens of 18 years-old and older that have a driving license and intend to purchase a new car in the near future. Finally, the DCE will be distributed as part of a bigger questionnaire, the development of which lies outside the scope of this research, as it was already created before this study commenced.

1.4 Research question and sub-questions

To achieve the research objective, the following research question will be answered in this thesis: *How can the adoption of electric vehicles in the Netherlands be increased?*

Sub-questions have been developed that will answer the research question step-by-step. These are:

1. How should the DCE be designed to elicit Dutch consumer preferences specifically for the new car market based on both existing literature and CODEC requirements?
2. What are Dutch consumer preferences for EVs according to the choice data?
3. How do different policy measures impact Dutch consumer preferences for EVs?

1.5 Scientific relevance of the research

While several DCEs were conducted to examine consumer preferences for EVs, more insights need to be gained into today's specific Dutch consumer preferences for EVs to decide on effective local policy measures. An extensive literature review, which will be touched upon in Chapter 2, revealed common attributes included in previous DCEs: purchase price, driving range, operation costs, recharging time, the availability or density of charging stations and the environmental performance. Not many studies have, however, measured the effects of social influence on the adoption of EVs. Yet, social influence plays an important role in consumers' adoption of innovations (Kim & Park, 2011). At the same time, this is also an important factor for CODEC, which models consumer behaviour. Furthermore, four papers reviewed in this study were performed in the Netherlands (Rasouli & Timmermans, 2013; Hoen & Koetse, 2014; Bočkarjova et al., 2015; Liao et al., 2019). However, most of these studies were conducted some time ago, so the results may no longer be fully applicable to the Dutch population, as a lot has changed in the meantime: driving ranges have improved, as well as the charging infrastructure. This study therefore contributes to the academic literature twofold. First, this study will include a social influence attribute besides the common critical vehicle attributes to produce more knowledge about the relative importance of social influence on preferences for EVs. Second, this study will produce recent figures for Dutch consumer preferences for EVs. These preferences can then be translated into policy measures necessary to overcome consumer barriers to purchase an EV.

1.6 Outline of the thesis

First, Chapter 2 describes the methods used for data collection and data analysis. It further describes the final experimental design of the DCE. After this, Chapter 3 presents the results of the data analysis. The discussion and conclusion are described immediately after the results and give an in-depth interpretation of the results, as well as an answer to the research question of this study. The references and appendices close off this thesis.

2. Methodology

This chapter describes the data collection method as well as the data analysis method that were used to answer the research question: *How can the adoption of electric vehicles in the Netherlands be increased?* In addition, the steps taken to arrive at the final design of the DCE will also be described, as well as the final experimental design: a D-efficient design, which will be explained below.

2.1 Data collection method

EVs are expected to play an important future role in decarbonising the transport sector. However, several obstacles should be overcome to increase its uptake in the Netherlands. Human behaviour is an important aspect in this context, and understanding it is important in order to act on it. For this reason, the model applied in this research is a DCE. This is a stated preference technique, which is a method that relies on asking people hypothetical questions with the aim to see their responses to a variety of choices and elicit their preferences from it (Pearce & Özdemiroğlu, 2002). The rationale for using this method lies in the fact that individuals make rational choices, either consciously or unconsciously. A DCE takes advantage of this skill by asking respondents to select their most preferred option between two or more alternatives, a number of times in a row depending on the experimental design of the DCE. The alternatives are presented on a so-called choice card and are described in terms of attributes and the different levels that these take (see Appendix B, Figure B1 for an example choice card).

Once the DCE was created, the research agency I&O Research was recruited by TNO to execute the data collection part of this research. I&O Research programmed and pre-tested the questionnaire that included the DCE and subsequently selected panel members from their panel who met the strict target group description of this study. The programmed questionnaire was distributed amongst the selected panel members and their online responses were collected and processed into a labelled SPSS data file. In order to have a representative sample for driving license holders in the Netherlands, I&O calculated a gross sample of 18,750 people, based on an expected redemption rate of 50% and a dropout rate of 80% due to the exceptional target group requirements. The net sample would be 1,500. In the end, 2,141 respondents were included in this study. The data cleaning process is described in this chapter.

2.2 Data analysis method

The method used for analysing the DCE data, the Multinomial Logit (MNL) model, is based on the Random Utility Model (RUM). Both will be described in the coming two sections. Furthermore, the analysis was performed using the RStudio software (https://www.rstudio.com/).

2.2.1 Random Utility Model (RUM)

A DCE assumes that the utility (i.e. value) of a consumer good depends on its attributes rather than on the good alone. In deciding between the alternatives presented, a consumer compares the different attributes of the alternatives. The levels that these attributes take are crucial in making this choice (Lancaster, 1966). A DCE also assumes that an individual seeks to maximise the utility they derive from a purchase decision. This utility is random from the researcher's point of view, but it is assumed that the decision maker chooses the alternative that provides the greatest utility. This economic assumption is derived from the Random Utility Model (RUM) by McFadden (1974).

In their decision making process, consumers weigh the pros and cons of each alternative against each other and make a rational choice based on that. The utility they derive from the chosen alternative can be mathematically represented by the following utility function (McFadden, 1974):

$$U_{ij} = V_{ij} + \varepsilon_{ij}$$

where U is the utility of the chosen alternative *j* by individual *i*, V is the observable part of this utility consisting of a vector of attributes and its levels for a given alternative *j*, and Ɛ is the error term capturing the unobservable attributes that affect an individual's utility (Langbroek et al., 2016; Croissant, 2012). From this utility function, various choice models can be obtained. The primary models are the Conditional Logit (CL) model and the MNL model.

2.2.2 Multinomial Logit (MNL) model

The data analysis method used in this study is the MNL model, which is derived from the RUM. The MNL model is a generalisation of the binomial logistic model, except instead of just two alternatives (i.e. bi), there can be more than two (i.e. multi). The observable part of the utility function (i.e. V_{ij}) is dependent on data that is observed and beta coefficients that need to be estimated. These coefficients are estimated using the MNL model based on the Maximum Likelihood Estimation (MLE) (Merino-Castello, 2003). The function underlying this estimation is:

$$V_{ij} = x_{ij}\beta + z_i\gamma_j$$

where x_{ij} are alternative-specific variables that vary over the individual *i* as well as the alternative *j*, these are the attribute levels for alternative *j*, z_i are case-specific variables that only vary over the individual, these are the individual-specific characteristics, and β and γ_j are the generic coefficient and the alternative-specific coefficient respectively to be estimated by the MNL model (Katchova, 2013). The utility function of alternative *j* underlying the MNL model is therefore:

$$U_j = V_{ij}(x_{ij}\beta + z_i\gamma_j) + ASC_j + \varepsilon_{ij}$$

where V is a function defined by the attribute levels and individual-specific variables as well as the beta coefficients, also preference weights or taste parameters, to be estimated by the MNL model. Furthermore, ASC_j is the Alternative Specific Constant (ASC), capturing the pre-assumed utility of the respondents to the alternatives, irrespective of the attributes. In order to capture the ASCs, one of the alternatives needs to be normalised in the MNL model so that all the other alternatives are relative to this reference level. Usually, the status quo alternative is the reference level that the other alternatives are compared to. Finally, ε is the error term capturing a part of the unobservable attributes. The MNL model is based on three hypotheses with respect to the distribution of error terms (Croissant, 2012):

1. Error terms are independent;
2. Error terms follow a Gumbel distribution;
3. Error terms are identically distributed.

Assuming that the error term, ε, is Identically and Independently Distributed (IID), the probability that an individual chooses alternative *d* over the other alternatives can be derived:

$$\Pr\ (d \mid V_{ij}) = \frac{exp\ (V_{id})}{\sum_{j=1}^{J} \exp\ (V_{ij})}$$

A higher utility for an alternative means a higher probability of that alternative being chosen. Choice probabilities of the alternatives always sum up to one.

Due to the assumption that the error terms are IID, however, the property of Independence of Irrelevant Alternatives (IIA) arises, which is a weakness in the MNL model. This states that the odds of choosing one alternative over another is independent of other alternatives in the model. Using a mixed logit or a nested logit model instead can relax the IIA property (SAS Institute Inc., 2018).

The estimated beta coefficients are not necessarily intuitively informative. The marginal effect of one unit increase in an attribute on the choice probability of an alternative can therefore produce more insight into the direction of the effects of the estimated beta coefficients. The marginal effect of an increase in an attribute on the probability of choosing alternative *j* can be estimated using the following formula (Katchova, 2013). The marginal effects of one independent variable always sum up to zero. Multiplying the values by 100% give the marginal effects in percentages.

$$\frac{\delta \mathrm{Pr_{ij}}}{\delta x_i} = Pr_{ij}\ (\gamma_j - \overline{\gamma_l})$$

Finally, the Relative Importance (RI) will have to be computed to produce insight into the importance of the attributes in the purchase decision of respondents. The way to calculate this is as follows: compute the part-worth utility of an attribute by multiplying the beta coefficient by the difference between the maximum and minimum levels included for this attribute and divide this by the sum of the part-worth utilities of all the attributes.

2.2.3 Willingness To Pay (WTP)

It is almost standard to include a so-called payment vehicle in the DCE so that the Willingness To Pay (WTP) can be computed. A payment vehicle is the monetary value of the alternatives, that is, the price someone would have to pay for an alternative. The advantage of computing the WTP is that it is a monetary representation of an increase in consumer utility an individual derives from the alternative due to a change in an attribute. It thus represents what the consumer is willing to give up in terms of money (€) to achieve an improvement in an attribute. The formula to calculate the WTP is:

$$WTP_j = -\frac{\beta_j}{\beta_{cost}}$$

2.3 Experimental design

The elaboration of the DCE is described in the following three sections. An extensive literature review preceded and determined the final experimental design of the DCE and therewith answered the first sub-question of this research: *How should the DCE be designed to elicit Dutch consumer preferences specifically for the new car market based on both existing literature and CODEC requirements?*

2.3.1 Alternatives

The alternatives that respondents could choose from in the DCE were an EV and a gasoline car. Only two alternatives were included to keep the experiment as simple and straightforward as possible. Furthermore, this enables to include more attributes without overwhelming the respondents too much. A plug-in hybrid vehicle was also considered, but excluded because it is assumed that these are going to be phased out in the Netherlands in the near future (Centraal Bureau voor de Statistiek, 2020a). The same applies to diesel cars (Tameling, 2020). In 2020, the number of diesel cars in the Netherlands decreased by 9.1% compared to 2019 (Centraal Bureau voor de Statistiek, 2020b). It is expected that gasoline cars and EVs will dominate the future car fleet.

Moreover, a choice experiment can either be labelled or unlabelled. The meaning of these different types is very well explained by Rose and Bliemer (2009):

> “labelled choice experiments involve studies where the names of the alternatives on offer convey meaning to the respondents beyond the order in which they are shown to respondents” whereas “in unlabelled choice experiments, the names of the alternatives are only meaningful in so far as they relate the order of the alternative as shown to the respondent.” (Rose & Bliemer, 2009, p. 613)

This study’s DCE is labelled in order to capture the ASCs. The alternatives were named after the fuel types: electric or gasoline.

2.3.2 Attributes

From the extensive literature review that was carried out, multiple attributes were identified. To ensure only relevant studies were reviewed, two criteria were decisive for the literature review:

- The studies performed a DCE and included EV as an alternative.
- The studies were performed recently, 2010 was roughly taken as a base line year.

Because this study aims to gain insight into Dutch consumer preferences for EVs and is executed in cooperation with TNO and the Ministry of Infrastructure and Water Management, two criteria determined the final selection of attributes. First, at least two to three attributes in the DCE had to represent key factors that influence the decision-making process of consumers buying a new car. This was necessary to allow respondents to make an informed choice in a real-life alike situation they can relate to, such that relevant results are obtained that can provide insight into actual consumer preferences. In order to define these vehicle attributes, a consumer research by the ANWB (2020b) and previous studies that executed a DCE were reviewed. Second, the attributes should match the input requirements for the Intention phase of CODEC (see Appendix A, Figure A1 for an overview of CODEC). This phase contains variables regarding financial attractiveness, personal advantages and social influence that affect the adoption of innovations. The attributes in the DCE should match these variables so that they can be combined in one regression and different weights can be determined as input for CODEC.

First of all, a literature review was conducted that revealed several critical attributes used in previous DCEs executed. Table 1 below provides an overview of these attributes.

Table 1: Attributes included in previous DCEs that were considered relevant for this study

	Achtnicht et al. (2012)	Bockarjova et al. (2013)	Hackbarth and Madlener (2013)	Jensen et al. (2013)	Rasouli and Timmermans (2013)	Hoen and Koetse (2014)	Bockarjova et al. (2015)	Helveston et al. (2015)	Hackbarth and Madlener (2016)	Langbroek et al. (2016)	Cherchi (2017)	Wolbertus et al. (2018)	Liao et al. (2019)	Noel et al. (2019)	Qian et al. (2019)	Guerra and Daziano (2020)	Li et al. (2020)
Fuel type	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Purchase price	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Operation costs	■	■	■	■	■	■	■	■	■		■		■		■	■	■
Driving range		■	■	■	■	■	■		■	■	■	■	■	■	■	■	■
Recharging time		■	■		■	■	■		■				■	■	■	■	■
Fuel availability	■		■	■				■	■	■		■	■		■		■
Ability to install private charging station															■		
Performance (e.g. speed, acceleration)	■			■	■			■						■			
Brand/ model availability and diversity						■		■									■
Additional detour time/ distance		■			■	■	■									■	
CO_2 emissions	■	■	■	■			■		■								
Policy incentives			■			■			■				■		■		■
Mobility guarantee													■				
Battery warranty																	■
Depreciation rate																	■
Battery lifetime				■													
Expected resale price		■					■										
Customer reviews					■												
Market share in inner circle					■												
Number of vehicles recently sold/ bought											■						
Tow hitch possibility		■					■										

This table provides a quick overview of attributes included in previous DCEs. On average, studies included seven attributes. It is worth mentioning that fuel type and purchase price were included in all studies, and that operation costs and driving range were included in all but three or two respectively. Both purchase price and operation costs were found, by all DCEs reviewed, to have a statistically significant as well as a negative effect on the adoption of EVs. A negative effect here means that an increase in either one decreases the likelihood of a car being chosen, and statistically significant means that the probability of the effect found occurring by chance alone is very small. Both attributes are thus important factors for people who consider buying an EV. Especially purchase price is key in this decision-making process since the price of an EV tends to be much higher than that of a conventional car. The driving range is also important in this decision-making process and was found to have a statistically significant and positive impact on EV adoption in all studies reviewed. Range anxiety makes many people reluctant to purchase an EV. A higher driving range and charging station density can therefore increase individuals' range confidence and consequently EV adoption. Fuel availability was also included in many DCEs and refers to the availability of charging possibilities to individuals. This was found significant in all studies except Helveston et al. (2015).

Furthermore, recharging time and the CO_2 emissions of a car have a negative impact in car purchase decisions. CO_2 emissions were found to be statistically significant in all studies, and recharging time in most. The attractiveness of EVs can be increased with policy incentives, which either increase the attractiveness of an EV or decrease that of a conventional car. In all studies, policy incentives were found to have a positive effect on EV adoption, but its significance varied among studies. Finally, the effect of social influence was estimated in two previous DCEs through consumer reviews about EVs, the market share of EVs among friends, relatives, peers and colleagues, and the amount of EVs recently bought. Social influence was found to play a minor role in consumer decisions. It was statistically significant but to a far lesser extent than purchase price and driving range.

A consumer research about electric driving by the ANWB (2020b), which included 1,937 respondents, was also studied. They aimed to measure the consumers' perspective on electric driving. The results provided insights into barriers for Dutch consumers to buy an EV. They concluded that, in 2020, more and more Dutch citizens are forming an opinion about electric driving as they see both the group of interested as well as uninterested people increase, while the group of neutrals decreases, compared to 2019. The most important reasons for consumers not to buy an EV are shown in Figure 1 below.

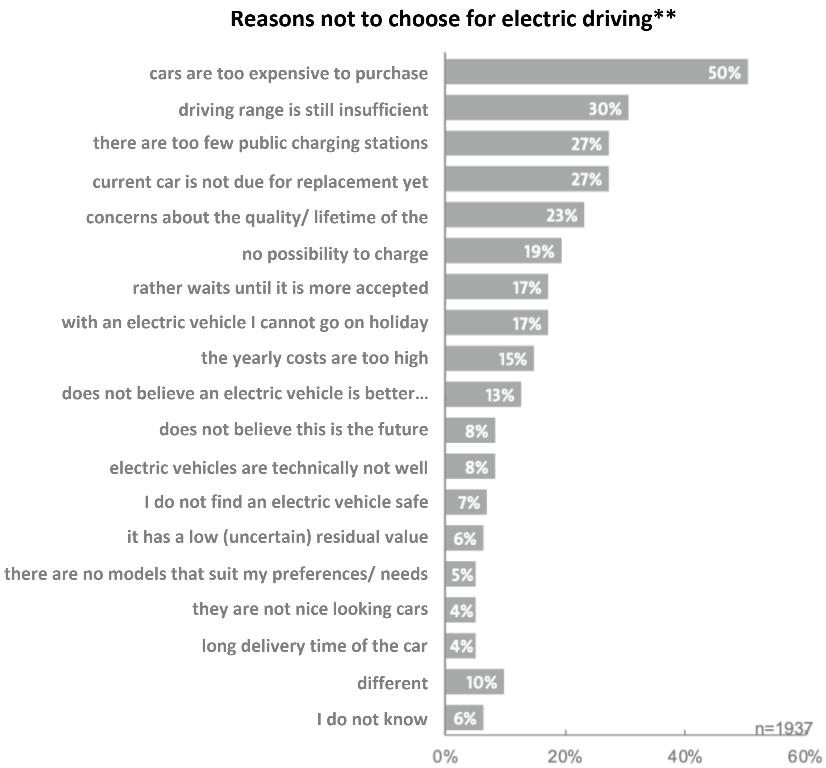

Figure 1: Reasons why Dutch consumers would not decide to purchase an EV translated to English (ANWB, 2020b)

According to the ANWB (2020b), in 2020, purchase price is still the most important barrier albeit to a smaller extend in comparison to 2019. After this, an insufficient driving range is the second most important barrier. This one is also closely related to the third, sixth and seventh barriers, respectively: there are too few public charging stations, no possibility to charge the car, and driving electrically is not yet common enough. Range confidence of (potential) EV drivers can be increased through a dense and reliable charging infrastructure. Although some consumers really just prefer to rely on the driving range and not the charging infrastructure alone. From the consumer research by ANWB, it can be concluded that many Dutch citizens are still reluctant to buy an EV for different reasons. Hence, it is of importance to understand these barriers in order to overcome them and increase the uptake of EVs. For this reason, these barriers were decisive for the final selection of attributes.

Based on the attributes used in previous DCEs executed, the barriers to buy an EV discovered by the ANWB and the input requirements for CODEC, seven attributes were selected: purchase price, monthly costs, driving range, additional detour time, fast-charging station density, CO_2 emissions, and the market share of a car in an individual's inner circle (see Table 2). These attributes were chosen for three different reasons.

First, purchase price and driving range are considered critical attributes for creating a real-life alike situation that enables respondents to make a well-informed choice. As can be seen in Figure 1, purchase price and driving range are the most important reasons for Dutch consumers not to drive electric (ANWB, 2020b). This matches the frequencies of the same vehicle attributes used in previous DCEs (see Table 1). From this, it can be concluded that these are critical factors to characterise an EV.

Second, additional detour time and fast-charging station density were chosen because the charging infrastructure in the Netherlands remains an important barrier for consumers to buy an EV (ANWB, 2020b). Additional detour time is a measure for the extra time and effort for EV-owners required to find a near-home charging station and is relevant for those consumers who cannot install a private charging station and need to share a public charging station with their neighbours.

Third, the above mentioned attributes as well as the other attributes needed to be included because of what CODEC requires from the DCE. Especially social influence is an important aspect of CODEC.

Table 2: The attributes included in the DCE in this order

Attribute	Explanation
Market share in people's inner circle	This is represented by the amount of friends, relative, colleagues and peers that own this car
CO_2 emissions	This includes CO_2 emissions of fuel combustion as well as of producing the car
Driving range	This is the range in kilometres (km) the car can drive when fully tanked/ charged
Additional detour time	This is the time it takes to find an available charging station near home in minutes/day
Fast-charging station density	This is the amount of fast-charging stations relative to ten gas stations. A fast-charging station approximately charges the battery to 80% in 15 to 30 minutes.
Monthly costs	The monthly costs include fuel costs, vehicle tax or Motorrijtuigenbelasting (MRB) in Dutch, insurance costs, and costs for maintenance and repair
Purchase price	This is the price to purchase a new vehicle (€)

Other attributes were also considered, but, in the end, not included in this DCE. Some of these were: policy incentives, brand, the performance of a car (e.g., acceleration, speed) and recharging time.

2.3.3 Attribute levels

Table 3 provides an overview of the attribute levels and to which alternatives in the DCE they applied. The information on a choice card should be easily interpretable and straightforward allowing respondents to make a well-informed choice without being overwhelmed. Otherwise, choice fatigue arises, meaning that respondents do not answer all the cards with the same level of attention. Choice fatigue could also arise due to too much alternatives, attributes and/or attribute levels to compare. In order to keep an efficient experimental design, it was therefore decided to maintain a maximum of six levels. Below this table, the motivations for the levels are described.

Table 3: Attributes included in the DCE with the corresponding attribute levels

Attribute	Item(s)	Explanation
Market share in people's inner circle	EV and gasoline car	No one, a few, more or less half, almost everyone
CO_2 emissions	EV	80% lower than the average gasoline car, 60% lower than the average gasoline car, 40% lower than the average gasoline car, 20% lower than the average gasoline car, and the same as average gasoline car
	Gasoline car	40% lower than the average gasoline car, 20% lower than the average gasoline car, the same as the average gasoline car, 20% higher than the average gasoline car, and 40% higher than the average gasoline car
Driving range	EV	150 km, 300 km, 450 km, 600 km
	Gasoline car	600 km
Additional detour time	EV	0, 5, 10, 15 minutes/day
Fast-charging station density	EV	For every 10 gas stations there are 2 fast-charging stations, for every 10 gas stations there are 4 fast-charging stations, for every 10 gas stations there are 6 fast-charging stations, for every 10 gas stations there are 8 fast-charging stations, same amount of fast-charging stations as gas stations
Monthly costs	EV and gasoline car	€100, €200, €300 and €400
Purchase price	EV and gasoline car	€10,000, €16,000, €22,000, €28,000, €34,000 and €40,000

1. Market share in inner circle

Social effects are an important element of CODEC and considered via the factors "look like others" and "distinguish from others" (see Appendix A), which are currently estimated through the market share of different cars (e.g. gasoline, diesel, electric). In contrast, in this DCE, the effect of social influence was estimated using the amount of people in an individual's inner circle (e.g. friends, family, neighbours and colleagues) that own a particular type of car. It is assumed that people can more easily relate to this than to a national market share, and are also more influenced by people in their inner circle. This attribute contained the following levels: no one, a few, more or less half, almost everyone. Respondents would have to imagine this amount of people owning this car and think about how much this will affect their choice.

2. CO_2 emissions

The CO_2 emissions were displayed as percentages in the DCE, as opposed to CO_2eq g/km which most studies did. The reason for this is that g/km is not easy to comprehend, as it is assumed that many individuals do not know what the seriousness of a certain amount of CO_2 is. Levels that are more easy to evaluate are linked to whether something is worse or better for the environment than a known alternative: a gasoline car. Consequently, the following five levels characterized the EV in the DCE: 1) 80% lower than the average gasoline car, 2) 60% lower than the average gasoline car, 3) 40% lower than the average gasoline car, 4) 20% lower than the average gasoline car, and 5) same as the average gasoline car. Five other levels were included for the gasoline car: 1) 40% lower than the average gasoline car, 2) 20% lower than the average gasoline car, 3) same as the average gasoline car, 4) 20% higher than the average gasoline car, and 5) 40% higher than the average gasoline car. Driving an EV may be emission free, but producing the car is not. Hence, not only levels were included where the emissions are lower than that of the average gasoline car, but also one level where it is the same.

3. Driving range

Driving range and purchase price are closely linked to each other since a higher battery capacity usually involves a higher purchase price. EVs of €40,000 or less have varying driving ranges, starting at 130 km and ranging until 425 km (ANWB, 2021a). However, it is expected that driving ranges will increase, also in a lower price range (NU.nl, 2021; Milieu Centraal, n.d.-a). Similar studies mostly included three or four levels. Furthermore, the diversity in driving range levels included is great. Some studies used 100 km as a lower limit, whereas other studies started at 200 or 300 km. Also the upper limit of levels are very diverse, ranging from 350 km to 550 km. Driving range levels included in this DCE for the EV were 150 km, 300 km, 450 km and 600 km. These levels match the purchase price levels chosen (ANWB, 2021) and the forecasts about future driving ranges. One level was included for the gasoline car: 600 km, which aims to reflect the opposite of an EV driving range, namely: sufficient and high.

4. Additional detour time

Consumers are concerned that charging an EV decreases driver convenience. They experience it as a hassle that they would need to change their usual activities. Following these concerns, the additional detour time was included as an attribute measured in minutes per day that it takes to find a charging station near-home. It was also considered to measure this as the percentage chance at an available charging station within a radius of 1 km from home, with the following levels: private charging station (100%), shared/ public charging station (75%), shared/ public charging station (50%). However, it is expected that the unit minutes/day is easier for people to interpret. Levels included were: 0, 5, 10 and 15 minutes per day, based on the extra time needed to find an available charging station near home, that could require driving around for a while, and to connect the car to the electricity net.

5. Fast-charging station density

The density of fast-charging stations near the highway was represented as the amount of fast-charging stations relative to ten gas stations so people can easily envision it in the DCE. During longer trips, fast-charging stations have the ability to recharge the battery up to 80% within 15-30 minutes (Liao et al., 2017), and therefore increase range confidence. The following five levels were included for the EV only: 1) for every ten gas stations there are two fast-charging stations, 2) for every ten gas stations there are four fast-charging stations, 3) for every ten gas stations there are six fast-charging stations, 4) for every ten gas stations there are eight fast-charging stations, and 5) the same amount of fast-charging stations as gas stations. These levels are based on the current amount of fast-charging stations and gas stations in the Netherlands. Currently, there are about 350 charging stations with approximately 2,200 fast-charger units situated next to the highway (ANWB, 2021b; Rijksdienst voor Ondernemend Nederland, 2021). The amount of gas stations was 4,121 in 2018 (VNPI, 2019).

6. Monthly costs

Another frequently measured attribute is operation costs, which was mostly represented by the costs per 100 km. This is, however, judged an unnatural unit people cannot easily comprehend in a DCE. It was therefore decided to include monthly costs calculated based on the average annual driving distance of Dutch citizens. In this way, respondents do not have to make any calculations themselves. Monthly costs comprise the following costs that were calculated by TNO, which are partly based on Milieu Centraal (n.d.-b):

- Vehicle tax, Motorrijtuigenbelasting (MRB) in Dutch, costs between €0 and €100 per month;

- Fuel costs cost between €36 and €110 per month based on 13,000 km per year, typical fuel prices and average consumption;
- Insurance costs between €62 - €70 per month;
- Maintenance and repair costs between €38 - €52 per month.

Monthly costs vary between €144 - €268. Hence, the following levels were included for both the EV and the gasoline car: €100, €200, €300 and €400. These levels are more manageable than this range and also allow to go a little above and below the average.

7. Purchase price

Currently, EVs are substantially more expensive than gasoline cars. New EVs start at a price of approximately €20,000, while gasoline cars start at a price half of this: €10,000 (ANWB, 2021a). The most frequently bought cars are those in segments A, B and C according to car segment statistics that TNO monitors and maintains (TNO, 2021b[1]). These are respectively mini cars, small cars and medium cars. Most EVs, on the other hand, are bought new in segment D. However, it is expected that this will change towards segments A, B and, in the near-future, C as well, as more EV models can and will be produced at a lower price due to continued innovations. Segment A starts at a purchase price of €10,000 and C ends at approximately €40,000 (Oostvogels, 2017; ANWB, 2021a). In the process of determining purchase price levels, it is good to mention that, according to the Ministry of Infrastructure and Water Management (Berveling et al., 2020), 36% of Dutch consumers have a maximum amount of €10,000 available for the purchase of another car, only 15% have a budget of €20,000 or more, and 33% have no budget in mind yet.

In order to include purchase price levels that match the price levels of most frequently bought cars as well as the budget people have available, a lower limit of €10,000 and an upper limit of €40,000 was chosen. It was decided to include six levels in order to have as many levels as possible for every person's budget. As a result, the following levels were included in the DCE for both the EV and the gasoline car: €10,000, €16,000, €22,000, €28,000, €34,000 and €40,000.

2.3.4 Choice set construction

The choice set construction is the way to allocate the attribute levels across the alternatives defining the different choice cards to be completed by respondents. The amount of attributes and attribute levels of this study give rise to a full factorial design of $6^1 \cdot 5^2 \cdot 4^4$, so 38,400 possible choice cards. It goes without saying that this would be too overwhelming to complete by a respondent. Hence, a D-efficient design was generated by team member Kevin Broecks using the software NGene (See Appendix C). The final experimental design influences whether an independent evaluation of the contribution of each attribute to the choices observed can be determined (Rose & Bliemer, 2009). In an efficient design, the combination of attribute levels across alternatives is optimised so that the impact of each attribute can be quantified with as few choice cards per respondent as possible. An efficient design aims to decrease the standard error, where a D-efficient design specifically aims to minimise the D-error statistic by taking in fixed prior parameters. These are beta coefficients estimated by previous studies (Rose & Bliemer, 2009; Walker et al., 2017).

[1] Excel file is extracted from TNO Sharepoint (not publicly accessible)

The final experimental design of this study existed of 32 different choice cards divided into four blocks. This means one respondent had to complete eight choice cards.

2.4 Survey design

The DCE was part of a bigger questionnaire containing 38 questions (see Appendix D for the complete questionnaire in Dutch). The final questionnaire could be divided into three parts. The first part involved five selection questions to screen out respondents that did not have a purchase intention and thus did not meet the target group description. The second part comprised the DCE. Each respondent was randomly assigned to a version. The order in which the choice cards were shown within one version was also randomised. Figure 2, translated to English, illustrates what a choice card looked like to respondents. Finally, the third part included another 33 questions about respondents' preferences for cars in general, current car conditions, considered future car conditions, feelings about EVs and other socio-demographic characteristics.

A pilot survey was launched of 1,500 individuals to identify points of improvement. Main comments from respondents were that people who do not own a car were not sufficiently recognised in the questionnaire, and that some questions were rather strange for EV drivers and for people who do not consider buying a car at all. Some questions were therefore rewritten and the routing of the questionnaire was adjusted. Finally, the improved questionnaire was sent out to the remaining 17,250 panel members of I&O. Response far exceeded expectations, as 5,488 respondents completed the questionnaire. After data cleansing, described in the next section, 2,141 respondents were included in the data analysis.

	Electric car	**Gasoline car**
The **amount of people in your inner circle** with this car ⓘ	A few	More or less half
The **CO_2-emissions** of the car relative to an average gasoline car ⓘ	80% lower than the average gasoline car	40% higher than the average gasoline car
The **driving range** of the car ⓘ	150 km	600 km
The **extra time** it takes every day to find an available charging station near home. Please assume here that you do not have a private charging station	0 minutes per day	
The **amount of fast-charging stations** relative to the amount of gas stations in the Netherlands ⓘ	For every 10 gas stations there are 6 fast-charging stations 	
The **monthly costs** of the car ⓘ	€400	€100
The **purchase price** of the car ⓘ	€22,000	€10,000

Please select your choice below.

- ○ **Electric car**
- ○ **Gasoline car**

Figure 2: An example choice card included in the final questionnaire translated to English

2.5 Data cleaning process

The importance of the data cleaning process lies in the fact that only respondents that match the target group description and filled in the questionnaire truthfully, should be included in the data analysis. A strict data cleaning process thus preceded the data analysis. First, respondents without an intention to buy a new car were filtered out of the sample. After that, respondents who completed the questionnaire within two minutes were purged from the sample. It was calculated, and indicated in advance of the questionnaire, that it would take about 15 minutes to complete, hence answers given within two minutes are assumed to be of bad quality. Finally, responses were tested for straightlining. This means that respondents ticked the same box for questions with the same scales, which could be due to respondents losing their motivation to engage with the questionnaire. The questionnaire included some questions with the same 7 point Likert scale: from strongly disagree to strongly agree. However, answers are contradictory if the same boxes are ticked for these questions. There were 13 respondents that provided these sorts of responses, which were also filtered out of the sample. This resulted in 2,141 respondents that were useful for the data analysis.

Finally, missing values needed to be dealt with. First, the household size variable (i.e. amount of people within one household) contained some missing values. These values were changed to the median value, which was 2 people. Finally, the income variable included some missing values as well as respondents who ticked the answer option “I don’t know/ I don’t want to say”. These values cannot be used in the data analysis. It was decided to change these values to the average income of the Netherlands: €36,500 (Centraal Planbureau, 2020).

3. Results

The results of the data analysis are described in this chapter. First, representativeness of the sample was checked by comparing sample characteristics with the Dutch population. Subsequently, the results of an MNL model are revealed in terms of beta coefficients, WTP, marginal effects and RI.

3.1 Socio-demographic characteristics

The final sample of 2,141 respondents used for the data analysis is assumed to represent the target group of this study: Dutch citizens of 18 years-old and older with a driving license and an intention to buy a new car. 80% of the Dutch population of 17 years-old and older have a driving license (Centraal Bureau voor de Statistiek, 2019). This part of the population are potential buyers of new cars and thus meet the target group description. Some socio-demographic characteristics of the sample are compared to this part of the population in Table 4 to verify representativeness of the sample. Numbers from Centraal Bureau voor de Statistiek (2019; 2021a; 2021b; 2021c) on the distribution of the Dutch population by gender, age and highest finished level of education were used to compute percentages of the population that have a driving license.

Table 4: Gender, age and highest finished level of education of the survey sample compared to the Dutch population

Socio-demographic characteristics	Value	% Sample N=2,141	% Dutch population
Gender	Male	57	53
	Female	43	47
Age	18-30	11.3	16.6
	30-40	12.3	15.8
	40-50	8.5	17.9
	50-65	38.4	28.6
	65-75	23.8	14.3
	80+ 75+	5.7	6.8
Highest finished level of education	Primary education	0.4	9.1
	LBO/ VBO/ VMBO/ MBO 1	5.2	11.5
	MAVO/ HAVO or VWO (first three years)	15.6	8.3
	MBO 2, 3 and 4, or MBO old structure (before 1998)	25.2	29.1
	HAVO or VWO (passed third grade, went to fourth grade)/ HBS/ MMS/ HBO propaedeutic year or WO propaedeutic year	13.4	9.4
	HBO/ WO-candidate/ WO-bachelor	23.4	20.6
	WO-doctorate/ WO-master/ HBO-master/ postgraduate education	16.7	12

Overall, men are over-represented in the sample, younger age groups are under-represented, and respondents are higher educated than the Dutch population. It turns out, however, that for two reasons these small differences actually reflect the target group of this study better. First, a report published by Centraal Bureau voor de Statistiek (Kampert et al., 2017) revealed that people over 65 years-old are most likely to buy a new car. This makes the over-representation of people in the age group 65 to 75 less of an issue. Second, a study by Hoekstra and Refa (2017) about characteristics of Dutch EV drivers stated that they are predominantly middle-aged men, with a higher level of education and a relatively high income. This was confirmed by Berveling et al. (2020). Hence, it can be concluded that the characteristics of the sample match the characteristics of potential new car buyers as well as Dutch EV drivers.

The sample provided more socio-demographic characteristics (see Table E1 in Appendix E) that could not be checked for representativeness because no data is available for the Dutch population to validate against. Yet, it further describes the sample. This data reveals that although the sample is well-distributed over the different degrees of urbanisation, most respondents have an above-average income and are married and/or living together without children living at home. Also, there is a clear preference for gasoline cars since most respondents drive in a gasoline car and consider buying one again. However, respondents are also open to driving electric, as an equal part are also considering an EV for their next car even though most of them do not have any experience driving one. Analysis of other questions in the questionnaire reveal that approximately 60% of respondents find that subsidies and tax benefits for EVs are unclear, and that most respondents characterise themselves as early majority and late majority. In addition, questions 34 to 38 were asked to check if respondents made their choices in the DCE truthfully. See Appendix F for the bar charts of these questions.

3.2 Choice model results

Consumer preferences for the attributes and the two alternatives will be elaborated in the following sections, thus answering the second sub-question of this research: *What are Dutch consumer preferences for EVs according to the choice data?* The equations are presented in Chapter 2.

3.2.1 Descriptive statistics of the choices

All respondents completed eight choice cards, resulting in 17,128 choices made in total. For each choice card, respondents were asked to choose between two alternatives and make trade-offs between the attributes. In these choices, the EV was chosen 39.7% and the gasoline car 60.3%. This indicates that consumer preferences are more leaning towards the gasoline car. Table 5 and 6 show the mean, median and standard deviation values of the attributes of the alternatives presented on the choice cards and the attributes of the alternatives that were selected by the respondents.

Table 5: Statistical distribution of EV attributes presented on all DCE choice cards and those selected by respondents

	All EVs in the choice sets			**Selected EVs**		
	Mean	Median	Std dev	Mean	Median	Std dev
Purchase price	24,191.9	22,000	10,350.4	18,684.1	16,000	9,812.1
Monthly costs	250.1	300	112	201.1	200	93.1
Driving range	372.8	300	168.1	434.3	450	136.5
Additional detour time	7.5	5	5.6	7	5	4.2
CO_2 emissions	-0.4	-0.4	0.3	-0.4	-0.4	0.2
Market share in inner circle	0.3	0.1	0.3	0.3	0.1	0.3
Fast-charging station density	5.8	6	2.9	7	8	2.7

Table 6: Statistical distribution of gasoline car attributes presented on all DCE choice cards and those selected by respondents

	All gasoline cars in the choice sets			**Selected gasoline cars**		
	Mean	Median	Std dev	Mean	Median	Std dev
Purchase price	24,237.4	22,000	10,369.7	20,147.4	16,000	8,616.2
Monthly costs	249.9	200	112	217.7	200	111.6
Driving range	600	600	0	600	600	0
CO_2 emissions	0.02	0	0.3	-0.02	-0.2	0.3
Market share in inner circle	0.3	0.1	0.3	0.3	0.1	0.4

The selected EVs were cheaper in both purchase price and monthly costs, tended to have a longer driving range, required less extra time to find an available charging station near home and involved a higher fast-charging station density when compared to all the EV alternatives included in the DCE and the selected gasoline cars by respondents.

3.2.2 Multinomial Logit (MNL) model estimations

The results of a MNL model, where the gasoline car was used as the reference level, are presented in Table 7. A total of 16 versions of a MNL model were estimated using the software RStudio. First, a reference model was estimated that only included the ASC for the EV. This was done to compute a baseline measurement of the Log Likelihood to compare all following models to. Several models were then tested with the attributes as well as different individual-specific variables. The variables gender, home and household composition were converted to dummy variables as a one unit increase cannot be considered linear. Variables that were not found to be statistically significant were tested in several models, but remained insignificant. This resulted in a final model with the highest (least negative) Log Likelihood value.

Table 7: Discrete choice model estimates of a Multinomial Logit (MNL) model

	Beta estimates	Std. error	z-value	Pr(>|Z|)	Significance level
ASC (EV)	-0.9	0.1	-6.7576	<.001	***
Purchase price	-0.00005	1.2326e-06	-36.5467	<.001	***
Monthly costs	-0.002	9.8348e-05	-20.4693	<.001	***
Driving range	0.002	1.3182e-04	12.9301	<.001	***
Additional detour time (EV)	-0.008	0.004	-2.1794	0.029	*
CO_2 emissions	-0.4	0.04	-10.1134	<.001	***
Market share in inner circle	0.09	0.03	2.8456	0.004	**
Fast-charging station density (EV)	0.03	0.008	3.5983	<.001	***
Income:EV	0.04	0.01	2.8398	0.005	**
Education level:EV	0.2	0.01	12.1273	<.001	***
Age in years:EV	-0.009	0.001	-6.5190	<.001	***
Degree of urbanisation:EV	-0.008	0.02	-0.4651	0.642	
Gender:EV (dummy coding)					
- Female	0.002	0.04	0.0614	0.951	
- Male	-0.002	0.04	-0.0614	0.951	
Household size:EV	-0.006	0.02	-0.3342	0.738	
Home:EV (dummy coding)					
- Detached house	0.01	0.05	1.8877	0.059	.
- Terraced, corner house	-0.1	0.06	-1.7499	0.080	.
- Flat/ apartment, high-rise (5 floors or more)	-0.3	0.08	-3.4827	<.001	***
- Student flat/ house	0.5	0.1	3.5532	<.001	***
- Farm	0.7	0.2	3.8031	<.001	***
Household composition:EV (dummy coding)					
- Married/ lives together without children living at home	0.1	0.04	2.3167	0.021	*
- Lives with parent(s)/ guardian(s)	-0.3	0.1	-2.4802	0.013	*
Significance codes	'***' 0.001	'**' 0.01	'*' 0.05	'.' 0.1	' ' 1
Null Log-Likelihood					-11506
Log-Likelihood					-8563.3
McFadden R^2					0.25419
Likelihood ratio test					chisq = 5849.5 (p.value = < 2.22e-16)

First of all, the ASC for the EV can be understood as the preference for this car relative to the gasoline car, which ASC is zero in this model because it was the reference level. The final MNL model indicates a negative ASC for the EV, meaning that when all attributes are equal to zero, the EV is less preferred than the gasoline car. Furthermore, all the attributes have a statistically significant effect, meaning that the probability of the effect found occurring by chance alone is very small. In addition, the estimated beta coefficients for the attributes have the expected direction of effects.

Both purchase price and monthly costs have a negative impact on the utility for both fuel types, meaning that when either one of these increases, an alternative is less likely to be chosen. This makes sense since something becomes less attractive if it gets more expensive. The driving range also has the expected sign: a greater EV driving range increases the utility an individual derives from an EV. Furthermore, a higher market share of an EV among friends and relatives as well as a higher fast-charging station density relative to ten gas stations both have a positive impact on the likelihood of an EV being chosen. On the other hand, more CO_2 emissions and a higher additional detour time decrease the attractiveness of an EV.

The additional detour time is statistically significant at a 5% level. This is lower than the other attributes that are statistically significant at a 0.1% level, except for the market share, which is statistically significant at a 1% level. A potential reason for the lower significance level of additional detour time is this attribute was more difficult to interpret for respondents because, for example, it did not apply to their situation. As a result, respondents might have been more likely to compromise on this attribute.

Besides attributes, individual-specific variables were also included in the final MNL model. First, gender is not found to be statistically significant, meaning that women and men are equally likely to purchase an EV. Also, the degree of urbanisation as well as household size are not statistically significant, meaning that that there is no relationship between these variables and the utility for an alternative, so the likelihood of any found effect occurring by chance alone is greater. On the other hand, income, age and education level are found highly significant. Potential EV buyers tend to be younger, and have a higher income and level of education. This corresponds to the characteristics of Dutch EV drivers suggested by Hoekstra and Refa (2017).

In addition, individuals living in a student flat or a farm are associated with higher likelihoods of purchasing an EV. Interestingly, students are more likely to purchase an EV, despite the fact that these are more expensive. A potential reason for this is that students are more environmentally aware, as sustainability issues are more integrated into school contents these days. On the other hand, individuals living in a flat are associated with lower likelihoods of purchasing an EV. A potential reason for this is that installing a private charging station is not possible for these individuals, which is why they may experience more hassle to charge the EV.

3.2.3 Willingness To Pay (WTP)

The WTP is computed by dividing the beta coefficients of all the attributes except purchase price by the beta coefficient of the purchase price. This gives the monetary representation of the increase in consumer welfare due to a change in an attribute. The WTP values are presented in Table 8. These values are in line with what previous studies have found (Hoen & Koetse, 2014; Jensen et al., 2013; Wolbertus et al., 2018; Noel et al., 2019).

Table 8: Willingness To Pay (WTP) values for an increase in the different attributes

	WTP
EV	- €20,379
Monthly costs (per euro)	- €45
Driving range (per km)	€38
Additional detour time (per minute/day)	- €172
Fast-charging station density (per fast-charging station relative to 10 gas stations)	€678
CO_2 emissions decrease relative to the average gasoline car (per 1%)	€818
Market share in inner circle	€2,095

The WTP values for the different attributes represent what the consumer is willing to give up in terms of money (€) to achieve an improvement in an attribute. As can be seen, the EV is negatively valued at €20,379, which is already lower than what other studies found. Hoen and Koetse (2014) found a WTP of - €35,909 and Noel et al. (2019) of on average - €41,141. A negative WTP for any attribute or alternative can also be interpreted as the Willingness To Accept (WTA) or the discount it takes to make an EV as attractive as a gasoline car. Potential reasons for this relatively high WTA are the lower driving range and insufficient charging infrastructure regarding EVs.

Furthermore, respondents are willing to pay €38 for an increase of 1 km in the driving range, which is in line with the findings of previous studies: €52 (Hoen & Koetse, 2014) and €47 (Jensen et al., 2013). In addition, a recent study found that "the WTP for a marginal km of range decreases as the range of EVs increases" (Noel et al., 2019), implying that the first increments are worth substantially more than the last increments. This indicates that it is more valuable to improve EVs with a low driving range.

A discount of €172 is required to make an EV as attractive as a gasoline car when the additional detour increases by one minute/day. This is lower than what a previous DCE from 2014 found: €234 (Hoen & Koetse, 2014). This can be explained by the fact that the amount of public charging stations increased rapidly since then, from 11,860 in 2014 to 75,560 in 2021 (Rijksdienst voor Ondernemend Nederland, 2019; Netherlands Enterprise Agency, 2021). Hence, the additional detour time may be less of an issue to individuals now. An increase in the fast-charging station density by one fast-charging station relative to ten gas stations is valued positively at €678. The high WTP for more fast-charging stations can be explained by the fact that during longer trips, fast-charging stations have the ability to recharge the battery up to 80% within 15-30 minutes (Liao et al., 2017) and thus increase range confidence.

Furthermore, the WTP for a CO_2 emission reduction of 1% relative to the average gasoline car is perceived at €818. From this, it can be concluded that respondents are environmentally aware and place a high value on CO_2 emission reductions, relatively more than the attributes already discussed. Finally, the WTP for an increase in the market share of a car in an individual's inner circle is highly valued at €2,095. Surprisingly, individuals place a high value on this market share.

3.2.4 Marginal effects

While beta coefficients are not easily interpretable, the marginal effects provide more insight into the effect of a change in an attribute on the probability of the outcome. This is useful in evaluating which policies can have the most as well as the desired effect on the adoption of EVs. In calculating the marginal effects, it was assumed that the attributes are linear. The sample average marginal effects are presented in Table 9 below.

Table 9: Marginal effects due to a one unit increase in an attribute on the probability of choosing an EV or a gasoline car

	Gasoline car	**EV**
Purchase price gasoline car	-0.00001	0.00001
Purchase price EV	0.00001	-0.00001
Monthly costs gasoline car	-0.0005	0.0005
Monthly costs EV	0.0005	-0.0005
Driving range gasoline car	0.0004	-0.0004
Driving range EV	-0.0004	0.0004
Additional detour time EV	0.002	-0.002
Fast-charging station density EV	-0.007	0.007
CO_2 emissions gasoline car	-0.009	0.009
CO_2 emissions EV	0.009	-0.009
Market share in inner circle regarding a gasoline car	0.02	-0.02
Market share in inner circle regarding an EV	-0.02	0.02

The way to interpret this is as follows: if the price of any car increases by €10,000 – which is a likely scenario for someone who favours a new gasoline car which prices start at €10,000 over an EV which prices start at approximately €20,000 – the probability that this car is chosen decreases on average by 10%. Fiscal incentives like a subsidy and purchase tax reduction decrease the purchase price and can thus increase the likelihood that an EV is chosen. A literature review by Liao et al. (2017) found that a purchase tax reduction was statistically significant and had a positive effect on EV adoption in two DCEs. This indicates that fiscal incentives can increase the utility for an EV.

While the purchase price of an EV is likely to be higher, the operation costs are lower (Hagman et al., 2016; Wu et al., 2015). If the monthly costs of an EV decrease by €100, the probability that an EV is chosen increase by 5%. Providing information about the TCO may thus have a significant impact on the adoption of EVs. The TCO includes the purchase price of a car as well as the additional driving costs. A study found that "adding information about total cost of ownership increases the probability that small/mid-sized car consumers express a preference to acquire a conventional hybrid, plug-in hybrid, or a battery-electric vehicle." (Dumortier et al., 2015).

Furthermore, the probability that an individual will buy an EV increases if the charging infrastructure is improved. When the fast-charging station density increases by five fast-charging stations relative to ten gas stations, and the additional detour time to find an available charging station near home decreases by five minutes/day, the probability increases by 3.5% and 1% respectively. In addition, when the driving range of an EV increases by 150 km, the probability that an EV is chosen increases by 6%. Improving the charging infrastructure also has an indirect effect on range confidence of EV drivers, as this reduces the chance of running out of electricity.

Moreover, when the market share of an EV among friends, relatives and colleagues increases from no one to a few, the probability that an individual will purchase an EV increases by 2%. So, more friends and relatives with an EV is perceived as positive. Finally, the probability that an individual will buy an EV increases by 9% if the CO_2 emissions reduce by 10% relative to an average gasoline car. This is a relatively high marginal effect compared to the other attributes.

3.2.5 Relative Importance (RI)

The beta coefficients in Table 7 tell a lot about the statistical significance of the attributes as well as the direction of effects. In addition, the marginal effects in Table 9 tell even more about how an increase of one unit in the attributes changes the outcome. However, because of the different attribute levels and the ranges that these take, nothing can be said about the importance of the attributes in the decision-making process based on these two calculations alone. Therefore, the RI was computed. It is assumed that the seven attributes together have 100% importance for people. With that in mind, the results are presented in Figure 3.

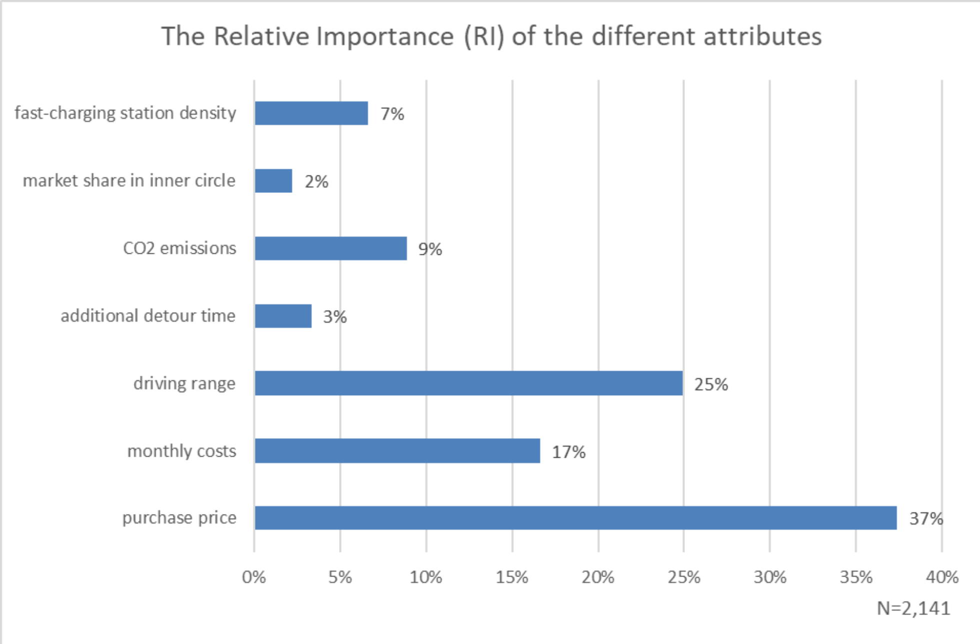

Figure 3: Relative Importance (RI) of the different attributes in a car purchase decision

The RI provides insight into the degree of importance of each attribute in the decision-making process, as this takes into account the minimum and maximum attribute levels. As can be seen, purchase price is the most important attribute that respondents look at when making a car purchase decision, followed by the driving range and monthly costs. The least important attribute that respondents take into account is the market share of a car in their inner circle. More friends and relatives with an EV is perceived as positive, but it only plays a small role in the decision-making process of respondents. Moreover, the environmental performance of a car is regarded more important by respondents than the charging infrastructure, hence respondents can be considered environmentally aware. Finally, improvements in the fast-charging station density and the additional detour time do not have such a high impact as improvements in the driving range. It can, therefore, be concluded that respondents rather rely on a higher driving range than on a more dense charging infrastructure.

Conclusion and discussion

This chapter discusses the results summarised in the previous chapter as well as the methods used to derive these results. Policy recommendations are then drawn from an interpretation of the results. Finally, this chapter ends with the conclusion of this study and the answer to the research question.

Discussion of the results

The Dutch government aims that by 2030 all new passenger cars sold will be emission-free, meaning that no emissions are released while driving the car. In reaching this goal, EVs play an important role. However, the adoption of EVs in the Netherlands is lacking behind. More EVs will have to be sold at the expense of conventional cars. But without the appropriate policy incentives, gasoline cars will remain dominant on the streets because consumers will stick to their existing purchase behaviour. The focus of this study was to discover consumer preferences for EVs, as it is expected that a better understanding of consumer preferences allows to identify effective policy measures to stimulate the uptake of EVs in the Netherlands. A DCE was conducted to elicit Dutch consumer preferences. The representativeness of the final survey sample regarding Dutch potential new car buyers was found to be nearly optimal due to a few minor differences.

The results revealed that potential EV buyers are younger, and have a higher income and level of education. Opportunities for the Dutch government therefore lie in facilitating these people since the motivation for driving electric is already more likely to be there, and motivating the rest. Gender, degree of urbanisation and household size, on the other hand, were not statistically significant. Liao et al. (2019) yielded similar results.

On average, it was found that Dutch potential car buyers have a negative preference for EVs, meaning that when all attributes are equal to zero, the gasoline car is preferred. Previous studies also found a negative preference for EVs. However, ASCs cannot be directly compared since each study includes different attributes. On the other hand, when the WTP for an EV is compared to what other studies found, it can be concluded that consumers' perception of an EV became less negative. Furthermore, all attributes were statistically significant at the critical significance levels, so the found effect of the attributes on the choices made occurring by chance alone is very small, making it likely that all of them are considered to some degree in purchasing decisions. The relative importance of the attributes differs however in a purchase decision.

Previous literature suggests that purchase price and operation costs are main barriers to EV adoption. This study has produced a similar result. The purchase price and monthly costs together account for 54% of the final decision. First, if the purchase price of an EV would drop to or close to the starting prices of a gasoline car, the probability that an individual will purchase an EV increases by 10 to 15%. This probability is fairly high and can be encouraged through fiscal incentives that lower the price of an EV. Second, if the monthly costs of a gasoline car increase by €100 relative to an EV, the probability that an individual purchases an EV increases by 5%. Two policy recommendations arise from this. First, the utility of an EV, and consequently the probability of buying an EV, increases considerably with improvements in purchase price. Although innovations will contribute to price benefits in the longer term, on the short term prices are not expected to drop soon. Therefore, fiscal incentives should make the price more accessible to everyone. Currently, the Dutch government provides a subsidy for EVs, but information provision is needed to increase awareness since 60% of the respondents indicated that they do not find the subsidies and tax benefits for EVs clear. Second, even though its purchase price is higher, the TCO of an EV is competitive with the TCO of a conventional car. However, at the moment people are used to gasoline and diesel cars, while EVs are relatively new and exciting. Providing information about the TCO may provide a new financial perspective to potential car buyers and thus have a significant impact on the adoption of EVs.

Across studies, driving range is a critical feature for an EV. This study has yielded similar results. At 25%, the driving range is the second-most important attribute respondents look at when making a purchase decision. Improvements in the driving range are positively valued at €38/km, and an increase in the driving range of 150 km, increases the choice probability by 6%. Moreover, in contrast to Liao et al. (2019), the fast-charging station density was found to be highly significant in this study. This indicates that Dutch potential car buyers are no longer indifferent to the fast-charging station density but derive more utility from a higher density. Nevertheless, respondents look at the fast-charging station density and the additional detour time much less, namely at 7% and 3% respectively. It can therefore be concluded that respondents rather rely on a sufficient driving range than on a denser charging infrastructure. At the moment, a larger driving range is accompanied by a larger battery and thus a higher purchase price. For people who cannot afford an expensive EV, improving the charging infrastructure is therefore a good start to increase range confidence. Furthermore, letting people experience an EV, providing more information and clarity about charging stations, as well as providing information about how people can go on holiday with an EV, all have the possibility of increasing range confidence and consequently EV probability.

Results also showed that a CO_2 emission reduction relative to the average gasoline car is also an important attribute. This attribute is found to be more important in consumer decisions than the fast-charging station density, additional detour time as well as the market share of an EV among e.g. friends and relatives. Respondents are thus environmentally aware and derive more utility from less CO_2 emissions. Finally, social influence only plays a minor role in the final decision for a new car, which corresponds to what previous studies found. In the end, the costs of a car as well as the driving range mostly influence the final decision.

This study did not include any attribute regarding the battery lifetime and/or quality. However, since this is an important barrier as to why Dutch consumers are reluctant to purchase an EV (ANWB, 2021b), future research should measure the effects of this on consumer preferences. Furthermore, the occasion market for EVs will increase in the coming years. Therefore, future studies should also look into consumer preferences for second-hand EVs, as these will also play an important future role in the uptake of clean mobility to achieve the goal of the Dutch government.

Discussion of the method

There are some limitations regarding the methods used for the data analysis in this study. A weakness in the MNL model is namely the IIA property that arises due to the assumption that the error terms are IID, i.e. not correlated. In other words, the relative probability of two alternatives in the model is independent of other alternatives and heterogeneity. A mixed logit or nested logit model can instead relax the IIA property. A mixed logit model assumes that parameters are different for each individual, hence accounting for heterogeneity in the sample. A nested logit model, on the other hand, allows to put the alternatives into different nests, while error terms are uncorrelated for different nests (Croissant, 2012).

Conclusion

To achieve the research objective, the following research question was formulated in this thesis: *How can the adoption of electric vehicles in the Netherlands be increased?*

In conclusion, preferences for EVs increase considerably with improvements in purchase price, monthly costs and driving range, while social influence only plays a minor role. Fiscal incentives as well as providing more information on these and the TCO can increase the adoption of EVs. In addition, improving the charging infrastructure clearly increases range confidence and as a result the preference for EVs, which is where opportunities for the Dutch government lie currently.

Furthermore, potential EV buyers are younger, and have a higher income and level of education. Also students are more likely to buy an EV. The Dutch government should facilitate these people since the motivation for driving electric is already more likely to be there. Higher gains regarding EV adoption can therefore be achieved in this group. Older as well as lower educated people could be facilitated through an information campaign about the benefits of EVs. In conclusion, people required some time to get used to gasoline and diesel cars, so in order for them to get used to EVs in a timely manner, sufficient information and support needs to be provided.

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Appendices

Appendix A: COnsumer DEcisions Comprehended (CODEC)

Figure A1 below illustrates the general calculation structure of CODEC. The number of new car sales, for example of EVs, in a certain year is determined based on car sales in the past. First, it is being estimated how many individuals will want to replace their car. Of these individuals who will make a purchase decision, a certain percentage will make a choice based on routine behaviour, while another percentage will make a more elaborate decision based on enabling and intention factors. This calculation takes place in the so-called Attention phase of CODEC (see Figure A2).

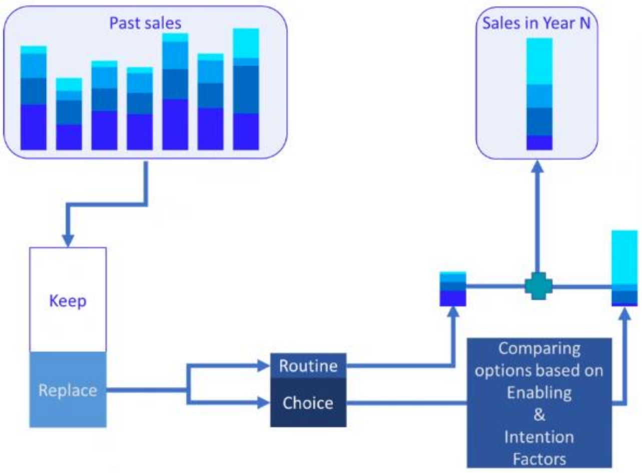

Figure A1: General calculation structure of CODEC (TNO, 2021a)[2]

In the Enable phase (see Figure A2), it is determined for how many individuals a particular car, in this case, is a realistic choice. This is estimated using the five questions formulated below. Finally, the relative attractiveness of each car is determined in the Intention phase. Each car option is then provided with a percentage of the population which is expected to purchase that car in a given year.

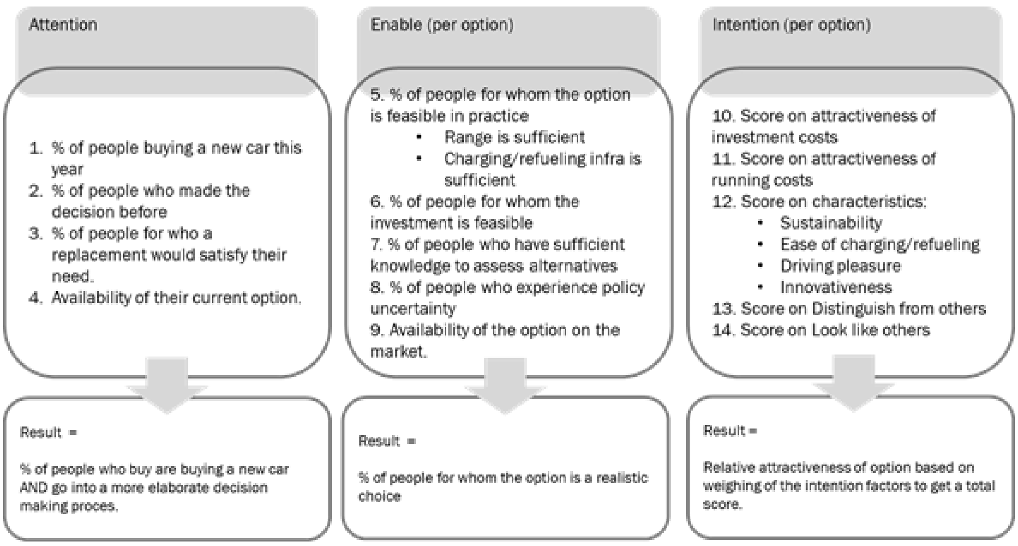

Figure A2: What CODEC needs (TNO, 2021)[1]

[2] Figure is extracted from TNO Sharepoint (not publicly accessible)

Appendix B: Example choice card

Figure B1 below illustrates how a choice card looked like in the final questionnaire. This is what respondents saw when making a choice between the two alternatives.

Hieronder ziet u twee verschillende auto's, namelijk een elektrische auto en een benzine auto. Uitgaande van onderstaande informatie, als u ervan uit moet gaan dat u enkel één van deze auto's kunt kopen, welke koopt u dan?

	Elektrische auto	**Benzine auto**
De **hoeveelheid mensen in uw omgeving** met deze auto ⓘ	een paar	ongeveer de helft
De CO_2**-uitstoot** van de auto in verhouding tot een gemiddelde benzine auto ⓘ	80% lager dan de gemiddelde benzine auto	40% hoger dan de gemiddelde benzine auto
De **actieradius** van de auto ⓘ	150 km	600 km
De **extra tijd** die het u dagelijks kost om een laadpaal dichtbij huis te vinden. Ga er hierbij vanuit dat u geen privé laadpaal heeft.	0 minuten per dag	
De **hoeveelheid snellaadstations** in verhouding tot de hoeveelheid tankstations in Nederland ⓘ	voor elke 10 tankstations zijn er 6 snellaadstations 	
De **maandelijkse kosten** van de auto ⓘ	€400	€100
De **aankoopprijs** van de auto	€22.000	€10.000

Selecteer alstublieft uw keuze hieronder.

- ◯ Elektrische auto
- ◯ Benzine auto

Figure B1: The choice card included in the final questionnaire in Dutch

Appendix C: D-efficient design

A D-efficient design was generated using NGene. The selection of priors, as well as the NGene syntax that generated the final D-efficient design are described below.

First of all, the selection of priors is based on similar DCEs executed. The studies used for this selection are, preferably, conducted both fairly recently and in the Netherlands. The priors used to create the final D-efficient design are:

1. **Price.** The prior for price was set at -0.2, based on the beta coefficients found by Noel et al. (2019), Wolbertus et al. (2019), Liao et al. (2019), and Hoen and Koetse (2014).
2. **Monthly cost.** The prior for monthly costs was set at -0.005, based on the beta coefficient found by Hoen and Koetse (2014).
3. **Driving range.** The prior for the driving range for EV was set at 0.005, based on the beta coefficients found by Wolbertus et al. (2019), Liao et al. (2019), and Hoen and Koetse (2014).
4. **Detour time.** The prior for additional detour time was set at -0.03, based on the beta coefficient found by Hoen and Koetse (2014).
5. **Environmental performance.** The prior for environmental performance was set at 0.002, based on the beta coefficient found by Hackbarth and Madlener (2013). Inverted sign because levels are displayed differently.
6. **Market size.** As no studies employing similar levels were found, and results were inconsistent for studies employing numerical market sizes, priors were set to 0 for all three dummies.
7. **Charging density.** The prior for charging station density was set to 0.5, based on the beta coefficient found by Li et al. (2020).

The final syntax used in NGene by Kevin Broekcs to create the D-efficient design is:

```
Design
;alts = bev, gas
;rows = 32
;eff = (mnl,d)
;block = 4
;cond:
if(bev.market=3, gas.market=[0,1]),
if(bev.market=2, gas.market=[0,1,2]),
if(gas.market=3, bev.market=[0,1]),
if(gas.market=2, bev.market=[0,1,2])
;model :
U (bev) = b1
+ b2[-0.2] * priceev[10,16,22,28,34,40]
+ b3[-0.005] * mcost[100,200,300,400]
+ b4[0.005] * range[150,300,450,600]
+ b5[-0.03] * detour[0,5,10,15]
+ b6[0.002] * envev[0,20,40,60,80]
+ b7.dummy[0|0|0] * market[0,1,2,3]
+ b8 [0.5] *charge[2,4,6,8,10]
/

U (gas) = b2 * pricegas[10,16,22,28,34,40]
+ b3 * mcost
+ b6 * envgas[-40,-20,0,20,40]
+ b7.dummy * market
$
```

Appendix D: The complete questionnaire in Dutch

Introductie tekst

Onderwerp: Het kopen van een auto, wat zijn uw voorkeuren?

Dit onderzoek gaat over het kopen van een auto en hoe u naar verschillende typen auto's kijkt. De uitkomsten worden gebruikt om meer zicht te krijgen op de toekomst van mobiliteit in Nederland, en hoe nationaal beleid hier een rol kan spelen.

Dit onderzoek wordt door xxx uitgevoerd in opdracht van TNO.

Uw privacy is gewaarborgd, want de door u gegeven antwoorden worden losgekoppeld van uw naam en e-mailgegevens. Deelname aan dit onderzoek neemt niet meer dan 15 minuten van uw tijd in beslag. U kunt tijdens het invullen van de vragenlijst op ieder moment stoppen.

Meer informatie?

Als u vragen heeft over het onderzoek of als er onduidelijkheden zijn, kunt u mailen naar …

Alvast bedankt voor uw deelname!

___

[Selectie (helemaal aan het begin van experiment en vragenlijst)]

Beantwoord de volgende vragen over uw eigen situatie. Heeft uw huishouden meer dan één auto, beantwoord dan de vragen voor de auto die u zelf het meest gebruikt.

1. Heeft u ooit eerder een auto gekocht?
   a. Ja
   b. Nee, wel geleased
   c. Nee, en ook niet geleased

[Routing: Indien ja, vraag 2 en 3 stellen]

2. De laatste keer dat u een auto heeft gekocht, was dat een nieuwe auto?
   a. Ja, nieuw
   b. Nee, tweedehands

3. Heeft u deze auto privé gekocht of zakelijk?
   a. Privé
   b. Zakelijk

[Routing: Vraag 4 weer aan iedereen stellen]

4. Overweegt u wanneer u een volgende auto zal kopen een nieuwe of een tweedehands auto?
   a. Ik overweeg dan een nieuwe auto [->deze mensen selecteren]
   b. Ik overweeg dan een tweedehands auto
   c. Ik overweeg zowel tweedehands als nieuw [->deze mensen selecteren]
   d. Niet van toepassing: ik zal nooit (meer) een auto kopen

[Selectie: de rest van de vragenlijst wordt alleen ingevuld door respondenten die 'ja' hebben geantwoord op vraag 2 en/of op vraag 4]

Beantwoord de volgende vragen over uw eigen situatie. Heeft uw huishouden meer dan één auto, beantwoord dan de vragen voor de auto die u zelf het meest gebruikt.

5. Wat voor soort auto heeft u?
   a. Benzine
   b. Diesel
   c. Hybride benzine
   d. Hybride diesel
   e. Plug-in hybride
   f. Elektrisch [-> deze mensen re-routen later in de vragenlijst]
   g. Gas (LPG, CNG)
   h. Waterstof
   i. Weet ik niet
   j. Anders, namelijk [invulveld]
   k. Ik heb geen auto

[Keuze-experiment: introductietekst]

In deze vragenlijst vragen we u om acht keer een keuze te maken tussen twee verschillende auto's: een elektrische auto en een benzine auto. Van beide auto's laten we steeds de volgende zeven kenmerken zien:

1) De **hoeveelheid mensen in uw omgeving met deze auto** (denk bijvoorbeeld aan vrienden, familieleden, buren en collega's).
2) De **CO_2-uitstoot** van de auto in verhouding tot een gemiddelde benzine auto (het gaat hier om zowel de uitstoot die vrijkomt bij het gebruik als bij de productie van de auto).
3) De **actieradius** van de auto (het aantal km dat u kunt rijden met één volle tank of batterij).
4) De **extra tijd** die het u dagelijks kost om een laadpaal dichtbij huis te vinden. Ga er hierbij van uit dat u geen privé laadpaal heeft.
5) De **hoeveelheid snellaadstations** in verhouding tot de hoeveelheid tankstations in Nederland (een snellaadstation kan uw elektrische auto in ongeveer 30 minuten weer tot 80% opladen).
6) De **maandelijkse kosten** van de auto (brandstofkosten, verzekering, motorrijtuigenbelasting en onderhouds- en reparatiekosten).
7) De **aankoopprijs** van de auto.

De waardes van deze kenmerken veranderen iedere keer. Op basis van deze kenmerken vragen we u vervolgens om acht keer een weloverwogen keuze te maken tussen de twee auto's. Maak deze keuzes alsof het een werkelijke situatie is.

Hieronder ziet u twee verschillende auto's, namelijk een elektrische auto en een benzine auto. Uitgaande van onderstaande informatie, als u ervan uit moet gaan dat u enkel één van deze auto's kunt kopen, welke koopt u dan?

	Elektrische auto	**Benzine auto**
De **hoeveelheid mensen in uw omgeving** met deze auto ⓘ	een paar	ongeveer de helft
De **CO_2-uitstoot** van de auto in verhouding tot een gemiddelde benzine auto ⓘ	80% lager dan de gemiddelde benzine auto	40% hoger dan de gemiddelde benzine auto
De **actieradius** van de auto ⓘ	150 km	600 km
De **extra tijd** die het u dagelijks kost om een laadpaal dichtbij huis te vinden. Ga er hierbij vanuit dat u geen privé laadpaal heeft.	0 minuten per dag	
De **hoeveelheid snellaadstations** in verhouding tot de hoeveelheid tankstations in Nederland ⓘ	voor elke 10 tankstations zijn er 6 snellaadstations 	
De **maandelijkse kosten** van de auto ⓘ	€400	€100
De **aankoopprijs** van de auto	€22.000	€10.000

Selecteer alstublieft uw keuze hieronder.

○ Elektrische auto
○ Benzine auto

Figure D1: Example choice card shown in the final questionnaire in Dutch

[Vragen omtrent routinegedrag bij het kopen van een auto]

[Routing: alleen mensen die al een auto hebben gekocht (1=a). Overslaan voor de rest van de deelnemers (1=b of c). Dit geldt voor 6, 7 en 8]

6. Hoeveel tijd besteedt u actief aan het kiezen van een auto?
   a. Maximaal een dag of een paar dagen
   b. Hier ben ik om en nabij een week mee bezig
   c. Hier kan ik een aantal weken mee bezig zijn
   d. Langer dan een aantal weken

[Routing: Vraag 7 en 8 verslaan als vraag 5 = k (ik heb geen auto)]

7. Ik heb bij mijn vorige aankoop al nagedacht over welk type motor past bij mijn behoeften, en dit type ga ik opnieuw kopen.
   a. Eens
   b. Oneens

8. Wanneer ik in de toekomst mijn volgende auto koop, ben ik van plan om naar auto's te kijken met een ander soort motor dan mijn huidige auto (diesel, benzine, hybride, elektrisch, etc.).
   a. Eens
   b. Oneens

[Routing: vanaf deze vraag weer stellen aan iedereen]

9. Voor mijn volgende auto neem ik dit type auto mee in mijn overweging (meerdere antwoorden mogelijk):
   a. Benzine
   b. Diesel
   c. Hybride benzine
   d. Hybride diesel
   e. Plug-in hybride
   f. Elektrisch
   g. Gas (LPG, CNG)
   h. Waterstof
   i. Geen van deze
   j. Alle bovenstaande types
   k. Ik weet het niet

10. Als ik een auto koop (vink er maximaal drie aan):
   a. Ga ik naar mijn vaste dealer
   b. Ga ik naar een aantal verschillende dealers
   c. Kijk ik online op een of meerdere vergelijkingssites
   d. Vraag ik rond bij mensen die ik ken
   e. Lees ik autobladen
   f. Anders, namelijk [invulveld]

[Vragen omtrent de praktische haalbaarheid van elektrisch rijden]

[Routing: vraag 11 t/m 16 stellen aan iedereen behalve mensen die een EV rijden, dus behalve 5=f]

11. Zou het voor u praktisch haalbaar zijn om een elektrische auto te gebruiken?
    a. Ja
    b. Nee

[Routing: Vraag 12 stellen bij 'nee' op vraag 11]

12. Waarom zou het voor u praktisch gezien niet haalbaar zijn om een elektrische auto te rijden? Noem 1 tot 5 redenen.

[Hier vijf wat ruimere tekstvakken met nummering ervoor (1 t/m 5)]

13. Het doorlopen van het aanvraagproces van een laadpaal bij de gemeente houdt me tegen om (eventueel) een elektrische auto te kopen.
    a. Helemaal oneens
    b. Oneens
    c. Een beetje oneens
    d. Neutraal
    e. Een beetje eens
    f. Eens
    g. Helemaal eens
    h. Niet van toepassing, ik zou kunnen laden op eigen terrein
    i. Ik weet het niet

In hoeverre bent u het eens met de volgende stellingen?

14. Het plannen van een rit met een elektrische auto lijkt me veel gedoe.
    a. Helemaal oneens
    b. Oneens
    c. Een beetje oneens
    d. Neutraal
    e. Een beetje eens
    f. Eens
    g. Helemaal eens

15. Als mijn huidige of favoriete merk/ model geen elektrische variant aanbiedt zal ik geen elektrische auto kopen.
    a. Helemaal oneens
    b. Oneens
    c. Een beetje oneens
    d. Neutraal
    e. Een beetje eens
    f. Eens
    g. Helemaal eens

16. Heeft u wel eens in een elektrische auto gereden als bestuurder?
    a. Ja, ik rijd een elektrische auto
    b. Ja, ik heb er een paar dagen of meer in gereden
    c. Ja, ik heb er een keer in gereden
    d. Nee

[Routing: vanaf vraag 17 ook mensen met een EV.]

In hoeverre bent u het eens met de volgende stelling?

17. Ik zou een benzine of diesel auto alleen kopen als deze auto zero emissie zones (milieuzones) in mag. Deze zones zullen vooral in grote steden komen.
    a. Helemaal oneens
    b. Oneens
    c. Een beetje oneens
    d. Neutraal
    e. Een beetje eens
    f. Eens
    g. Helemaal eens

[Vragen omtrent de aanschafprijs en maandelijkse kosten van de auto]

18. Hoeveel euro bent u bereid maximaal uit te geven wanneer u een auto koopt (aanschafprijs, inclusief aanschafbelastingen zoals de BPM)?
    a. Tot 10.000 euro
    b. 10.000-20.000 euro
    c. 20.000-30.000 euro
    d. 30.000-40.000 euro
    e. 40.000-50.000 euro
    f. 50.000-60.000 euro
    g. Meer dan 60.000 euro
    h. Weet ik niet

19. Hoeveel euro bent u bereid maximaal uit te geven per maand aan kosten voor motorrijtuigenbelastingen, brandstof/elektriciteit, en reparaties?
    a. Tot 100 euro per maand
    b. 100 – 200 euro per maand
    c. 200 – 300 euro per maand
    d. 300 – 400 euro per maand
    e. 400 – 500 euro per maand
    f. Meer dan 500 euro per maand
    g. Weet ik niet

[Vragen omtrent kennis, ervaren beleidsonzekerheid en technologie-onzekerheid]

In hoeverre bent u het eens met de volgende stellingen?

20. "Ik denk dat ik voldoende kennis heb om te beslissen of een … geschikt is voor mij."
    1. Elektrische auto
    2. Benzine auto

    a. Helemaal oneens
    b. Oneens
    c. Een beetje oneens
    d. Neutraal
    e. Een beetje eens
    f. Eens
    g. Helemaal eens

In hoeverre bent u het eens met de volgende stellingen?

21. Voor mij zijn de subsidies en belastingvoordelen voor elektrisch rijden onduidelijk.
    a. Helemaal oneens
    b. Oneens
    c. Een beetje oneens
    d. Neutraal
    e. Een beetje eens
    f. Eens
    g. Helemaal eens

22. Voor mij is de onzekerheid groot of diesel en benzine auto's in de toekomst toegang hebben tot zero emissiezones en milieuzones.
    a. Helemaal oneens
    b. Oneens
    c. Een beetje oneens
    d. Neutraal
    e. Een beetje eens
    f. Eens
    g. Helemaal eens

[Vragen omtrent sociale effecten]

In hoeverre bent u het eens met de volgende stellingen?

23. Ik kijk naar anderen om te zien wat handig is als ik een aankoop doe: ik hecht veel waarde aan ervaringen en advies van familie en vrienden.
    a. Helemaal oneens
    b. Oneens
    c. Een beetje oneens
    d. Neutraal
    e. Een beetje eens
    f. Eens
    g. Helemaal eens

24. Ik onderscheid mezelf graag van anderen: als ik de eerste of de enige ben die iets koopt, dan geeft mij dat voldoening.
    a. Helemaal oneens
    b. Oneens
    c. Een beetje oneens
    d. Neutraal
    e. Een beetje eens
    f. Eens
    g. Helemaal eens

25. Hoeveel elektrische auto's denkt u dat er ongeveer zijn in Nederland?
    a. 0,5%
    b. 1%
    c. 2%
    d. 5%
    e. 10%
    f. 15%
    g. 20%
    h. Meer dan 20%

26. Hoeveel mensen in uw directe omgeving rijden een elektrische auto, voor zover u weet?
    a. Geen
    b. Een aantal
    c. Ongeveer de helft
    d. Vrijwel iedereen
    e. Weet ik niet

[Vragen omtrent de persoonlijke situatie]

[Routing: vraag 27 niet laten zien als 5=k]

Beantwoord de volgende vragen over uw eigen situatie.

27. Hoeveel auto's zijn er binnen uw huishouden?
    a. Geen
    b. 1 auto
    c. 2 auto's
    d. 3 auto's
    e. Meer dan 3 auto's

[Routing: indien 27 = 2 of meer: Uw huishouden heeft meer dan één auto: beantwoord dan de vragen voor de auto die u zelf het meest gebruikt]

[Routing: vraag 28 overslaan als vraag 5 = k (ik heb geen auto)]

28. In welk segment valt uw auto?
    a. A-segment: submini's (Bijv.: Citroën C1, Toyota Aygo, Volkswagen Up, Skoda Citigo, SEAT Mii)
    b. B-segment: kleine auto's (Bijv.: Ford Fiesta, Volkswagen Polo, Opel Corsa, Hyundai Kona, Renault Zoe)
    c. C-segment: kleine middenklasse (Bijv.: Ford Focus, Volkswagen Golf, Audi A3, Nissan Leaf, Kia Niro).
    d. D-segment: middenklasse (Bijv.: Audi A4, Peugeot 508, Opel Insignia, Tesla Model 3, Polestar 2, BMW iX3)
    e. E-segment: hogere middenklasse (Bijv.: Volvo S90, BMW 5 Serie, Mercedes-Benz E-Klasse, Jaguar I-Pace, Audi e-tron 50 quattro)
    f. F-segment: grote auto's (Bijv.: Audi A8, Mercedes-Benz S-klasse, Jaguar XJ, Tesla Model S, Tesla Model X, Porsche Taycan 4S)
    g. G-segment: sportieve modellen (Bijv.: Mazda MX-5, Audi TT, Mercedes-Benz SLC)
    h. H-segment: sportauto's/supercars
    i. I-segment: groot en luxueus (Bijv.: Rolls Royce Ghost, Bentley Mulsanne, Aston Martin Rapide)
    j. J-segment: medium MPV's (Bijv.: Renault Scénic, Volkswagen Touran, Opel Zafira Tourer)
    k. K-segment: upper MPV's (Bijv.: Renault Espace, Ford S-Max)
       L-segment: lower SUV's (Bijv.: Hyundai Tucson, Volvo XC60)
       M-segment: upper SUV's (Bijv.: BMW X5, Audi Q7)
       N-segment: bestelauto's (Bijv.: Renault Kangoo, Peugeot Partner, Nissan e-NV200 Evalia)
       Ik weet het niet

29. Heeft u zonnepanelen op uw eigen dak?
    a. Ja
    b. Nee

[Routing: vraag 30 overslaan als vraag 5 = k (ik heb geen auto) of als vraag 27 = a (geen auto's in huishouden]

30. Welke situatie is op u van toepassing?
    a. Ik heb een eigen erf of oprit waar ik mijn auto parkeer.
    b. Ik parkeer bij mij in de straat of buurt
    c. Ik parkeer in de gedeelde parkeergarage van mijn appartementencomplex
    d. Ik parkeer op afstand van mijn huis, en neem vanaf daar bijv. fiets of OV naar huis
    e. Anders, namelijk

31. Is het voor u momenteel praktisch haalbaar om een elektrische auto op te laden in de buurt van uw huis?
    a. Ja, op mijn eigen erf
    b. Ja, in mijn straat of buurt
    c. Nee
    d. Ik weet het niet

[Routing: vraag 32 overslaan als vraag 5 = k (ik heb geen auto)]

32. Hoeveel km rijdt u ongeveer per jaar?
    a. 0 tot 2.500 km
    b. 2.500 tot 5000 km
    c. 5.000 tot 7.500 km
    d. 7.500 tot 10.000 km
    e. 10.000 tot 12.500 km
    f. 12.500 tot 15.000 km
    g. 15.000 tot 17.500 km
    h. 17.500 tot 20.000 km
    i. 20.000 tot 22.500 km
    j. 22.500 tot 25.000 km
    k. Meer dan 25.000 km
    l. Weet ik niet
    m. Ik rijd geen auto

[Vragen omtrent de eigenschappen van innovatiegroepen]

33. Stelt u zich voor dat u overweegt een nieuwe auto te kopen. Welke van de onderstaande beschrijvingen past het best bij u? (kies één van de 5 mogelijkheden)
    a. Ik ben iemand die nieuwe technologische ontwikkelingen goed in de gaten houdt en risico's neemt door als eerste innovatieve auto's uit te proberen en aan te schaffen.
    b. Ik ben iemand die mogelijke voordelen ziet van een innovatieve auto en die één van de eersten wil zijn die daarvan gebruik maakt en profiteert.
    c. Ik ben iemand die innovatieve auto's leuk vindt, maar toch pragmatisch is. Ik baseer mijn beslissingen (voornamelijk) op aanbevelingen van bestaande gebruikers. Ik wil eerst tijd nemen om alles te overwegen en overtuigd te worden van de voordelen die een innovatieve auto biedt.
    d. Ik ben iemand die niet om innovaties staat te springen, maar het zekere voor het onzekere neemt. Het is pas veilig om een innovatieve auto aan te schaffen als het al een tijdje op de markt is en overduidelijke voordelen heeft.
    e. Ik ben iemand die traditioneel is en weinig affiniteit heeft met innovatieve auto's; ik houd niet van veranderingen en ga pas een nieuw type auto aanschaffen als een bestaand model niet meer wordt geproduceerd.

[Checkvragen om de attributen testen]

Stel, u overweegt een elektrische auto als volgende auto.

34. Welke afstand moet uw elektrische auto minimaal kunnen rijden zonder te hoeven opladen?
    a. 150 km
    b. 300 km
    c. 450 km
    d. 600 km
    e. Meer dan 600 km
    a. Ik weet het niet
    b. Dit vind ik niet belangrijk

Stel, u overweegt een elektrische auto als volgende auto en er zijn net zoveel snellaadstations als tankstations (waar een elektrische auto vrijwel volledig kan laden in 15-30 minuten).

35. Welke afstand moet uw auto minimaal kunnen rijden zonder te hoeven opladen?
    a. 150 km
    a. 300 km
    b. 450 km
    c. 600 km
    d. Meer dan 600 km
    e. Ik weet het niet
    f. Dit vind ik niet belangrijk

Stel, u overweegt een elektrische auto als volgende auto.

36. Hoeveel minuten zou u maximaal bereid zijn om te zoeken naar een beschikbare laadplek in uw buurt? Als u niet wilt zoeken, kies dan “0”.
    a. 0 minuten (bijvoorbeeld omdat u op eigen terrein zou willen laden)
    b. 5 minuten
    c. 10 minuten
    d. 15 minuten
    e. Meer dan 15 minuten
    a. Ik weet het niet
    b. Dit vind ik niet belangrijk

Stel, u overweegt een elektrische auto als volgende auto.

37. Hoeveel snellaadstations vindt u dat er minimaal nodig zijn in Nederland?
    a. Voor elke 10 tankstations zijn er 2 snellaadstations
    b. Voor elke 10 tankstations zijn er 4 snellaadstations
    c. Voor elke 10 tankstations zijn er 6 snellaadstations
    d. Voor elke 10 tankstations zijn er 8 snellaadstations
    e. Er zijn evenveel snellaadstations als tankstations
    f. Ik weet het niet
    g. Dit vind ik niet belangrijk

Stel, u overweegt een elektrische auto als volgende auto.

38. Hoe milieuvriendelijk wilt u dat uw auto minimaal is?
    a. 40% meer CO2-uitstoot dan de gemiddelde benzine auto
    b. 20% meer CO2-uitstoot dan de gemiddelde benzine auto
    c. Hetzelfde als de gemiddelde benzine auto
    d. 20% minder CO2-uitstoot dan de gemiddelde benzine auto
    e. 40% minder CO2-uitstoot dan de gemiddelde benzine auto
    f. 60% minder CO2-uitstoot dan de gemiddelde benzine auto
    g. 80% minder CO2-uitstoot dan de gemiddelde benzine auto
    h. Ik weet het niet
    i. Dit vind ik niet belangrijk

Appendix E: Socio-demographic characteristics

In Table E1 below, the socio-demographic characteristics of the sample that could not be compared to the Dutch population are shown.

Table E1:More socio-demographic characteristics of the survey sample

Socio-demographic characteristics	Value	% Sample N=2,141
Income	Until €14.100	3.7
	€14.100 to €29.500	8.9
	€29.500 to €36.500	11.5
	€36.500 to €43.500	18.4
	€43.500 to €73.000	25.1
	€73.000 to €87.100	8.1
	From €87.100	11.2
Degree of urbanity	Very strongly urban	20.9
	Highly urban	32.4
	Moderately urban	14.8
	Little urban	23.4
	Not urban	8.5
Household composition	Lives alone	23.7
	Lives alone with children	2.3
	Married/ lives together without children living at home	50.8
	Married/ lives together with children living at home	18
	Lives with parent(s)/ guardian(s)	2.8
	Different	2.2
Home	Detached house	19
	2- under-1-roof house	16.3
	Terraced house	25.8
	Terraced house, corner house	10.9
	Flat/ apartment, low-rise (maximum 4 floors)	16.4
	Flat/ apartment, high-rise (5 floors or more)	6.9
	Senior housing/ service flat	0.6
	Student flat/ student house	1.7
	Nursing home	1
	Farm	1.4
Fuel type of current car	Gasoline	70.3
	Diesel	7.6
	Hybrid gasoline	8.6
	Hybrid diesel	0.1
	Plug-in hybrid	0.8
	Electric	4
	Gas (LPG, CNG)	0.9
	Hydrogen	0.2
	Does not have a car	6.5
	Different	1

Previous experience driving an EV[3]	Yes, a few days or more	7.9
	Yes, once	17.5
	No	74.6
Considered future car types	Condition:	
	- New	46.8
	- New as well as second-hand	53.2
	Fuel (more options were possible):	
	- Gasoline	60.4
	- Diesel	8.2
	- Hybrid gasoline	57.5
	- Hybrid diesel	7
	- Plug-in hybrid	34
	- Electric	60.3
	- Gas (LPG, CNG)	5.4
	- Hydrogen	31.3
	- All of the above	3.1

[3] N=2,055: without respondents who already drive electric

Appendix F: Descriptive statistics of questions from the questionnaire

In this appendix, bar charts are included that show the frequencies of the different answer options for certain questions from the questionnaire. The questions for which bar charts have been created are: questions 12, 20 to 22, 26 and 32 to 38.

Question 12

Question 12 asked respondents whether it would be practically feasible to drive an EV or not. 778 respondents answered it would not be, after which they could write down five reasons why not. Figure F1 presents the twenty most given reasons.

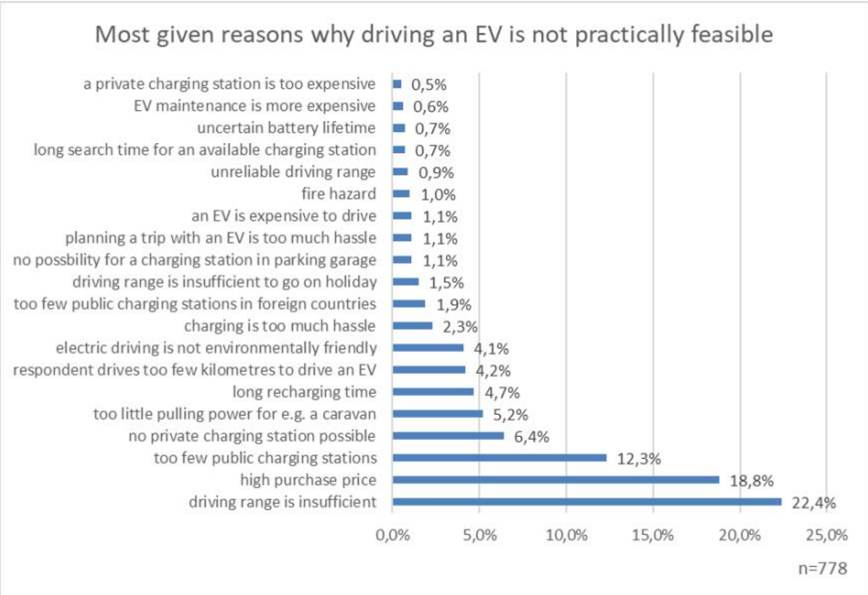

Figure F1: Twenty most given reasons by respondents (n=778) why it is not practically feasible to drive an EV

As can be seen, the three most given reasons, i.e. driving range, purchase price and too few public charging stations, correspond to the top three reasons found by ANWB (2020b) (see Figure 1). Only purchase price and driving range are turned around. The three most given reasons after that were not observed by the ANWB (2020b), but are important indicators why consumers will not buy an EV. These are there is no private charging station possible, an EV has too little pulling power for e.g. a caravan and the recharging time is too long, respectively.

Question 20

Question 20 consisted of two different statement on a 7 point Likert scale from strongly disagree to strongly agree. The bar charts are shown below (see Figures F2 and F3).

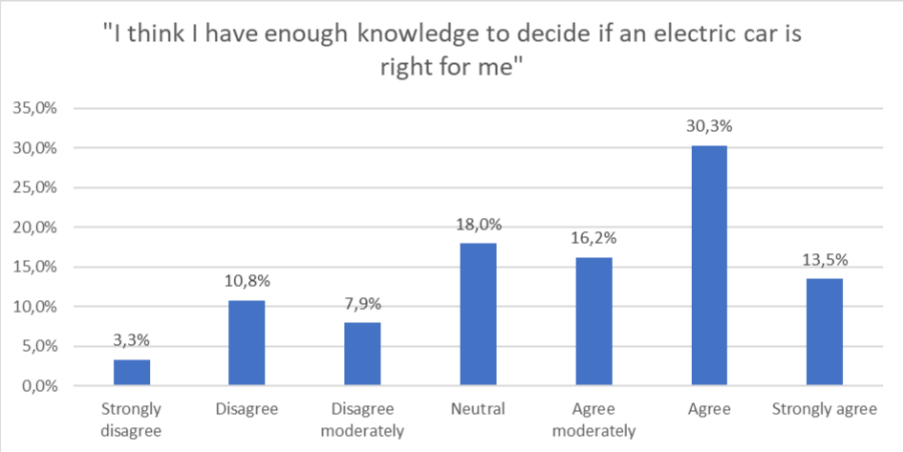

Figure F2: Bar chart of question 20, part 1

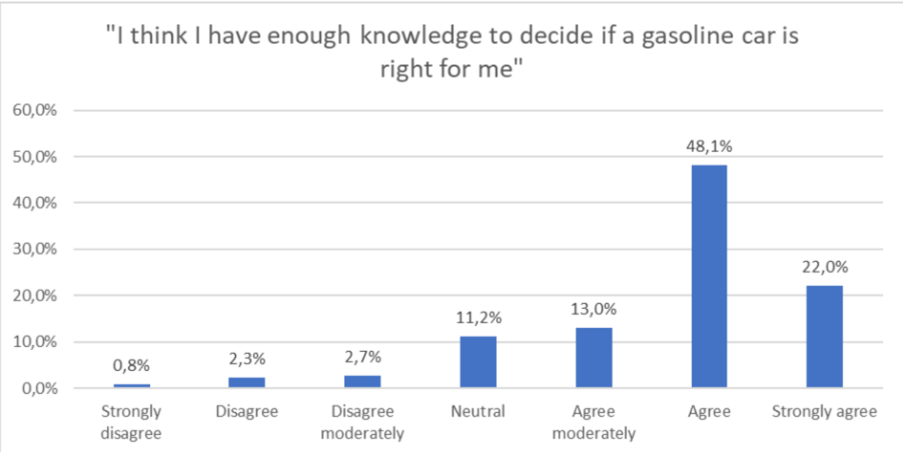

Figure F3: Bar chart of question 20, part 2

Question 21 and 22

Then, question 21 and 22 also contained answer options on a 7 point Likert scale from strongly disagree to strongly agree. The bar charts of which are shown below (see Figures F4 and F5).

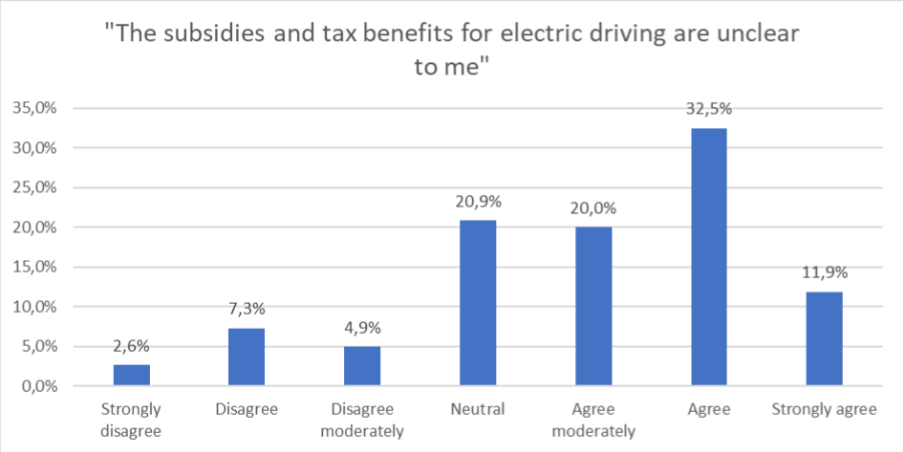

Figure F4: Bar chart of question 21

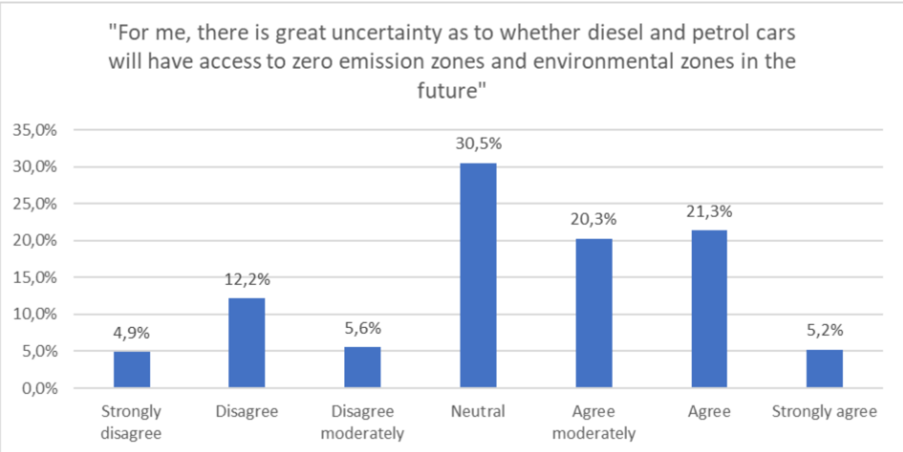

Figure F5: Bar chart of question 22

Question 26

Question 26 asked respondents how many people in their inner circle drive electric. The bar chart with the frequencies of the different answer options is shown below (see Figure F6).

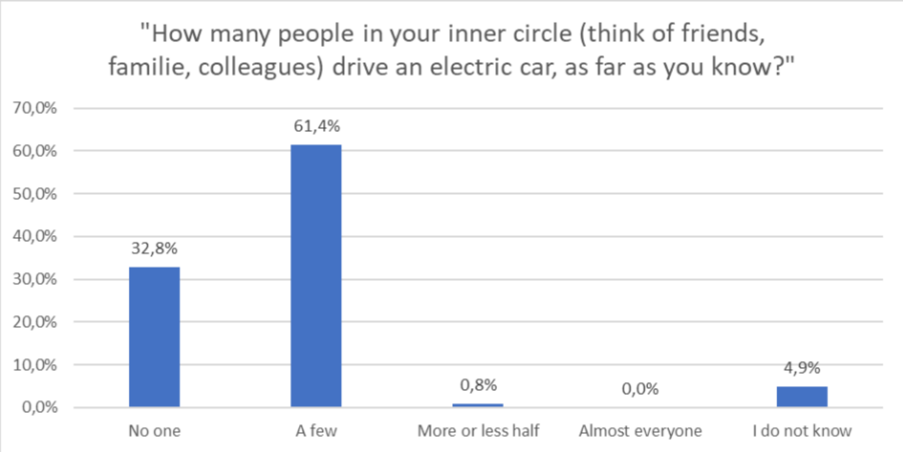

Figure F6: Bar chart of question 26

Question 32

Question 32 asks about the annual driving distance of respondents. The bar chart illustrating the distribution of annual driving distances of respondents is shown below (see Figure F7).

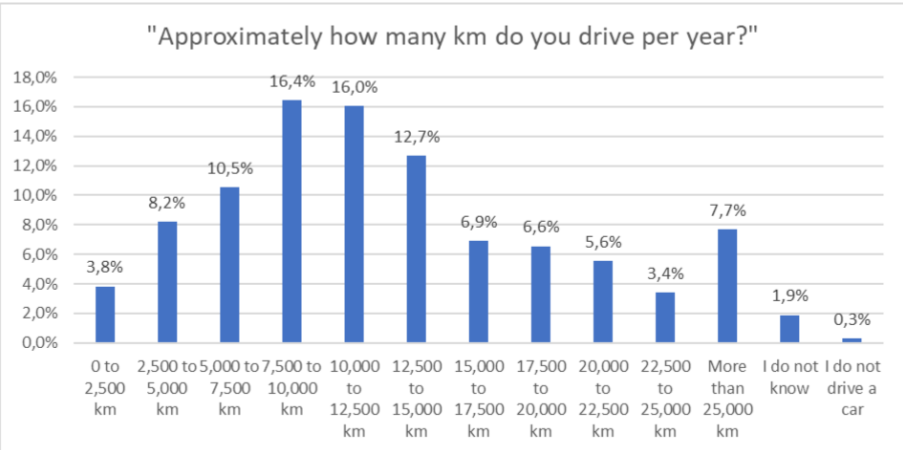

Figure F7: Bar chart of question 32

Question 33

Another question in the questionnaire asked respondents which of five statements suited them best. These statements were describing the five different innovation groups defined by Rogers. The distribution of respondents over these different groups is depicted in Figure F8 below.

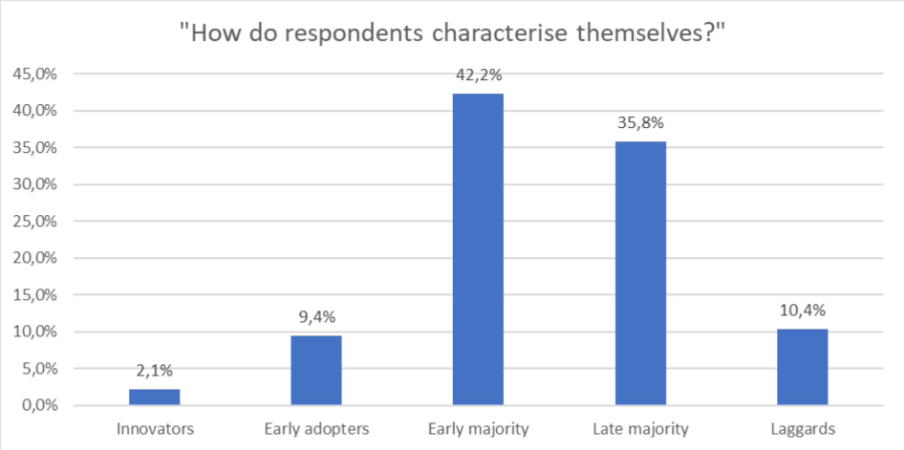

Figure F8: Bar chart of question 33

Question 34 and 35

Figure F9 below depicts the frequencies that the different answer options to question 34 were chosen.

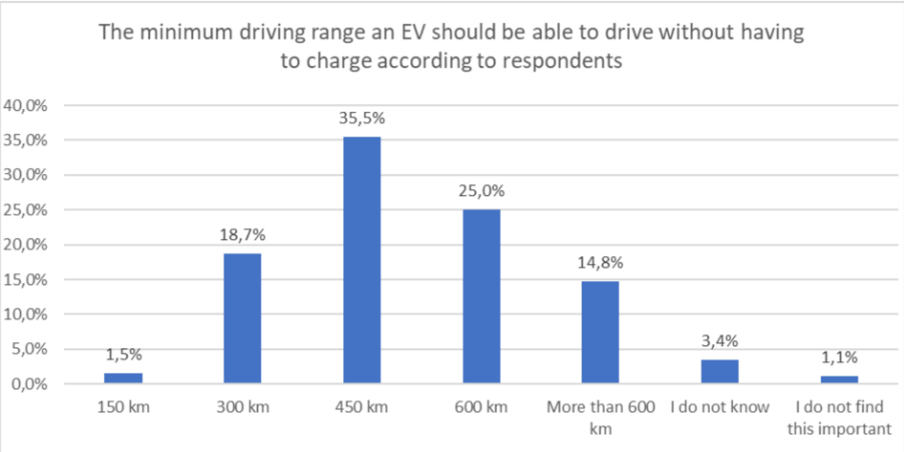

Figure F9: Bar chart of question 34

Figure F10 below depicts the frequencies in which the different answer options to question 35 were chosen. This question was similar to question 34, only the fast-charging station density was added as an extra layer of information.

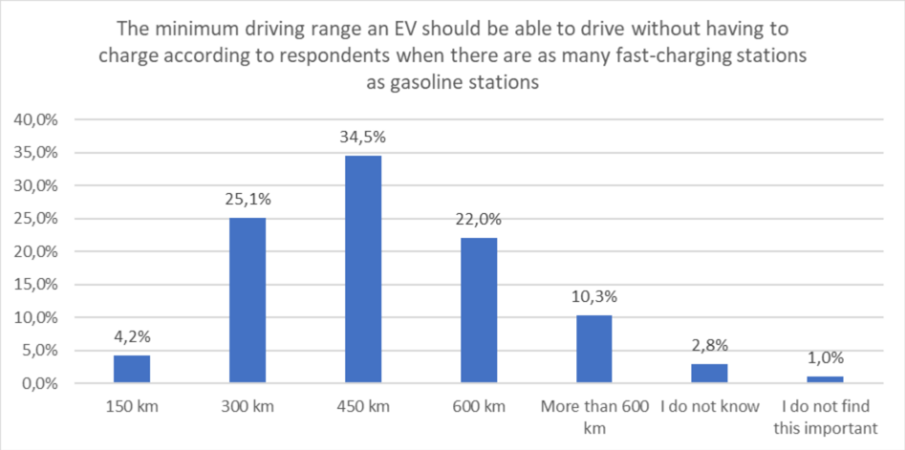

Figure F10: Bar chart of question 35

At first sight, I does not look like anything changed, but looking at the frequencies, more people choose the options 150 km and 300 km at the expensive of higher driving ranges.

Question 36

Figure F11 below depicts the frequencies that the different answer options to question 36 were chosen.

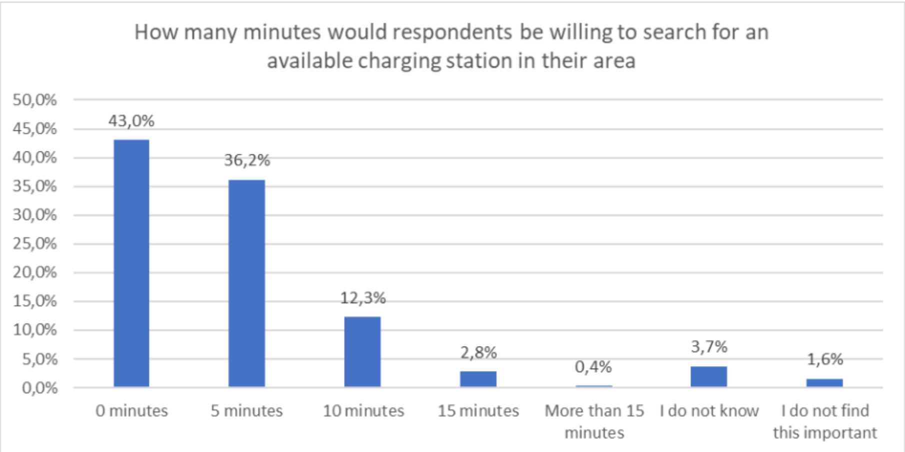

Figure F11: Bar chart of question 36

Question 37

Figure F12 below depicts the frequencies that the different answer options to question 37 were chosen.

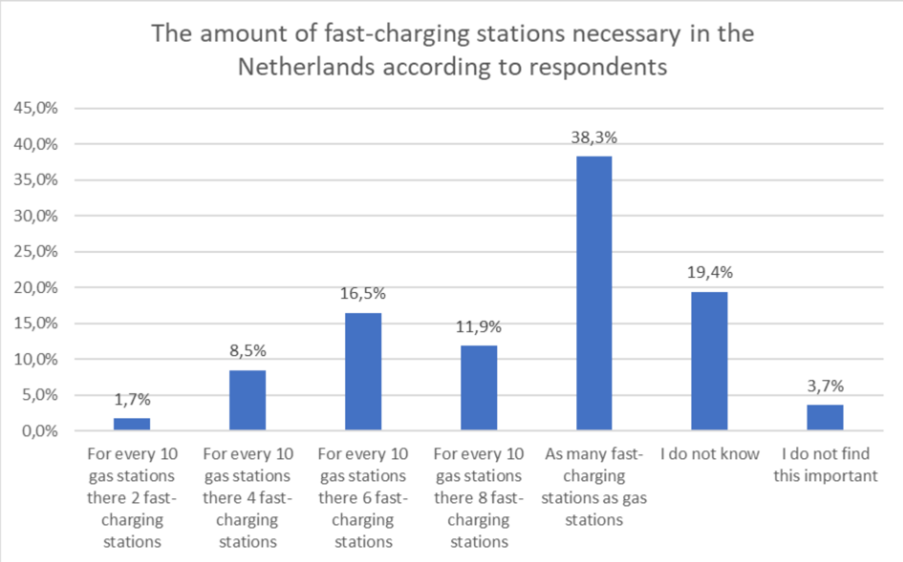

Figure F12: Bar chart of question 37

Question 38

Finally, Figure F13 below depicts the frequencies that the different answer options to question 38 were chosen.

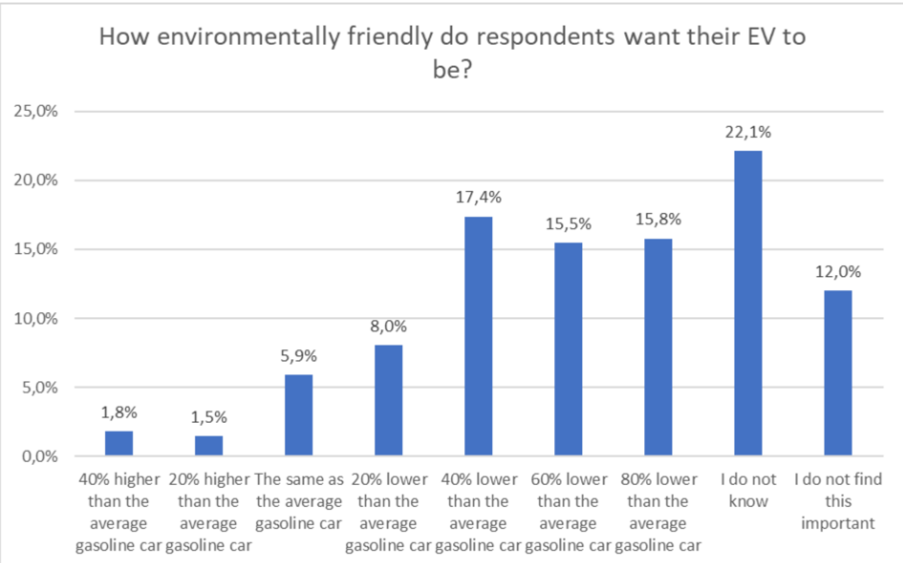

Figure F13: Bar chart of question 38