MASTER

User preferences related to public charging
A stated choice approach

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Award date:
2023

Master Thesis M.R. (Mark) Polet – 1238416

User preferences related to public charging

A stated choice approach

7CC40 – Graduation project Construction Management and Engineering (Master track Construction Management and Engineering)
7Z45M0 - Graduation project Urban Systems & Real Estate (Master track Architecture, Building and Planning, Urban Systems and Real Estate)

60 ECTS

2022 – 2023

Graduation committee 7CC40:

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Graduation date:

09-05-2023

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Preface

In front of you lies the report of my combined master graduation thesis, for the masters Construction Management & Engineering (CME) and Urban Systems and Real Estate (USRE) both followed at the Eindhoven University of Technology, with the title "User preferences related to public charging". Writing this graduation thesis has been one of the most challenging parts of my combined master track, however, being able to present this thesis is at the same time also one of the most rewarding parts of the master track.

In the past nine months (September 2022 till May 2023), I was able to gain more knowledge about electric vehicles, charging demand and user preferences regarding the location of public charging squares which is in line with my interests. Next to that, I was able to gain more experience in complex analysis methods and expand my knowledge.

I would like to thank my supervisors of the Eindhoven University of Technology Peter van der Waerden, Aloys Borgers and Bauke de Vries for being part of my graduation committee and dedicating their time and resources in order for me to be able to graduate.

In addition, I would like to thank René Heintz and Roy van Lieshout, my supervisors of Dura Vermeer Vastgoed, for always being available to patiently help me whenever I encountered problems during my research or had any questions. Not only René and Roy, but the whole Dura Vermeer Vastgoed division was always willing to help me during my graduation internship and for that, I would like to thank all colleagues of Dura Vermeer Vastgoed.

Next, I would like to thank the ANWB and BOVAG for helping me to distribute the questionnaire among potential respondents. Without these companies it would not have been possible to acquire the sample. I would also like to thank all respondents that participated in this study for taking the time to complete the questionnaire since without their contribution, this study would not be possible.

Finally, I would like to thank my friends and family for listening and discussing topics of my graduation thesis in order to help me solve any problems faced as well as help with testing the questionnaire. With this thesis, my time as a student at the Eindhoven University of Technology has officially come to an end and I am very happy about the personal development throughout my time as a student and this thesis as end result.

I hope you enjoy reading this report.

Mark Polet

Capelle aan den IJssel, April 28th, 2023

Summary

New European regulations will restrict the sales of new fossil-fuel vehicles as of 2035 and the Netherlands will already restrict the sales of new fossil-fuel vehicles from 2030 onwards. In addition, the European Union wants to be climate neutral by 2050 and reduce the emission of greenhouse gasses. This will result in more and more electric vehicles on the Dutch car market which will need adequate locations to be able to charge. Since many electric vehicle drivers in urban environments do not have the possibility to charge on private property, the demand for public charging locations in urban environments will increase in the upcoming years as more and more electric vehicles are adopted. In order to provide public charging in an efficient way in urban environments, public charging squares are considered in this thesis.

A charging square consist of multiple charging points (each with one or more charging ports) with a shared grid connection located at a single location which is publicly accessible and has several benefits compared to individual charging points, like lower impact on the grid, lower overall costs, easier to find, easier to install and maintain and future proof. If electric vehicles are grouped in one location, implementing new techniques will be more cost-effective. Techniques that can be implemented are load balancing or a microgrid for example. Moreover, by grouping electric vehicles and implementing new techniques, fewer connections are needed and the impact on the power grid can be reduced by implementing smart charging techniques. Besides, by grouping public charging points together electric vehicle drivers will be more confident in finding a suitable charging spot, increasing the adoption of electric vehicles. Currently, the Netherlands already has one of the densest charging networks in the European Union with 699 public chargers per 100,000 inhabitants while the European average is 73 per 100,000 inhabitants. In total, the Netherlands has 108,908 publicly available charging points of which 3,157 fast-charging points (reference date October 2022). However, 1.7 million chargers need to be realized by 2030 in order to provide adequate public charging.

In order to determine suitable locations for public charging squares in urban environments it is key to know what the users want. In this way, public charging squares will be located where users are also willing to use them. Therefore, this thesis investigates which user preferences are most important to be included in a tool that evaluates locations for public charging squares in metropolitan areas. In order to determine which user-preferences have the largest impact on the location decision, a stated choice experiment has been conducted among Dutch electric vehicle drivers as well as fossil-fuel drivers. Each respondent of the online distributed questionnaire using Limesurvey was presented with twelve different choice sets (out of 486 available choice sets). Each choice set contained two different charging locations and the option to choose neither of the charging locations. Every choice set presented to the respondents had two context variables which varied over the choice tasks. The included context variables were the range that needed to be charged and the available time to charge the given range.

Every alternative presented in the stated choice experiment contained the same attributes: type of charger, costs for slow charging, costs for fast charging, walking distance, charge certainty, supervision on the charging location, having to relocate the vehicle once the battery is completely charged and the alternative function for repurposed parking spots in the street. In order to participate in this study, the respondent had to have a driver's license and had to have driven more than zero kilometers in the last twelve months. Additionally, before submitting the results of the stated choice experiment each respondent had to answer several socio-demographic related questions. After the data collection period was terminated, the collected dataset was recoded and only useful cases were selected, ultimately resulting in 485 responses in the dataset. Using Nlogit, a Multinomial Logit model and Latent Class model were estimated. In order to test for representativeness, Chi-Square tests were conducted. The sample used to estimate the different models in this study does not represent the sample of the "Nationaal Laadonderzoek". In addition, the sample is not representative for the entire Dutch population since educated males with a high income are overrepresented in the dataset.

Based on the results, slow chargers are preferred over fast chargers when considering a public charging square in residential environments. Additionally, the results of the Multinomial Logit model show that of the attributes included in the stated choice experiment, cost is the most important attribute when

deciding on a public charging location. If the costs increase, the utility of the public charging location will rapidly decrease. Additional attributes which have a major impact on the overall utility are the walking distance, having to relocate the vehicle and the charge certainty at a certain location. Based on the presented results of the Multinomial Logit model, a walking distance around 150 meters does not seem to influence the overall utility of the charging square. If walking distances increase, the utility of a public charging location will decrease while shorter distances increase the overall utility of a public charging location (all else equal). These two main user aspects are followed by having to relocate the electric vehicle once the battery is completely charged and charge certainty. Only if the electric vehicle does not need to be relocated, a positive part-worth utility effect is found. The lower the charge certainty is at a certain location, the less likely an electric vehicle driver is to choose for that location.

The remaining two attributes, supervision on the charging location and the alternative function for parking seem not to influence the location decision since their part-worth utility values are close to zero. Even though the results only show a limited influence on the location decision, the results show that locations with CCTV supervision are preferred (all else equal). Of the different levels included for this attribute CCTV supervision is considered the highest level of supervision since CCTV is able to monitor the charging square 24/7. This is in line with the literature review which indicated that users are not willing to use unsafe charging squares. Since realizing a charging square will result in clustered parking for electric vehicles, part of the existing parking spots in the street can be repurposed. The results of this thesis have indicated that the respondents prefer more greenery in their neighborhood if existing parking spots are repurposed.

Next to the Multinomial Logit model a Latent Class model was estimated in order to check for the existence of different clusters (or classes) of respondents in the dataset. Given a set number of classes, Nlogit was used to cluster the respondents in classes and estimate the parameter values (of a Multinomial Logit model) for the respondents in each class. Of the estimated Latent Class models, the model which consisted of two different classes and did not include any class membership parameters performed best according to the calculations of the Bayesian Information Criterion value. Since no class membership variables have been included in the final Latent Class model, it was not possible to identify what makes a respondent belong to either of the created classes. The reason for excluding the different class membership variables was because the Latent Class model showed that all class membership variables excluding the constant were insignificant at the 10% level. Class one contains 86% of all respondents while class two contains the remaining 14% of the respondents. Since class two is a relatively small class compared to class one, it is possible that this has caused the statistical insignificance of the class membership results. Additionally, almost all Multinomial Logit model parameter values estimated by the Latent Class model for class two were insignificant, likely as a result of the small class, while in class one, the results were comparable to the Multinomial Logit model.

As a last part of this thesis, the practical application of the results was shown. Since the results of the Latent Class model were mainly insignificant for the second class and the results of the first class were in line with the Multinomial Logit model estimations, the practical application has been shown based on the results of the final Multinomial Logit model. The practical application showed that the presented results are indeed able to determine the probability of choosing between two public charging squares. However, in order to show the practical application, several assumptions were made which might differ from reality. Ultimately, the intention was to show that the results of this thesis yield a practical application which is the case. Therefore, the results presented throughout this thesis can be used in a design tool to determine the probability that a resident chooses between two public charging squares if potential sites have been identified. Additionally, if the urban planners have to make decisions on how to increase the probability that a charging square is chosen, the results of this thesis can be used as well.

Samenvatting

Nieuwe Europese regelgeving legt per 2035 de verkoop van nieuwe voertuigen op fossiele brandstoffen aan banden en in Nederland gebeurt dit al vanaf 2030. Daarnaast wil de Europese Unie in 2050 klimaatneutraal zijn en de uitstoot van broeikasgassen verminderen. Dit zal ertoe leiden dat er steeds meer elektrische voertuigen op de Nederlandse automarkt komen die voldoende locaties nodig hebben om te kunnen laden. Aangezien veel bestuurders van elektrische voertuigen in stedelijke omgevingen niet de mogelijkheid hebben om op privéterrein te laden, zal de vraag naar openbare laadlocaties in stedelijke gebieden de komende jaren toenemen naarmate er steeds meer elektrische voertuigen worden verkocht. Om openbaar laden op een efficiënte manier mogelijk te maken in stedelijke gebieden, wordt in dit afstudeerverslag gekeken naar openbare laadpleinen.

Een laadplein bestaat uit meerdere laadpunten (elk met één of meer laadpoorten) met een gedeelde netaansluiting op één locatie die publiek toegankelijk is en heeft verschillende voordelen ten opzichte van individuele laadpunten, zoals een lagere belasting van het elektriciteitsnet, lagere totale kosten, gemakkelijker te vinden, gemakkelijker te installeren en te onderhouden en toekomstbestendig. Als elektrische voertuigen op één locatie worden gegroepeerd, is de implementatie van nieuwe technieken daarnaast kosteneffectiever. Technieken die kunnen worden toegepast zijn bijvoorbeeld loadbalancing of een microgrid. Door elektrische voertuigen te groeperen en nieuwe technieken toe te passen, zijn bovendien minder aansluitingen nodig en kan de impact op het elektriciteitsnet worden verminderd door slimme laadtechnieken toe te passen. Bovendien zullen bestuurders van elektrische voertuigen meer vertrouwen hebben in het vinden van een geschikte oplaadplek door openbare oplaadpunten te groeperen, waardoor de acceptatie van elektrische voertuigen toeneemt. Op dit moment heeft Nederland al een van de hoogste dichtheden in de Europese Unie als het gaat om openbare laders met 699 openbare laders per 100.000 inwoners terwijl het Europese gemiddelde ligt op 73 per 100.000 inwoners. In totaal telde Nederland 108.908 openbare laadpunten waarvan 3.157 snellaadpunten (peildatum oktober 2022). Echter, er moeten in 2030 1,7 miljoen laders gerealiseerd zijn om voldoende publiek te kunnen laden.

Om geschikte locaties voor openbare laadpleinen in stedelijke gebieden te bepalen, is het belangrijk om te weten wat de gebruikers willen. Zo komen er openbare laadpleinen waar gebruikers er ook gebruik van willen maken. Daarom onderzoekt dit afstudeerverslag welke voorkeuren van gebruikers het belangrijkst zijn om opgenomen te worden in een tool die locaties voor openbare laadpleinen in stedelijke gebieden evalueert. Om te bepalen welke gebruikersvoorkeuren de meeste invloed hebben op de locatiebeslissing is een keuze-experiment uitgevoerd onder zowel Nederlandse bestuurders van elektrische voertuigen als bestuurders die op fossiele brandstoffen rijden. Elke respondent van de online gedeelde vragenlijst met behulp van Limesurvey kreeg twaalf verschillende keuzesets gepresenteerd (van de 486 beschikbare keuzesets). Elke keuzeset bevatte twee verschillende laadlocaties en de mogelijkheid om geen van de laadlocaties te kiezen. Elke keuze die aan de respondent werd gepresenteerd, had twee contextvariabelen die varieerden over de keuzetaken. De inbegrepen contextvariabelen waren het bereik dat moest worden opgeladen en de beschikbare tijd om het opgegeven bereik op te laden.

Alle gepresenteerde alternatieven in het genoemde keuze-experiment bevatten dezelfde attributen: type lader, kosten voor langzaam laden, kosten voor snelladen, loopafstand, laadzekerheid, toezicht op de laadlocatie, het moeten verplaatsen van het voertuig zodra de accu volledig is opgeladen en de alternatieve functie voor herbestemde parkeerplaatsen in de straat. Om deel te kunnen nemen aan dit onderzoek moest de respondent in het bezit zijn van een rijbewijs en in de afgelopen twaalf maanden meer dan nul kilometer hebben gereden. Bovendien moest elke respondent, voordat deze de resultaten van het keuze-experiment indiende, verschillende sociaal-demografische vragen beantwoorden. Nadat de gegevensverzamelingsperiode was beëindigd, werd de verzamelde dataset opnieuw gecodeerd en werden alleen geschikte antwoorden geselecteerd, wat uiteindelijk resulteerde in 485 antwoorden in de dataset. Nlogit is hierna gebruikt om een Multinomial Logit-model en een Latent Class-model te schatten. Om te testen op representativiteit zijn meerdere Chi-kwadraattoetsen uitgevoerd. De steekproef die is gebruikt om de verschillende modellen in dit onderzoek te schatten, is niet representatief voor de steekproef van het Nationaal Laadonderzoek. Daarnaast is de steekproef niet

representatief voor de gehele Nederlandse bevolking, aangezien hoogopgeleide mannen met een hoog inkomen oververtegenwoordigd zijn in de dataset.

Op basis van de resultaten krijgen langzaamladers de voorkeur boven snelladers bij het overwegen van een openbaar laadplein in woonomgevingen. Bovendien laten de resultaten van het Multinomial Logit-model zien dat van de attributen die zijn opgenomen in het keuze-experiment, de kosten het belangrijkste attribuut zijn bij het kiezen van een openbare laadlocatie. Als de kosten stijgen, zal het nut van de openbare laadplaats snel afnemen. Bijkomende attributen die een grote impact hebben op het totale nut zijn de loopafstand, het moeten verplaatsen van het voertuig en de laadzekerheid op een bepaalde locatie. Op basis van de gepresenteerde resultaten van het Multinomial Logit-model lijkt een loopafstand van circa 150 meter geen invloed te hebben op het totale nut van het laadplein. Als de loopafstanden toenemen, neemt het nut van een openbare laadplek af, terwijl kortere afstanden het totale nut van een openbare laadplek vergroten (alle overige gelijk). Deze twee belangrijkste gebruikersaspecten worden gevolgd door het verplaatsen van het elektrische voertuig zodra de batterij volledig is opgeladen en laadzekerheid. Alleen als de elektrische auto niet verplaatst hoeft te worden, is er sprake van een positief deel nut. Hoe lager de laadzekerheid op een bepaalde locatie, hoe kleiner de kans dat een bestuurder van een elektrische auto voor die locatie kiest.

De overige twee attributen, toezicht op de laadlocatie en de alternatieve functie voor parkeren, lijken de locatiebeslissing niet te beïnvloeden aangezien deze deel nutten bijna nul zijn. Hoewel de resultaten slechts een beperkte invloed op de locatiebeslissing laten zien, laten de resultaten zien dat locaties met cameratoezicht de voorkeur hebben (alle overige gelijk). Van de verschillende niveaus die voor dit attribuut zijn opgenomen, wordt cameratoezicht beschouwd als het hoogste niveau van toezicht, aangezien cameratoezicht het laadplein 24/7 kan bewaken. Dit is in lijn met het literatuuronderzoek waaruit blijkt dat gebruikers niet bereid zijn gebruik te maken van onveilige laadpleinen. Omdat door het realiseren van een laadplein geclusterd parkeren voor elektrische voertuigen ontstaat, kan een deel van de bestaande parkeerplaatsen in de straat een nieuwe bestemming krijgen. Uit de resultaten van dit afstudeerverslag blijkt dat de respondenten de voorkeur geven aan meer groen in hun buurt als bestaande parkeerplaatsen een nieuwe bestemming krijgen.

Naast het Multinomial Logit-model werd een Latent Class-model geschat om te controleren op het bestaan van verschillende clusters (of klassen) van respondenten in de dataset. Gegeven een bepaald aantal klassen, werd Nlogit gebruikt om de respondenten in klassen te clusteren en de parameterwaarden (van een Multinomial Logit-model) voor de respondenten in elke klasse te schatten. Van de geschatte Latent Class-modellen presteerde het model dat uit twee verschillende klassen bestond en geen persoonskenmerken bevatte, het beste volgens de Bayesiaanse informatiecriteriumwaarde. Aangezien er geen persoonskenmerken zijn opgenomen in het uiteindelijke Latent Class-model, was het niet mogelijk om te identificeren waardoor een respondent tot een van de gecreëerde klassen behoort. De reden voor het uitsluiten van de verschillende persoonskenmerken was dat het Latent Class-model aantoonde dat alle persoonskenmerken met uitzondering van de constante insignificant waren op het 10%-niveau. Klasse één bevat 86% van alle respondenten, terwijl klasse twee de resterende 14% van de respondenten bevat. Aangezien klasse twee een relatief kleine klasse is in vergelijking met klasse één, is het mogelijk dat dit de statistische insignificantie van de resultaten van de persoonskenmerken heeft veroorzaakt. Bovendien waren bijna alle Multinomial Logit-modelparameterwaarden geschat door het Latent Class-model voor klasse twee insignificant, waarschijnlijk als gevolg van de kleine klasse, terwijl in klasse één de resultaten vergelijkbaar waren met het Multinomial Logit-model.

Als laatste deel van dit afstudeerverslag werd de praktische toepasbaarheid van de resultaten getoond. Aangezien de resultaten van het Latent Class-model voornamelijk insignificant waren voor de tweede klasse en de resultaten van de eerste klasse in overeenstemming waren met de schattingen van het Multinomial Logit-model, is de praktische toepasbaarheid getoond op basis van de resultaten van het uiteindelijke Multinomial Logit-model. Uit de toepasbaarheid bleek dat de gepresenteerde resultaten inderdaad in staat zijn om de kans op een keuze tussen twee openbare laadpleinen te bepalen. Om de praktische toepasbaarheid te laten zien, zijn er echter verschillende aannames gedaan die kunnen afwijken van de werkelijkheid. Uiteindelijk was het de bedoeling om aan te tonen dat de resultaten van dit afstudeerverslag een praktische toepassing opleveren, wat ook het geval is. Daarom kunnen de gepresenteerde resultaten van dit afstudeerverslag worden gebruikt in een ontwerptool om de kans te bepalen dat een bewoner tussen twee openbare laadpleinen kiest als er potentiële locaties zijn geïdentificeerd. Daarnaast kunnen de resultaten van dit afstudeerverslag worden gebruikt als stedenbouwkundigen beslissingen moeten nemen over hoe ze de kans op de keuze van een laadplein kunnen vergroten.

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Abstract

With policies restricting the sales of fossil-fuel vehicles, more electric vehicles are going to be sold on the Dutch car market. In urban environments, electric vehicles will need a place to charge and since fewer residents in urban environments have the possibility to charge on private property, more electric vehicle drivers are in need of a public charging location. An efficient way to provide public charging in urban residential environments is through public charging squares. In order to evaluate different locations for charging squares, it is key to know which user preferences are most important to be included in a tool that evaluates the different locations. Therefore, this study provides new information related to user preferences when deciding on a location to charge an electric vehicle.

In order to identify user preferences, a stated choice experiment has been used to determine the most important user preferences when deciding on a location to charge an electric vehicle in urban environments. In order to determine the most important aspects when deciding on a public charging location, the results of the stated choice experiment are analyzed using a Multinomial Logit model. Additionally, a Latent Class model is estimated in order to check for the existence of different clusters of respondents given a preset number of classes. The main findings presented in this thesis show that when deciding which public charging location to use in an urban environment, cost have the largest impact on the location decision according to the respondents participating in this study. Other significant aspects which influence the location decision are walking distance, charge certainty and not having to relocate the electric vehicle once the battery is completely charged.

Key words: electric vehicle, charging square, discrete choice experiment, parking, public charging

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Contents

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List of definitions

Concept	Definition
Charging square	A charging square consist of multiple charging points (each with one or more charging ports) with a shared grid connection located at a single location which is publicly accessible.
Charging point	A charging point is one electrical connection that delivers the electric energy for one electric vehicle.
Free-floating parking	Free floating parking refers to a fleet of vehicles that have no predefined pick-up or drop-off locations. The vehicles are parked on available parking spots around a certain area (Car Rental Gateway, 2022; Renault Group, 2019).
Parking spot	A spot reserved for the parking of one motor vehicle (Law Insider, 2023).
Charging location	The location (of a charging square) where electric vehicles can recharge their battery which is publicly accessible.

List of abbreviations

AC – Alternating currents

BIC – Bayesian Information Criterion

CBS – Centraal bureau voor de statistiek / Statistics Netherlands

DC – Direct currents

ISO - International Standardization Organization

km^2 - square kilometer

kW - kilowatts

LC – Latent Class

MNL – Multinomial Logit model

NEN – “Nederlandse Norm” (*Dutch standard*)

List of figures

List of tables

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1. Introduction

The demand for public charging locations for electric vehicles will increase in the future due to several factors. The first section of this introduction will describe the background that causes the increase in demand for public chargers. In the second section, a detailed description of the problem definition for this thesis will be given based on the context of section one. The research question is defined in section three. After defining the research question, the relevance and research design will be described. Finally, the introduction will be concluded with a reading guide.

1.1. Background

The European Commission (2021) states that an average CO_2 reduction of 100% must be achieved for all new vehicles sold after 2035. In the Netherlands, new fossil-fuel vehicles are no longer allowed to be sold from 2030 onwards (Netherlands Enterprise Agency, 2022a). In addition, new legislation is being prepared so that business lease drivers are only allowed to choose a new full-electric vehicle as of 2025 (BNR, 2022).

At the start of 2022, there were 725.6 thousand (partially) electric vehicles on the road in the Netherlands (CBS, 2022a). Research by the Netherlands Enterprise Agency (2017) and PwC (2021) concluded that the Netherlands will have 1.9 million electric vehicles in 2030. Additionally, all new vehicles added to the vehicle pool each year will be electric after 2030. In the study of PwC (2021), this number was estimated to be 400,000 new electric vehicles each year. To put this in context, the sales of new vehicles fluctuated around 430,000 per year in the past decades (Netherlands Enterprise Agency & Revnext, 2021). Therefore, the number of electric vehicles in the Netherlands will increase in the future and an adequate location to charge is needed just like the 4,147 publicly available gas stations where fossil-fuel vehicles currently can fuel up (Stichting BOVAG-RAI Mobiliteit, 2021).

Another reason why there will be an increase in electric vehicles in the Netherlands is because acquiring a parking permit has become more difficult for drivers of fossil-fuel vehicles (Gemeente Amsterdam, 2022). In addition, social pressure as well as awareness of climate change results in people switching to electric vehicles. Next to the policies of the European Union and the Dutch national government, the power grid in the Netherlands is reaching its maximum capacity (Netbeheer Nederland, 2022). This means that it is not possible to automatically acquire a new connection to the grid (Netbeheer Nederland, 2022), making it impossible to locate a charging point near every existing parking spot.

1.1.1. Public versus private chargers

The current users of electrified mobility mainly charge near their residence or at their work (González et al., 2014; Netherlands Enterprise Agency, Vereniging Elektrische Rijders, & ElaadNL, 2021b). Quee (2022) and Kleine Schaars (2022)[1] expect that in the upcoming years charging will shift from private to public charging. These expectations are confirmed by the results of the "Nationaal Laadonderzoek 2022" which shows that in 2022 more people used a public charger compared to the previous year (Netherlands Enterprise Agency, Vereniging Elektrische Rijders, & ElaadNL, 2022). A shift towards public charging is expected since a larger share of the charging demand will be in neighborhoods where electric vehicle owners cannot charge on private property (Quee, 2022). Next to that, on average seven out of ten Dutch households currently rely on public parking (Ministry of Infastructure and Water Management, 2019). As a result, if more people who rely on public parking adopt the electric vehicle, the demand for public chargers in the Netherlands will increase as well in the future.

Based on Anderson, Lehne, & Hardinghaus (2018), a major challenge for electric vehicles remains the need for adequate public charging infrastructure in terms of connections and spaces. 49% of the respondents in the study of Wilman (2022) indicated that more charging locations and higher availability would increase the adoption rates of electric vehicles. In order to supply in future demand for charging in the Netherlands, the number of charging points needs to be tripled by 2025 and must be eight-folded by 2030 (Netherlands Enterprise Agency, 2022a).

[1] Personal communication, October 18th, 2022

1.1.2. Future possession of electric vehicles

Figure 1 shows the expected number of electric vehicles per municipality in 2030 and 2050 (ElaadNL, 2021). Based on this figure, it can be concluded that a major share of electric vehicles will be in urban environments which is in line with the distribution of the Dutch population. Since the largest number of electric vehicles will be in urban environments, and the number of charging points needs to be eight-folded by 2030, the largest demand for (new) public charging locations will be in urban environments.

Not only private transportation but also shared mobility will become more electrified. According to the Netherlands Institute for Transportation Policy Analysis (2021), most users of shared mobility are living in urban environments and shared mobility will therefore also use public charging facilities since shared mobility uses the concept of free-floating parking. By using a free-floating parking concept, drivers can park the vehicle anywhere in the operating area of the shared mobility provider. Several shared mobility providers indicated that their vehicle pool will be completely electrified within the next five years (Greenwheels, 2022; Rombout, 2022[2]; SHARE NOW, 2022[3]). The contacted shared mobility providers had a combined market share of 17% at the end of 2021 (the total number of shared cars in 2021 was equal to 87,825 (Over Morgen, 2022)).

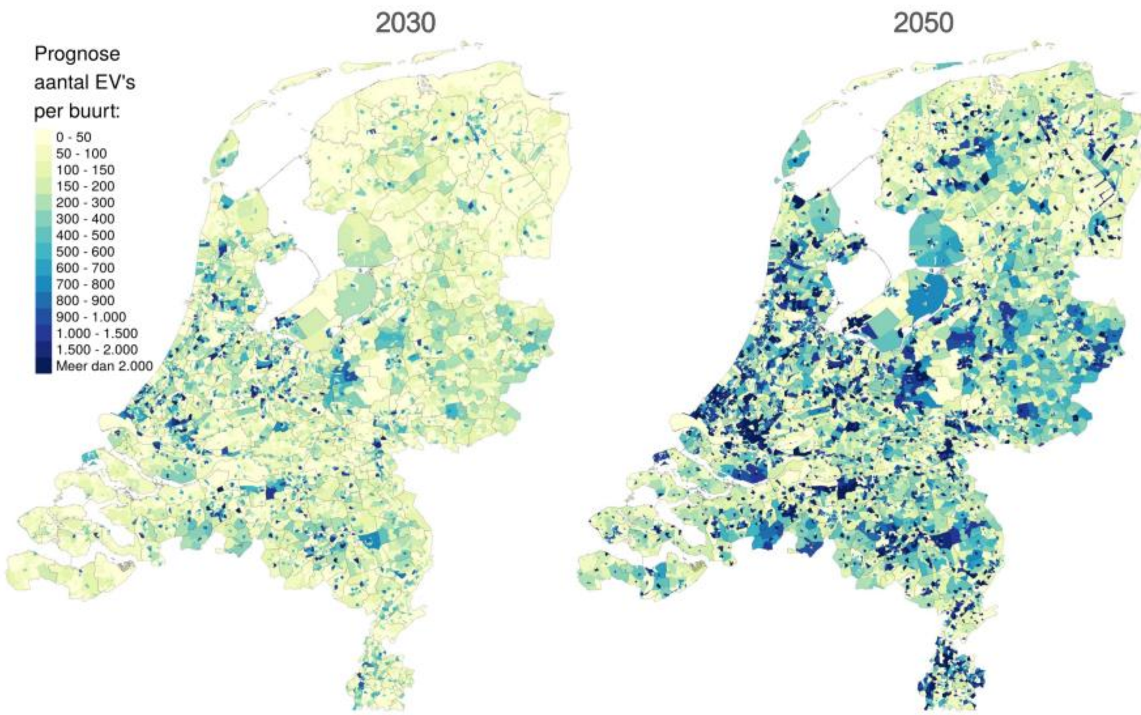

Figure 1. Expected number of electric vehicles per municipality in 2030 and 2050 (ElaadNL, 2021)

1.1.3. Demand locations for public charging in urban environments

The locations in urban environments where people can charge are grouped into roughly three categories: near their work, near their residence and near destinations which are visited (ElaadNL, 2021).

As of 2020, it is required for new construction of businesses to have at least one charging point if there are over ten parking spaces (ANWB, 2022c; Elix, 2022; Ondernemersplein KvK, 2022). Additionally, one in five parking spaces needs to be prepared for charging an electric vehicle (Netherlands Enterprise Agency, 2019a). For existing businesses, the legislation states that there should be at least one charging point from 2025 onwards (ANWB, 2022c; Elix, 2022; Ondernemersplein KvK, 2022).

[2] E-mail, September 22nd, 2022
[3] E-mail, September 21st, 2022

For retail, customers are increasingly shopping online and, in the future, more and more people are going to shop online (ABN AMRO, 2021; CBS, 2019; Retail insiders, n.d.; Roest, 2021). However, for some retailers, online shopping is only a very little percentage of the total sales. For example, the total online sales of grocery shopping are 5.4% (Supermarkt & Ruimte, 2022) while for IT, 71% of the total sales is online (Retail insiders, 2022). According to the Centraal Bureau Levensmiddelenhandel (2022), people spend on average 26 minutes in a grocery store per visit. Therefore, in order to significantly charge an electric vehicle when grocery shopping, fast chargers are needed. Fast chargers will be common near retail locations in the future (Gilleran et al., 2021), however, these fast chargers will have a larger impact on the electricity grid compared to slow chargers (Chau, 2014). Due to the electricity grid reaching its maximum capacity and the need for fast chargers near retail locations due to the short visiting time, retail is not considered in this thesis.

In residential areas, a lot of space is publicly owned and therefore there are more possibilities to locate public chargers in residential areas. Residential areas can be subdivided into new construction and the existing built environment. In new construction, public charging facilities can be incorporated from the start while in the existing built environment, there are more limitations when incorporating public charging facilities. Currently, 42% of the driven kilometers are charged at home while only 13% is charged near the office (Netherlands Enterprise Agency et al., 2022). Additionally, people are working more from home and will do even more so in the future, resulting in the electric vehicle being charged more near the residence (Accountant, 2022; Netherlands Bureau for Economic Policy Analysis, 2021; Netherlands Institute for Transportation Policy Analysis, 2022). Moreover, 88.5% of all vehicles in the Netherlands is privately owned (CBS, 2022b) and if all these vehicles become electric vehicles in the future, more public charging facilities are needed near the residences.

1.2. Problem definition

The Netherlands will see an increase in population and income, resulting in increasing car ownership (Hilbers et al., 2020; Netherlands Environmental Assessment Agency, 2022). Due to legislation, the increasing car ownership will, in the future, result in more electric vehicles, and therefore more chargers are needed in the Netherlands. Many of these chargers will need to be publicly available due to the shift from private to public charging (Netherlands Enterprise Agency et al., 2022). Additionally, more public charging locations are needed for higher adoption rates of electric vehicles in urban residential environments (Anderson et al., 2018; Wilman, 2022). The need for adequate public charging locations is therefore the problem that will be addressed in this thesis. If there are not enough public charging locations available or located where users are not willing to charge, the adoption of the electric vehicle will slow down.

The focus is on urban residential environments since public chargers should be located where electric vehicles are highly concentrated and parked for longer periods of time (U.S. Department of Energy, 2022). Since the reliance on on-street parking is the highest in urban residential areas, the need for public chargers will here also be the highest.

As more electric vehicles are adopted, the electricity demand will increase, resulting in more stress on the electricity grid. Since the electricity grid is reaching its maximum capacity, smart solutions have to be adopted to offer all electric vehicle users charging solutions without exceeding the maximum capacity of the grid. One of the possible solutions is a charging square (NKL Nederland, 2021a). A charging square has multiple benefits compared to individual charging points, like lower impact on the grid, future proof, easier to find, lower overall costs, and easier to install and maintain (De Croon, 2022[4]; NKL Nederland, 2021a). Additionally, smart charging techniques can be implemented at lower costs compared to individual charging points.

The core of the problem for public chargers is that there will be a need for space to charge electric vehicles in the future. This space needs to be located where users are willing to use it since investors

[4] Personal communication, October 20th, 2022

only want to invest in profitable business cases. Therefore, the problem statement will be approached from a user's perspective since users will have to accept the charging locations.

The aim is to provide information about the user preferences for charging locations to improve and optimize the location of public charging squares so that users will be satisfied with the locations and are more likely to choose the public charging square. This thesis will determine important user aspects to determine suitable public charging square locations, in order to increase electric vehicle adoption rates and meet climate goals. Using the results, decision-makers are more likely to select sites that are in line with user demands.

1.2.1. How long will this problem exist?

This section examines the different developments and their influence on the demand for charging locations.

New charging techniques are being developed in order to enable electric vehicles to charge their battery in ten minutes up to 90% when the battery is almost empty (American Chemical Society, 2022). However, fast charging can result in higher battery degradation if used constantly (Al-Saadi, Olmos, Saez-de-Ibarra, Van Mierlo, & Berecibar, 2022; Mathieu, Briat, Gyan, & Vinassa, 2021; Tom, 2022). Constantly fast charging a battery can reduce the lifespan of the battery by a factor of three (ae-electronics, 2022). In the future, this reduction of battery lifespan might be more limited due to battery developments. In addition, fast charging has a larger impact on the electricity grid compared to slow charging due to the higher power and therefore also needs a transformer (NKL Nederland, 2020b). A transformer has some negative side-effects like its costs, the level of sound production and the magnetic field which are not preferred in residential environments (GGD leefomgeving, 2022a). Therefore, in the future, there will still be a need for slow chargers.

Another development is wireless charging which uses a magnetic field to charge the battery of an electric vehicle (Amjad, Farooq-i-Azam, Ni, Dong, & Ansari, 2022; ElaadNL, 2022a; Lanova, 2022; Mude, 2018). However, for wireless charging the receiver and transmitter need to be aligned properly (Ching & Wong, 2013; Mude, 2018). Not properly aligning the receiver and transmitter can result in a power loss of up to 25% (Lanova, 2023). Additionally, the current electric vehicle pool does not support wireless charging while these electric vehicles can be expected to be on the road for several years. Therefore, this technique needs further development before it can be implemented on a large scale.

The battery is not only the largest, heaviest and most expensive component of the electric vehicle (ANWB, 2022b), but also a key component since it influences the range and charging time of the electric vehicle. The current batteries for electric vehicles are Lithium-ion batteries (ANWB, 2022b) and result in an average range of 425 kilometers for a large electric vehicle, 310 kilometers for a middle-class electric vehicle and 230 kilometers for a small electric vehicle (Milieu centraal, 2022a). Since, on average, a car drives 35 kilometers a day and only a few cars drive more than 100 kilometers on a regular daily basis (ElaadNL, 2022b), the current electric vehicles can provide the range for the daily commutes of most users. As new innovations will increase the range with the same battery size in the future, it will not be needed to charge an electric vehicle daily.

The advantage of a hydrogen powered vehicle is that refueling will be just like the current fossil-fuel vehicle (Hordijk, 2021; Shell, 2020). However, only a limited number (fifty) of refueling stations will be available in the Netherlands in 2025 (H2Platform, 2018; Rijkswaterstaat, 2022; Shell, 2020). Next to that, the production of hydrogen uses a lot of energy (Hordijk, 2021; Nauta, 2021).

If autonomous vehicles become the standard, it is not needed to have a parking location in the direct vicinity of the user since all vehicles can drive autonomously to remote charging sites. Currently, vehicles can drive autonomously under controlled circumstances, however, driving autonomously in cities is only expected to be realized in 2040 at the earliest (Hilbers et al., 2020; Hogeveen, Steinbuch, Verbong, & Hoekstra, 2021).

Shared mobility and Mobility as a Service can reduce overall car ownership in the Netherlands (Hilbers et al., 2020). However, car ownership is more likely to increase than decrease up to 2040 (Ministry of

Infrastructure and Water Management, 2021; Netherlands Environmental Assessment Agency & Netherlands Bureau for Economic Policy Analysis, 2020). It has to be noted however that there is a small decline in young people owning a vehicle (CBS, 2020; Netherlands Environmental Assessment Agency, 2016). But, even if shared mobility increases, there will still be a need for public charging points due to free-floating parking.

Concluding the mentioned developments, also in the near future there will be a need for places where electric vehicles can stay for a longer duration in order to charge the battery at a slower pace. Consequently, suitable locations need to be found to provide charging for electric vehicles in the future.

1.2.2. What are the consequences if the problem is not solved?

Not providing enough public charging locations in the future will have several consequences. First, the goal of the European Union to have a net-zero emission of greenhouse gasses in 2050 will be harder to achieve (European Commission, 2011). To reduce greenhouse gas emissions, the use of electric vehicles on a large scale is crucial according to Anderson et al. (2018), González et al. (2014), Lopez-Behar et al. (2019) and Pan, Tian, Tang, & Yang (2019). In order to increase adoption rates, Wilman (2022) states that more charging locations and higher availability of charging locations are needed.

Air pollution in the Netherlands has been reduced considerably in the last decades and by using electric vehicles, which do not emit any pollutants, air pollution can be reduced even further (GGD leefomgeving, 2022b). Another major benefit of using electric vehicles compared to traditional fossil-fuel vehicles is that an electric vehicle battery only uses 30kg of raw materials (taking recycling into account), while a fossil-fuel vehicle uses 17,000 liters of fuel during its lifespan (European Federation for Transport and Environment, 2021).

Other important benefits of electric vehicles are the lower emissions of CO_2 (up to 40%) and no emission of nitrogen dioxide (Netherlands Enterprise Agency, 2022b). Due to the higher weight of electric vehicles, the emission of non-exhaust particulate matter is higher but overall, the OECD (2020) states that the relative particulate matter emissions are lower compared to the internal combustion engine. Consequently, the electric vehicle will contribute to a better public health.

Finally, many cities worldwide are embracing electric vehicles as a way to create more sustainable transportation fleets in their city (He, Ma, Qi, & Wang, 2020). Moreover, cities are also seeing electric vehicles as a major contributor to creating smart cities as well as reducing the emissions and pollutants in the city. According to He et al. (2020), stricter environmental regulations on emissions boost vehicle electrification and the phasing out of fossil-fuel vehicles.

1.2.3. What is an efficient way to provide charging?

As already briefly mentioned, an efficient way to provide public charging in urban residential environments is through charging squares. In this thesis, a charging square is defined as follows: "*A charging square consist of multiple charging points (each with one or more charging ports) with a shared grid connection located at a single location which is publicly accessible*". In the literature review (chapter 2), a more detailed elaboration on this definition is given.

A charging square has several benefits compared to individual charging points, like lower impact on the electricity grid, easier to find, lower overall costs, easier to install and maintain and future proof (De Croon, 2022[5]; NKL Nederland, 2021a). If public chargers are grouped in one location, implementing new techniques will be more cost-effective. Techniques that can be implemented are load balancing, Vehicle-to-Grid, or a microgrid for example. Furthermore, by grouping public chargers and implementing new techniques, fewer connections are needed and the impact on the grid can be reduced.

For a resident of an urban environment, the benefits of a charging square will result in a lower search time for an available charger since charging squares are easier to find. Additionally, since charging squares are future proof, charging squares can easily be expanded when demand increases over time. Another benefit for the user of a charging square is that the charge certainty will be higher since smart

[5] Personal communication, October 20th, 2022

charging techniques can be implemented. Additionally, by grouping public chargers together electric vehicle drivers will be more confident in finding a suitable charging spot, increasing the adoption of electric vehicles.

1.3. Research question

In order to make a well-informed decision for the location of a charging square, it is needed to know what attracts users to a certain location. Therefore, in this thesis the main research question will be:

“Which user preferences are most important to be included in a tool that evaluates locations for charging squares in metropolitan areas?”

In order to be able to answer the main research question, the following sub-questions have been identified:

- Which stakeholders are involved in charging locations and what are their interests?
- Which built environment aspects influence the location of a charging square?
- Which user aspects influence the choice for a charging location?

1.4. Relevance

As the problem definition indicated, the Netherlands will see an increase in public charging locations in order to keep up with the growth of electric vehicles in urban residential environments. To provide suitable public charging locations, knowing the user preferences is key. Since this study tries to identify important user aspects related to charging an electric vehicle, this thesis will contribute to the academic knowledge about user preferences for public charging locations.

Existing studies have identified important parking choice attributes but have not considered them in relation to charging an electric vehicle. The studies that did identify both parking and charging attributes, did not analyze them collectively. By combining the different aspects, trade-offs have to be made when deciding on a location for charging. By using the intended approach (section 1.5), more insights will be provided on the identified problem.

Next to the scientific contribution, there will also be a societal contribution. By considering the user preferences for public charging locations from the start of the development, the decision-process on this topic can be improved, reducing the effort needed to create suitable locations and costs can be reduced. By improving the decision-process, fewer societal resources will be needed during the decision-making process and the saved resources can now be allocated elsewhere in society. Another societal benefit of this thesis is that future policies can be based on this thesis’s results and help underpin the decisions made. Therefore, the knowledge that is obtained in this thesis, can be used in future studies related to charging electric vehicles, as well as by public decision-makers.

Additionally, if electric vehicle adoption is halted, through for example not providing enough public charging locations, achieving the set climate goals will be hard. In order to meet the climate goals, the adoption of electric vehicles is key and in order to adopt the electric vehicle, more public charging locations are needed (Anderson et al., 2018; Wilman, 2022).

1.5. Research design

This sub-section will describe the approach that will be used in this thesis to get to the final output. Figure 2 shows the main steps that will be taken during this study.

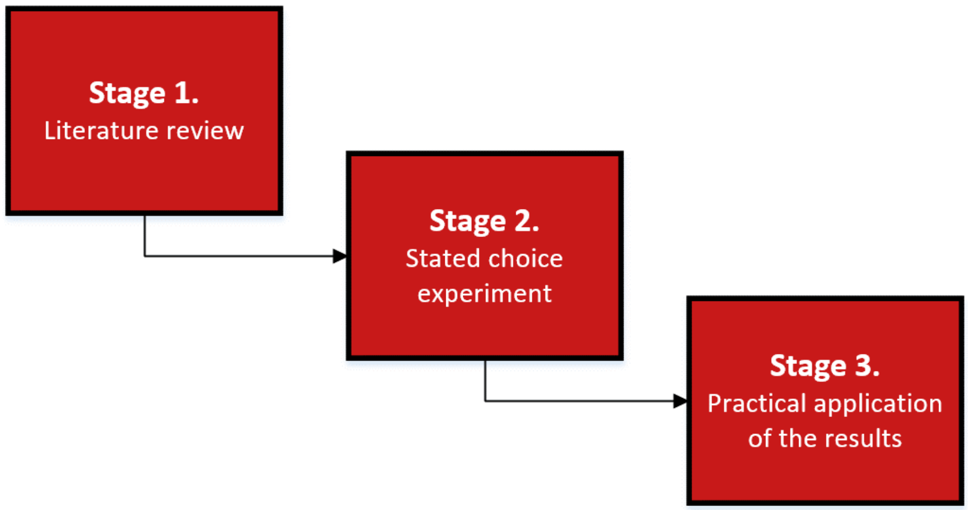

Figure 2. Research approach

1.5.1. Literature review

The first step in this thesis is a literature review. During the literature review, the existing literature related to this topic will be reviewed. After the literature review, sub-question one can be answered and important items for sub-questions two and three can be identified. Additionally, the extended literature review will provide the needed theoretical substantiation that is needed throughout this thesis.

1.5.2. Stated choice experiment

After the literature review, a stated choice experiment will be set up to capture the user preferences that impact the location choice. The literature review will reveal potential important aspects related to publicly charging electric vehicles which will have an influence on the electric vehicle driver choosing between charging locations. The results of the literature review are used to create the choice alternatives in the stated choice experiment. In the stated choice experiment, trade-offs have to be made by the respondents between the different attributes and their corresponding level included in the choice alternatives. Additionally, during the stated choice experiment, unproven techniques/aspects that are not yet considered in the literature but are expected to have an effect on the choice for a public charging location can be tested (Brown, 2003; Hensher, 1993).

1.5.3. Practical application of the results

After the stated choice experiment has been conducted, the practical application of the results will be shown by determining the demand for public chargers at potential public charging squares in a predefined region. The practical application of the results will show that a tool is able to help deciding on the locations for public charging squares as well as determining the probability that a location is chosen by residents. Additionally, by showing the practical application of the results, the procedure to tackle the allocation problem will be shown.

1.6. Reading guide

The remainder of this thesis is structured as follows. The next chapter, chapter two, will describe what is currently published in the literature. Chapter three will focus on the methodology that is going to be used in this thesis and chapter four will present the results of the stated choice experiment and analysis performed. Chapter five will show the practical application of the results presented in chapter four. Finally, this thesis will be concluded with a discussion and conclusion including recommendations for future studies (chapter six).

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2. Literature study

In this literature study, a closer look will be taken at the existing literature related to the subject of this thesis. The purpose of this literature review is to analyze the existing knowledge related to public charging as well as public parking. Furthermore, the literature review will help to include relevant attributes in the stated choice experiment. Additionally, if any assumptions need to be made during this study, the literature review will provide a theoretical substantiation.

The literature review will be build-up in the same order as the sub-questions that have been identified in chapter one. The topics that will be addressed in this literature review are an analysis of the current charging infrastructure in the Netherlands (section 2.1) followed by a definition of charging squares (section 2.2). The third part of this literature review is about the user preferences for parking (section 2.3) followed by the build environment aspects that influence the choice for a suitable charging location (section 2.4). After section 2.4, the stakeholders involved in the location decision process will be elaborated (section 2.5). Next, a look will be taken at the current policy for allocating a public charging point (section 2.6). The literature review will be concluded with a conclusion that summarizes all findings.

2.1. Current charging infrastructure

In order to meet future demand for charging, the Netherlands Enterprise Agency (2019b) estimates that 1.7 million charging points are needed in 2030. The current public charging infrastructure in the Netherlands is already well developed since **the Netherlands has one of the highest charging densities in the European Union** (Netherlands Enterprise Agency, 2022d). In the Netherlands there are 699 public chargers per 100,000 inhabitants while the European average is 73 per 100,000 inhabitants (Eckardt, 2022). In October 2022, the Netherlands had 108,908 publicly available charging points of which 3,157 fast-charging points (Netherlands Enterprise Agency, 2022c). However, in order to have 1.7 million chargers in 2030, many more public chargers need to be installed. The total number of electric and hybrid vehicles in October 2022 in the Netherlands was equal to 978,087 (Netherlands Enterprise Agency, 2022c) which means that one publicly available charging point has to be shared by nine electric vehicles. However, it has to be noted that there are also private charging points in the Netherlands (around 327,000 (Netherlands Enterprise Agency, 2022c)) and therefore the total number of electric vehicles that have to share a public charging point will in reality be lower.

The time it will take to charge an electric vehicle depends on both the maximum speed that the battery of the vehicle is able to charge as well as the capacity of the charger (Hampton, Schwanen, & Doody, 2019). In the Netherlands there are **two types of charging points**, those for charging at a slow rate and charging points for fast charging an electric vehicle (EV-database, 2022). The difference between slow chargers and fast chargers is the capacity and the electric current used to charge. Slow chargers use alternating currents (AC), while fast chargers use direct currents (DC). When charging with AC currents, the AC/DC converter in the electric vehicle converts the AC current of the charger into DC current stored in the battery. A fast charger already charges with DC current and therefore, the AC/DC converter in the car can be bypassed (evcompany, 2022). By bypassing the AC/DC converter, it is possible to reach higher charging capacities when using fast chargers since the converter in the car has a maximum capacity. Table 1 below gives more detailed information regarding the main charging types (European Environment Agency, 2016).

Table 1. Overview of charging types (European Environment Agency, 2016)

Type	Current	Capacity	Charging time	Accessibility
Slow charging	AC - single phase	3.7 kW	6-8 hours	Private
		7.4 kW	3-4 hours	Public and private
	AC - three phase	11 kW	2-3 hours	
		22 kW	1-2 hours	
Fast charging	DC	50 kW	20-30 minutes	Public
		>120 kW	10 minutes	

The **most common charging point in the Netherlands is the slow charging point**, with a capacity of up to 22 kilowatts (kW) (EV-database, 2022). As can be noted in table 1, fast chargers have a much higher capacity than slow chargers. Older models have a capacity of 50 kW while the new, more modern fast chargers can reach capacities between 150 - 350 kW (EV-database, 2022). The study of Anderson et al. (2018) allowed respondents to specify the characteristics for public charging stations and the respondents showed a clear preference for charging points with a capacity of 22 kW AC.

Considering the current **distribution of publicly available charging points**, the province of Zuid-Holland has the largest number of charging points and the province of Drenthe the smallest (Netherlands Enterprise Agency, 2019b; Netherlands Enterprise Agency et al., 2021b). Since the largest share of electric vehicle owners currently lives in Zuid-Holland and the fewest in Drenthe, this distribution is logical. Next to that, in Zuid-Holland there are fewer locations to charge on private property and therefore, the share of publicly available charging points is higher.

The charging infrastructure in the Netherlands is not managed by only one organization (NKL Nederland, 2020a). Energy companies, local governments as well as charging network operators are managing the charging infrastructure in the Netherlands (Buck Consultants International et al., 2019; NKL Nederland, 2021c). These different organizations cooperate to provide an adequate distribution of charging points that covers the whole Netherlands, make sure that the charging network is well maintained and meets the growing demand for charging. Examples of some of the largest charging network operators in the Netherlands are Fastned, Allego, and Shell recharge.

In order to be able to use the public charging infrastructure in the Netherlands, the owner of the electric vehicle needs to scan/use a so-called charging card ("laadpas" in Dutch) or initiate the charging session through the operator's website or app (ANWB, 2022a; Milieu centraal, 2023). In the Netherlands, it is possible to charge an electric vehicle at any public charging point using any type of charging card, however, every supplier of a charging card has its own terms & conditions and prices (EVkenniscentrum, 2023). **On average, the Dutch electric vehicle owner therefore has 2.55 charging cards** to be able to initiate and pay for a charging session (Netherlands Enterprise Agency et al., 2021b). By having multiple cards, the electric vehicle owner can choose for the lowest price each time a charging session is initiated.

2.2. Definition of a charging square

In order to create a clear understanding of what is meant by a charging square in this thesis, this section will provide a more detailed description.

After having reviewed multiple literature resources, the current definition of a charging square is defined as "*A charging square consist of more than two charging points for electric vehicles with a shared grid connection at public parking facilities*" (Netherlands Enterprise Agency, 2021; NKL Nederland, 2019, 2021b; Overheid.nl, 2021). A charging point, as mentioned in the definition, can be equipped with one or more charging ports to connect the electric vehicle to a charging point.

The theoretical definition of a charging square is given above, however, theory and practice might not be the same. After consulting several experts, it became evident that when talking about a charging square in practice, a charging square is defined as "*A charging square consist of eight to ten/twelve charging points (each with one or more charging ports), with a shared grid connection at a public parking facility*" (Berg, 2022[6]; Hoekzema, 2022[7]; Van Der Kraan, 2022[8]).

Based on both the theoretical as well as practical definition, a charging square in this thesis is defined as "*A charging square consist of multiple charging points (each with one or more charging ports) with a shared grid connection located at a single location which is publicly accessible"*. A charging point can either be a slow charging point or a fast-charging point.

Benefits of a charging square compared to individual charging points are that charging squares are easier to find, have a lower impact on the electricity grid since new techniques can be implemented, and charging squares are future proof since additional charging points can be added once the demand increases over time.

2.3. User preferences in residential areas

According to Yan & Ma (2016) electric vehicle charging points can be considered a public service facility and therefore, convenience for the user is important. In order to create convenience for the user, knowing their preferences is key. As mentioned in the introduction, public chargers need to be located on a location where users are willing to use them. Since current knowledge to support the location decision for a public charging square in urban residential environments is lacking, the existing literature has been reviewed on parking behavior and preferences in general. This is because part of the problem that has been identified in this thesis is related to finding a suitable parking location in urban residential environments. Looking for a public charging location could be considered as looking for a public parking facility including a public charger. Therefore, the literature is reviewed on parking preferences, since this thesis is aimed at finding user preferences of electric vehicle drivers when deciding on a public charging location. If it is known what users take into consideration when looking for a public parking facility, this can be taken into account when making a decision for realizing a new public charging square at a certain location.

2.3.1. Costs

The studies of Chakraborty, Bunch, Lee, & Tal (2019), Chaniotakis & Pel (2015), Golias, Yannis, & Harvatis (2002), Hassine, Mraihi, Lachiheb, & Kooli (2022), Hilvert, Toledo, & Bekhor (2012), Ibeas, dell'Olio, Bordagaray, & Ortúzar (2014), Kobus, Gutiérrez-i-Puigarnau, Rietveld, & Van Ommeren (2012) and Litman & Burwell (2006) showed that when deciding on a location to park, cost is the most important aspect considered. In the city center of the four largest metropolitan areas of the Netherlands, the parking costs result in a price elasticity of -0.7 for household car ownership (Ostermeijer, Koster, & van Ommeren, 2019). Not only in city centers does parking fee influence the number of parked cars, also in the suburbs results an increase in parking fees in a reduction of parked cars according to Nissan, Ntriankos, Eliasson, Näsman, & Börjesson (2020) who studied how the introduction of parking fees impacts parking demand in the suburbs of Stockholm.

For electric vehicles, the costs are not only related to the parking fee. The cost of charging also impacts the location choice (Chakraborty et al., 2019; Hampton et al., 2019). The majority of car users only want to pay for the charged kWh and do not want to pay any basic subscription fee in order to be allowed to use public charging infrastructure (Globisch, Plötz, Dütschke, & Wietschel, 2018). Costs are

[6] E-mail, September 29th, 2022
[7] E-mail, October 3rd, 2022
[8] E-mail, October 4th, 2022

therefore an important tool to regulate the demand for parking (Netherlands Institute for Transportation Policy Analysis, 2018).

2.3.2. Availability

According to Chaniotakis & Pel (2015), Hassine, Mraihi, & Kooli (2019) and Litman & Burwell (2006), availability is another important aspect related to finding a suitable parking location. Availability is related to the number of spots that are present at the location and the number of vehicles served by that location. The public charging location should therefore offer enough charging points for multiple electric vehicles to be charged at the same time since the literature showed that both men and women are reluctant to move their electric vehicle when their battery is completely charged (Philipsen, Schmidt, Van Heek, & Ziefle, 2016). If there are not enough parking facilities in an area, car drivers will look for an available parking spot in the nearest area (Al-Fouzan, 2012). This will than reduce the availability in that area since the additional demand was not considered when determining the number of spots.

2.3.3. Search time

Search time is another important consideration related to finding a suitable parking location (Golias et al., 2002; Hassine et al., 2022; Hassine et al., 2019; Ibeas et al., 2014). Search time is the amount of time a driver needs in order to find a vacant parking spot, therefore, search time can be related to availability (Brooke, Ison, & Quddus, 2014). Drivers are, on average, willing to search for eight minutes before going to the next parking location (Chaniotakis & Pel, 2015). Anderson et al. (2018) state that charging infrastructure should be provided at destinations which are often visited by the users of electric vehicles, such as the residence for example, in order to prevent the need to make significant detours.

Currently, users of electric vehicles do not expect public charging points to meet their daily charging needs since users want to have additional charging backup (Anderson et al., 2018). A possible explanation for this is that the majority of the current electric vehicle drives are able to charge at home and therefore do not need to use public charging points on a regular basis. However, they are still reluctant to make significant detours (Philipsen, Schmidt, & Ziefle, 2015).

Search time is not only related to finding a suitable parking location for the electric vehicle driver, but also related to being able to find a public charging point in order to charge the electric vehicle. In order to charge an electric vehicle, the driver must search for an available parking spot with an available charger. Therefore, electric vehicle drivers are searching for a more specific location.

2.3.4. Distance between parking location and final destination

Distance between the parking location and the final destination is another important aspect related to the choice where to park (Golias et al., 2002; Hassine et al., 2022; Hassine et al., 2019; Ibeas et al., 2014; Litman & Burwell, 2006). Drivers would like to have the parking location as close as possible to the final destination, like their home for example, in order to reduce the walking distance (Netherlands Institute for Transportation Policy Analysis, 2018). The maximum acceptable walking distance is mainly determined by the duration spend at this location; an acceptable walking distance to the residence is around 150 meters (Christiansen, Fearnley, Hanssen, & Skollerud, 2017; Netherlands Institute for Transportation Policy Analysis, 2018).

2.3.5. Other

Next to the criteria mentioned above, the literature also mentioned other user criteria. These criteria are however not mentioned extensively in the literature but are still considered important when deciding on a location to charge the electric vehicle.

In order to be able to create a safe parking space, visibility is very important according to Philipsen et al. (2015). If the place is visible from multiple directions people will feel safer due to the enhanced social control. Additionally, by indicating the route to the parking location as well as the number of free spots at the parking location, the likelihood of people using the parking location will increase which will again result in a higher social safety level (Philipsen et al., 2015). It is assumed that with higher safety levels, electric vehicle drivers will be more inclined to leave their electric vehicle behind due to the presumed lower change of vandalism or theft. Another way to increase the safety level of a parking location is by having adequate lighting (Classic architectural group, 2022; Philipsen et al., 2016). Other user aspects that are related to user safety are safe pedestrian paths, minimizing visual obstructions and maximizing passive surveillance (Classic architectural group, 2022; TransPark, 2022).

A final user aspect is reliability (Philipsen et al., 2015). Reliability refers to the availability of a working charging point. If there is always a charging point available when you need it, it is possible to rely on that location to charge. In this way, there will be no waiting time for the users. However, reliability does not only refer to availability and the ability to find a charging point. Reliability also means that there should be no technical issues that obstruct charging, like malfunctioning chargers or electric current dropouts for example. According to the results of O'Connor, Barnes, & Urquhart (2022) the most common frustration of electric vehicle owners is a broken/nonfunctional charger or having too few charging points available. This is because if an electric vehicle has to be charged, the owner wants to be able to connect their electric vehicle to a charger immediately when arriving at the charging location (Philipsen et al., 2016).

2.4. Built environment aspects

Different aspects of the built environment also play a role in the suitability to locate a charging square somewhere. According to Wu & Niu (2017), the geographical environment near the charging square is indeed one of the most important factors that needs to be considered since it will have a direct impact on determining the feasibility of the location. Below, multiple aspects that are affecting the suitability of a certain location according to the literature will be elaborated upon.

2.4.1. Accessibility, coverage & traffic flow

Based on findings of Helmus & van den Hoed (2016), Melaina & Bremson (2008) and Wang, Liu, Cui, Xi, & Zhang (2013), it is recommended that the access to electric charging facilities needs to be satisfactory, in order to increase electric vehicle adoption. Achieving higher accessibility can be done by locating the charging points on a central location where there is the possibility to access the site from many different directions (Philipsen et al., 2016). Even though Philipsen et al. (2016) showed that accessibility is ranked as the third most important criterion when deciding on a location for fast-chargers, it is considered to be a highly important aspect when locating charging squares in the residential environment.

Having access to a charging location does not only mean that it is accessible when the driver needs it. It also refers to having a place nearby. This means that accessibility is related to both temporal as well as spatial accessibility. The larger the distance between the demand point and the charging location becomes, the lower the use will be (Efthymiou, Antoniou, Tyrinopoylos, & Mitsakis, 2012). Therefore, if the distance to the charging location becomes smaller, the accessibility increases, which will encourage drivers to switch to electric vehicles according to He, Kuo, & Wu (2016).

According to Bian et al. (2019), Dong, Ma, Wei, & Haycox (2019), Qian et al. (2017) and Wu & Niu (2017), the traffic flow will have an impact on the decision to create a charging location since if more traffic is coming to the location, the profits and service capabilities will also increase. Therefore, good accessibility is also related to the structure of the road network since having a good road network surrounding the charging location, will result in fewer congestions, reduced search time and therefore increases the accessibility (Yan & Ma, 2016). Not only the access to and from the location is important, but also the number of vehicles entering and leaving the charging location determines the profitability and suitability of the location (Wu & Niu, 2017). If electric vehicles leave the charging facility directly or shortly after their battery is completely charged, a charging point will not be unnecessarily occupied. This will make the charging point available for the next electric vehicle driver that needs to charge. Therefore, the distance to and from the charging location needs to be taken into account.

2.4.2. Parking situation

When the electric vehicle is not used, it can be parked on a parking spot with or without a charging facility. If the electric vehicle does not need to be charged, the possibility to charge an electric vehicle has no influence on the choice for a parking spot and the electric vehicle user is free to choose from all available parking spots. If the electric vehicle does need to be charged, the driving pattern of the electric vehicle will be influenced by the location of charging points. The location of the charging point influences the driving pattern since the electric vehicle user needs to search for an available charger and is limited in the number of available parking spots.

Not only the location of the charging point in the neighborhood plays a key role in the usage but also its location relative to other charging points plays a role (Van Montfort, Kooi, Van Der Poel, & Van Den Hoed, 2016). If the charging points are well distributed across the service area, search traffic will be reduced. Additionally, the number of charging points has to be sufficient for the service area. If this is not the case and there is more demand for charging than available supply, electric vehicle users will need to search for available charging points in the surrounding neighborhoods increasing the search traffic (Philipsen et al., 2016). Consequently, clusters of public chargers should be sufficiently distributed over the service area in order to supply a larger group of potential users and prevent search traffic and congestions

2.4.3. Safety of the vehicle

When deciding on a place to create a public charging location, safety of the electric vehicle needs to be taken into account. Safety refers here to the prevention of vandalism and theft and a good safety level can result in long-term business (Li, Ma, Cui, Ghiasi, & Zhou, 2016; Silvester et al., n.d.). Adequate safety levels will therefore result in a higher willingness to use a charging location. Two possible solutions to increase the safety levels and reduce vandalism and theft are having adequate lighting and having adequate security measures in place (WCCTV, 2023). Not only vandalism and theft are important, but also the road safety on the charging square is important. Possible solutions to increase the road safety on a charging square are performing adequate maintenance to the road surface, restricting the maximum speed, and a car park management system (Image Extra, 2021; Seton, 2022).

Another aspect of safety is related to fire safety. It is very important to take fire safety into account since electrical fires are different compared to regular fires (Nederlands Instituut Publieke Veiligheid, 2022; Rosmuller, van der Graaf, & Hessels, 2021). Fires in electrical vehicles are different because the fire initiation takes place at a slower pace and takes longer to reach the maximum temperature (Rosmuller et al., 2021). Additionally, it is possible for a battery to ignite itself again, even after the fire has been extinguished, which is called a "thermal runaway" (Nederlands Instituut Publieke Veiligheid, 2022). However, at this moment there are no specific fire safety requirements in the building decree of the Netherlands regarding electrical vehicles and charging these vehicles (September 2022) (Nederlands Instituut Publieke Veiligheid, 2022). As of January 2024, a new building decree "Besluit Bouwwerken Leefomgeving" will have specific requirements regarding electric vehicle charging (Overheid.nl, 2022b). The NEN-4010 has published specific requirements regarding the electrical installations, including among others automatic power cut-off requirements, protection against overload and prevention of short circuits (NEN, 2022). The chargers used to charge an electric vehicle must comply with these regulations.

According to Sun, Bisschop, Niu, & Huang (2020), the probability that a parked electric vehicle which is not charging catches fire is not significantly higher than for a conventional vehicle. However, when an electric vehicle is being charged, there is a higher probability of the vehicle catching fire due to the extra action that takes place (Rosmuller et al., 2021). The extra action here refers to the electric vehicle being charged instead of only being parked (like a petrol vehicle). If an electric vehicle's battery catches fire, extinguishing the fire completely is more difficult due to the thermal runaway. Other safety aspects that should be considered are the electrical installation used as well as the fact that the development of charging techniques always have start-up problems (Nederlands Instituut Publieke Veiligheid, 2022; Rosmuller et al., 2021).

2.4.4. Grid capacity

In order to be able to charge an electric vehicle there is a need for electricity. This electricity is transported from the producers to the electric vehicle over the electricity grid in the Netherlands. However, the maximum capacity of the electricity grid in the Netherlands has been reached in some provinces (Netbeheer Nederland, 2022), making it impossible to locate a new public charging point near every existing parking spot. Even if parking spots are spatially well distributed, locating a charging point near every spot is not possible due to the limited capacity on the electricity grid.

An advantage of charging squares is that it is possible to reduce the impact on the grid through charging electric vehicles by controlled charging. This means that there will be some sort of regulation on which vehicle is charged at what time. This is because Nour, Ramadan, Ali, & Farkas (2018) showed that uncontrolled charging (when a vehicle is plugged-in, the electric vehicle starts to charge) has a large impact on the grid. Since the majority of electric vehicles will arrive at the residence around the same time and are therefore plugged-in around the same time, uncontrolled charging has a large impact on the grid (Abul, El, & AFatah Mohamed, 2017).

Not only the time that an electric vehicle is charged has an impact on the available capacity of the grid, also the size of the battery has an impact. Shahidinejad, Filizadeh, & Bibeau (2012) showed that a larger storage size of the battery has a positive effect on the grid capacity. If the storage size of the battery is larger, the confidence to make the next trip without the need to plug-in the electric vehicle is higher (Shahidinejad et al., 2012). This will therefore free up capacity on the grid. However, when this electric vehicle is being charged, more time is needed due to the larger battery size.

2.5. Stakeholders

This section of the literature review will take a look at the different stakeholders that are involved in the location decision for public charging squares. The literature is not only reviewed to be able to identify the different stakeholders that are involved but also to take a look at the different interests of each stakeholder.

According to the literature, there are six main groups of stakeholders involved in electric vehicle charging, which are the (1) government (both local as well as national), (2) site managers or service providers, (3) power grid operators, (4) car manufacturers, (5) charging point manufacturers and (6) electric vehicle owners. There are of course more than only these six stakeholders involved, like for example research and education or consultancy agents, but these are not involved in the process of deciding on a new public charging location and are therefore not taken into consideration in the remainder of this section. Additional to the literature, experts were consulted to see if the stakeholders found in the literature are in line with practice.

2.5.1. Government

Based on Bakker, Maat, & van Wee (2014), Michiels, Beckx, Schrooten, Vernaillen, & Denys (2012), Santos & Davies (2020), Wirges (2016) and Wolbertus, Jansen, & Kroesen (2020) the government is considered one of the main stakeholders related to the location decision for publicly available chargers for electric vehicles. According to Wolbertus et al. (2020), the Dutch government has been supporting and regulating the implementation of electric vehicle charging facilities in the Netherlands.

The reason why the Dutch government has been supporting the implementation of electric vehicle charging facilities is because the national government aims to position the Netherlands as a country where charging infrastructure can be tested (in Dutch so called *proeftuinen*) (Ministry of Economic Affairs Argiculture and Innovation, 2011). In this way, the Dutch government hopes to reduce greenhouse gas emissions. The national government is furthermore interested in electric vehicle charging due to several positive externalities associated with the use of electric vehicles (Wirges, 2016). Potential positive effects are a lower level of pollutants, fewer noise disturbances and lower greenhouse gas emissions according to Bakker et al. (2014), Ministry of Economic Affairs, Argiculture and Innovation (2011) and Wirges (2016). A negative effect of the increased usage of electric vehicles is the increasing demand for electricity which has to be transported over the already congested power grid.

Local governments are interested in electric vehicles since electric vehicles do not emit any pollutants into their environment and therefore the air quality in the cities can be improved by higher adoption rates. Another reason for local governments to be interested according to Wirges (2016) is that if the electric vehicles are charged locally, the infrastructure should be provided locally which will create jobs.

The local government is considered a major stakeholder in the location decision for charging squares because the government is responsible for the allocation of public parking spaces (Overheid.nl, 2022a; Wirges, 2016). In land-use plans, possible locations for charging squares can be indicated by the local as well as national government and all developments have to adhere to these plans. If a development does not comply with the land-use plan or other regulations in place, the government has the power to stop the development. Since the local government is responsible for administrating the permits to install the public charging infrastructure, the local government has a high power (Wirges, 2016). If the development is in line with the regulations, the government has no possibility to object to the development. This section will not elaborate on the current policy regarding the location-allocation of public chargers, the current policy is elaborated in section 2.6.

2.5.2. Site managers or service providers

Various parties identified the site manager or service provider as another key stakeholder concerning electric vehicle charging (ChargemapBlog, 2021; EVreporter, 2020; Griden Technologies Pvt., 2022; Wirges, 2016; Wolbertus et al., 2020). Site managers or service providers are the local governments and charging network operators who provide public charging. The site manager or service provider is responsible for the premises where the public charging facilities are provided and supervises the charging location (ChargemapBlog, 2021; EVreporter, 2020; Griden Technologies Pvt., 2022). They provide this service on public or semi-public locations and users get access to the facilities by scanning their RFID-tag or charging card (Wolbertus et al., 2020).

The interest of site managers or service providers on the location of a charging square is very high. Site managers or service providers want to have the best location possible in order to have as many customers as possible. Another reason for the site manager to be interested in the location decision is because if the location is not satisfactory for the site manager, the site will not be exploited.

If the land-use plan of the municipality does not include any location for charging facilities, the site manager is able to request a change of the land-use plan. Therefore, the decision power is lower since site managers are dependent on the government. However, the site managers still have a medium power in the ultimate location decision since they are going to exploit the location. If the site manager is not satisfied with the location decision, the site manager can decide to not exploit the charging location and appeal to the new land-use plan.

2.5.3. Power grid operators

Since electric vehicles need electricity to be able to charge their battery, the power grid operators are considered a major stakeholder (Bakker et al., 2014; EVreporter, 2020; Griden Technologies Pvt., 2022; Michiels et al., 2012; Wirges, 2016; Wolbertus et al., 2020). Power grid operators are the companies which maintain the electricity grid and invest in this grid. In this way, it is possible to transport electricity from producer to consumer in an efficient way. According to EVreporter (2020) the power grid operators earn more revenue as new customers are added to their network. This is because the power grid operators in the Netherlands earn their money through so-called connection and network management fees (Solar Magazine, 2021). Therefore, more connections to the grid will result in higher revenues for the power grid operator. However, and advisory report written by CE Delft (2022) on behalf of Netbeheer Nederland states that charging points should be clustered and connected to the grid with one connection instead of several individual connections.

However, it has to be taken into account that the power grid operators are responsible for controlling the network and capacity on the grid (Bakker et al., 2014). If there is a large increase in electric vehicles, the stability of the grid could be threatened if there are no reinforcements to the grid (Bakker et al., 2014). Therefore, power grid operators have the power to object to proposed locations if the capacity on the grid is too limited. Power grid operators are a major stakeholder because they have the power to withhold a connection to the grid. If the maximum capacity of the grid is reached, power grid operators will not connect new customers to the grid in order to prevent overloading the grid. Additionally, power grid operators are interested in the location of charging points to be able to upgrade the grid at the right location.

2.5.4. Car manufacturers

Based on the literature, Bakker et al. (2014), Hans et al. (2012), Santos & Davies (2020), Wirges (2016) and Wolbertus et al. (2020) identified the car manufacturer as one of the key stakeholders as well. The reasoning behind this is that all of the major car manufacturers realize the need to produce zero-emission vehicles, and the electric vehicle is a way to do so (Bakker et al., 2014). Even though the car manufacturer is considered a major stakeholder in electric vehicle charging, their power concerning the location choice of a charging square is limited because this stakeholder is mainly concerned with producing electric vehicles and not with providing public charging squares. Therefore, their power in the location decision is low.

Car manufacturers do however have a medium interest in the location of charging squares. If car manufacturers want to sell their electrified vehicles in large numbers, they are dependent on the number of publicly available charging points (Wirges, 2016). The adoption rate of electric vehicles depends on the availability of charging facilities because if there is no place to recharge an electric vehicle, the adoption rates will be low.

To charge an electric vehicle, a plug is needed. According to European regulations, the Type 2 plug is set as the standard to support interoperability as of 2014 (European Parliament & Council of the European Union, 2014). Since fast charging has a higher power compared to slow charging, the Type 2 Combo plug is allowed for fast charging. The difference between the Type 2 and the Combo Type 2 plug is that the Combo Type 2 plug uses the same socket as the Type 2 plug but has two additional power contacts that support DC fast charging. Due to the standardization of the Type 2 (combo) plug in the European Union, all electric vehicles produced by car manufacturers can charge near any charging point.

2.5.5. Charging point manufacturers

In order to be able to charge an electric vehicle, it is needed to have access to a charging point which is produced by the charging point manufacturers. The charging point manufacturer is therefore considered one of the key stakeholders (Griden Technologies Pvt., 2022; Wirges, 2016; Wolbertus et al., 2020). According to Wirges (2016) the interest of the charging point manufacturers is to sell their products and associated services. When selling their product, it can be expected of these manufacturers that they prefer to sell the variant with the most features since this will probably result in the highest profit. The number of ports (one or multiple) on a charging point does not matter for the charging point manufacturer since they are mainly concerned with selling their chargers. However, when deciding on a suitable location for charging squares, the manufacturer does not have much power because if manufacturer A does not want to deliver the charging points for the intended location, manufacturer B might.

2.5.6. Electric vehicle owner

Another major stakeholder related to electric vehicle charging is the owner of an electric vehicle (EVreporter, 2020; Lopez-Behar et al., 2019; Santos & Davies, 2020; Wirges, 2016). The electric vehicle owner currently mainly relies on private household charging or access to a public charging point if there is no possibility for the owner to charge their vehicle on private property (EVreporter, 2020). The main reason why electric vehicle owners have a high interest in electric vehicle charging locations is because they want charging solutions that function, are low in costs, are always available and are close by (Wirges, 2016). However, when it concerns the location decision of a charging square, a single owner of an electric vehicle does not have much power simply because a location will not be changed for only one person. According to Netherlands Institute for Transportation Policy Analysis (2018) drivers park as close as possible to the final destination and therefore, it is likely that the electric vehicle owner will choose the closest possible charging location. All owners combined do have power in the location decision because eventually they have to use the location. If the electric vehicle owners collectively do not use the public charging location, the location is not feasible (Wirges, 2016).

2.5.7. Additional stakeholders not identified by the literature

In this sub-section additional stakeholders that are important when deciding on the location of a charging square will be elaborated on. The stakeholders mentioned in this sub-section were not mentioned in the literature but were identified as important stakeholders in the allocation of charging squares according to the experts of Dura Vermeer Vastgoed (Heintz, 2022[9]; Kal, 2022[10]; Van Lieshout, 2022[11]).

2.5.7.1. Project developer

The first stakeholder that was mentioned by the experts of Dura Vermeer Vastgoed is the project developer. The experts argued that within an integrated area development, the project developer is responsible for the complete development including all publicly available charging facilities in the development. In these integrated area developments, general requirements will be set out by the government to which the project developer has to adhere to. These requirements can be as general as a number of square meters per function or very detailed according to the experts. The project developer himself/herself can decide on the final design and layout of the development as long as the requirements set by the government and/or client are met. In essence, the project developer is responsible and has to make all decisions for the complete development of a large area.

If the project developer needs to provide public charging facilities within the area development, the developer can decide on the location. In an integrated area development, the project developer has the power to make all decisions and, in the end, the municipality only checks if the set requirements are met. Therefore, the project developer has almost the same power compared to the municipality. Project developers are interested in finding suitable locations for charging facilities, because they want to fulfil as many preferences for the end-user as possible (Heuninckx, Boveldt, Macharis, & Coosemans, 2022). The project developer has the power to make a decision on the final location of the charging facilities within the development area since the developer is ultimately responsible for the complete development. Therefore, only if the project developer is satisfied with the location for the charging facilities, then these will be realized, otherwise another location will be looked for according to the experts.

2.5.7.2. Building owner

The second stakeholder that was identified by the experts next to the beforementioned stakeholders, is the building owner. A building owner can be an owner-occupier, investor or an owner's association that owns the building. The reason why the building owner is an important stakeholder in the location decision of a charging square is because if public chargers would be provided in/on the building, the owner always has to agree with the decision. If the building owner does not agree with the allocation of charging facilities inside or on the building, no new charging facilities will be realized. There might be some regulations set out by the government to provide a minimum number of chargers to which the building owner has to adhere to, but the owner still has the power to decide on the location of the chargers in/on the building.

The building owner has a low interest in the location decision of public charging points because the building owner is only concerned with its own building. The building owner has an interest in the location decision since providing public charging points in the building can result in an increased fire hazard, possibly resulting in a higher insurance fee. Additionally, the installation of the chargers in the building must be paid by the building owner. Furthermore, building owners are interested in the location decision since locating a charger in/on a building results in a higher value of the property (Jaap, 2022). However, ultimately, if the owner does not want to have charging points in the building, the building owner cannot be forced to provide the chargers in the building.

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[9] Personal communication, September 21st, 2022
[10] Personal communication, September 21st, 2022
[11] Personal communication, September 21st, 2022

2.5.7.3. *Fire department*

The experts of Dura Vermeer Vastgoed also mentioned the fire department as a major stakeholder, especially if the charging facilities are located in a building or close to gas stations. When applying for a permit, the government will likely consult the fire department about the fire safety of the building and if the fire department is not satisfied with the fire prevention measures taken or there is no decent plan to prevent a potential fire, the government will not sign off on the permit (brandveiliggebouw.nu, 2022).

All the experts collectively agreed that deciding to ignore the advice of the fire department on the fire protection plan is never an option. The experts indicated that due to this power, the fire department is a major stakeholder in the location decision.

The interest of the fire department is currently also considered to be high. Currently, there are no regulations regarding fire safety of charging electric vehicles in the building decree of 2012. Since these developments are new, the fire department shows interest in all developments, but it can be expected that the interest of this stakeholder will decrease as new regulations will be set in the future.

2.5.7.4. *Shared mobility provider*

A final stakeholder that was mentioned by the experts was the shared mobility provider. Shared mobility providers are companies that provide access to transportation services on an as-needed basis (shared-use mobility center, 2022). According to the experts, the shared mobility providers have a medium interest and some wishes regarding the location of a charging square which might support their business. This is because if the charging location for their shared mobility vehicles are located at a location which is hard to reach, the use of their vehicles will be lower.

By contacting several shared mobility providers, it became clear that the providers expect to only have electric vehicles in their vehicle pool within five years (Rombout, 2022[12]; SHARE NOW, 2022[13]). It has to be noted that possibly not all shared mobility providers will rely on public charging squares for their electric vehicles since in some cases shared mobility providers have a permanent parking location which can be used to charge an electric vehicle as well. This results in a low power with a medium interest for the shared mobility providers on the location decision of charging squares according to the experts of Dura Vermeer Vastgoed.

2.5.8. Stakeholder matrix

In the previous sections, the stakeholders have been mentioned that are considered important in relation to the location decision of public charging squares for electric vehicles according to the literature and the consulted experts. For all stakeholders it is described who they are, what their interest is in the location decision and their power in the decision process. As became clear from the information gathered, every stakeholder has a different level of power and interest regarding the allocating process of a charging square. Below, in figure 3, an overview is given of each stakeholder and their level of power/interest when deciding on the location of a charging square.

[12] E-mail, September 22nd, 2022
[13] E-mail, September 21st, 2022

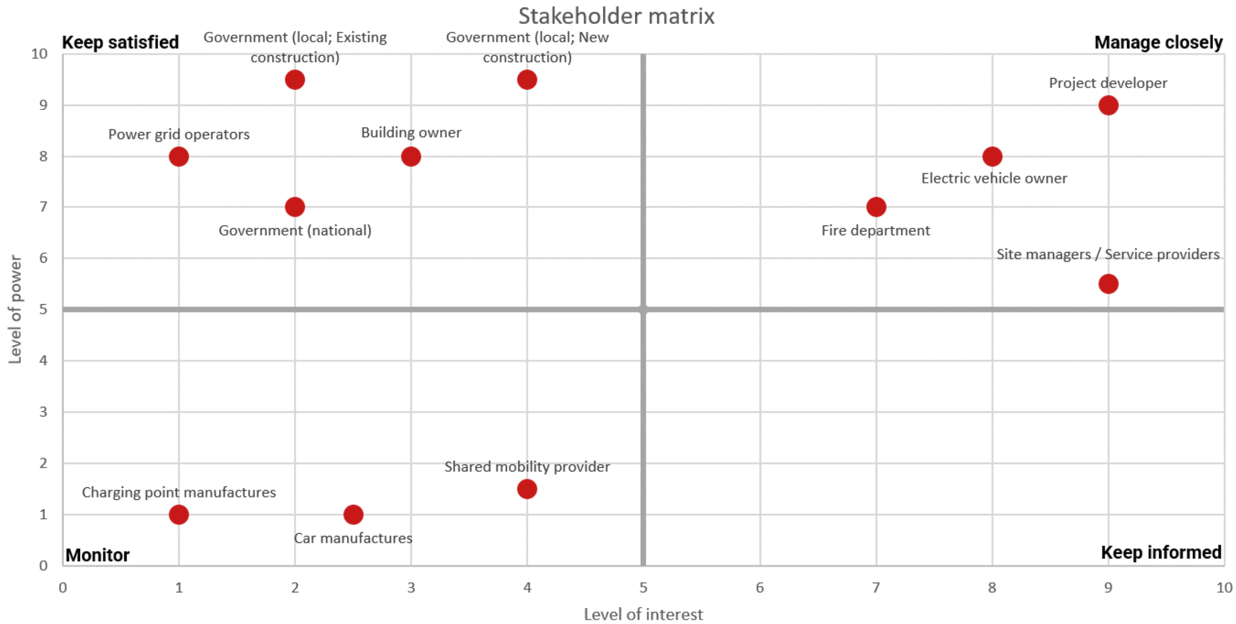

Figure 3. Stakeholder matrix

Of all the stakeholders that have been identified, the project developer is the most important stakeholder in the location decision for a public charging square. However, not every project involves a project developer. If the project developer is involved and not satisfied with the location in the development area, the charging square will not be developed. The site manager is also very interested in the location decision of a charging square, since the location will influence their business case and profitability of the site. Their power in the location decision is medium since if site manager A does not want to exploit the site, site manager B might. However, the site managers still have to be managed closely since ultimately a site manager will exploit the location.

Electric vehicle owners also have to be managed closely since they are interested in the location decision so it meets their demands and also have a power in this decision. If the public charging location is not matching the demand of the electric vehicle owners, the location is not going to be used. Therefore, if the user is not willing to use the charging square it might be useless or inefficient since the user might have different alternatives to charge her/his vehicle. The fire department is the final stakeholder that needs to be managed closely because they have the power to withhold a permit and are currently very interested in the development of these new charging facilities since no regulations exist yet. In the future, their interest might be lower compared to their current interest if adequate regulations are in place.

As is visible from figure 3, the stakeholders that have to be kept satisfied are mainly the governmental stakeholders. The governmental stakeholders have the highest power of all stakeholders involved since they have to ensure that the location is in line with the current regulations and land-use plans. If this is not the case, the government has the power to withhold the permit. The governmental parties are considered to have a low interest in the decision regarding the actual location of a charging square since their main task is to make sure that the developments are in line with the regulations and if this is the case, the location of the development is not considered to be their concern. It could however also be argued that the governmental parties need to be kept informed during the location decision process since they only check the development when a permit is filed, however, this thesis considers the governmental parties from their decision power perspective and therefore the governmental parties need to be kept satisfied.

The power grid operators must be kept satisfied since they are responsible for the continuity of the whole power grid and if this stakeholder is not satisfied with the location choice, it might be the case that it will not be possible to acquire a new connection to the power grid. Finally, the building owner needs to be kept satisfied since if the charging points are going to be located in/on a building, the owner of the building has to approve this decision.

The three remaining stakeholders only have to be monitored and do not have much power nor interest in the location decision. These stakeholders are the charging point manufacturer, car manufacturer, and shared mobility provider. The reason why the charging point manufacturer only has to be monitored is because of the fact that if manufacturer A does not want to deliver the charging points, manufacturer B might. Finally, the car manufacturer also only has to be monitored since their developments and adoption rates of electric vehicles depend on the availability of charging facilities and not the other way around.

2.6. Current policy & location allocation

Currently, the decision for locating a new public charging point in the Netherlands is the responsibility of the local municipality (Overheid.nl, 2021). However, when deciding on the location for a new public charging point the government also takes into consideration market forces and does not only base their decision for a new location on current policy. Below, the guidelines for the application for a single new public charging point set out by the government are presented. Currently, there are no general guidelines for the realization of a charging square. The goal is to ensure that the charging infrastructure is available for everyone and accessible for every electric vehicle driver (Overheid.nl, 2021):

- The applicant should be an inhabitant or work in the municipality.
- There is no possibility to charge on private property.
- The applicant drives more than 10,000 kilometers on a yearly basis.
- There should not be an existing charging point with the possibility to reserve an additional parking space for charging and/or the energy consumption should not be less than 250 kWh/charging point/month on average and/or the number of transactions should not be lower than 25 transactions/charging point/month on average within 200 meters.
- There should not be a charging square within 500 meters of the applicants' address.

Figure 4 shows a graphical representation of the decision to locate a new public charging point.

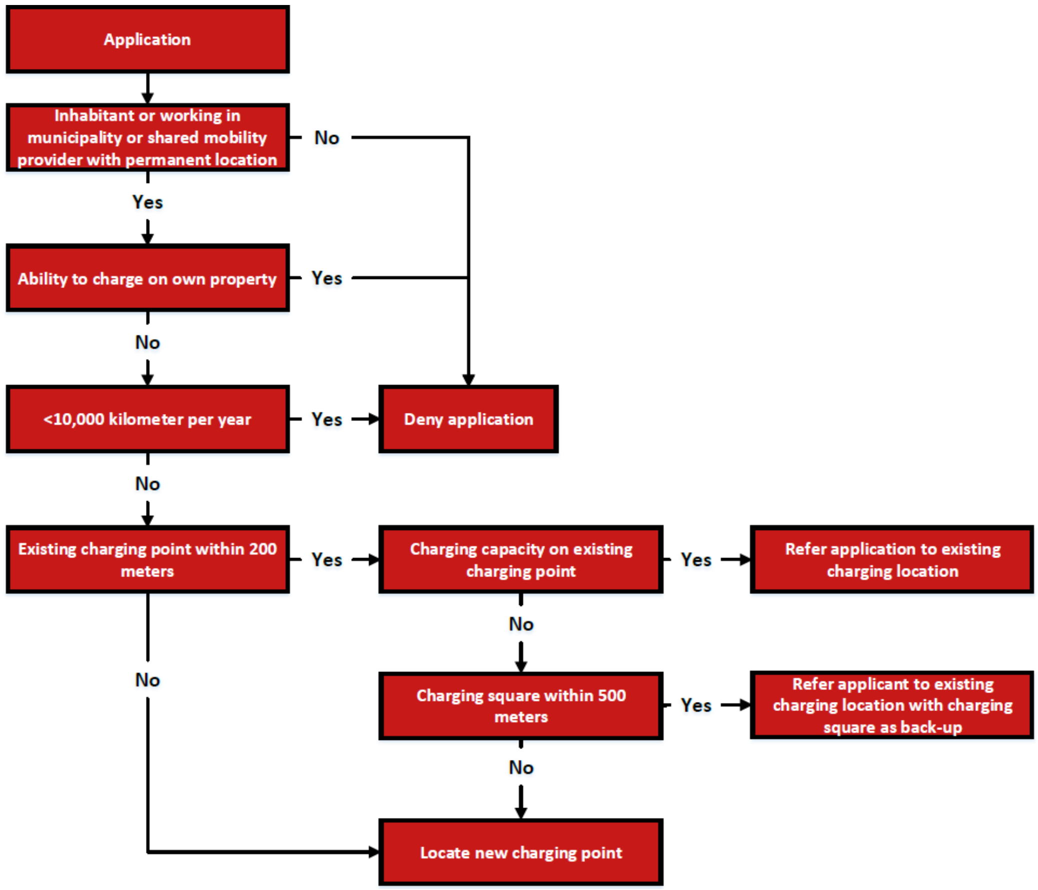

Figure 4. Decision tree new charging point. Adopted from Overheid.nl (2021)

In addition to the regulations set out by the government in order to decide on a new location for a public charging point, private companies are also allowed to provide charging infrastructure which is publicly available (Agentschap NL, 2013; Nationale Agenda Laadinfrastructuur, 2022). Private companies want to make a profit as a result of the growing demand for charging points by the growing number of electric vehicles. Private companies are able to provide public charging since in the Netherlands it is possible to use a public charging point with any type of charging card. In this way, the user can decide on the charging card provider that best suits the user since every provider has different price levels and terms & conditions. Altogether, the goal of the current policies and regulations is to ensure that all electric vehicle drivers in general have access to a wide range of charging points in the Netherlands.

2.7. Conclusion

According to the literature review, previous studies indicated several important aspects related to choosing a parking location. As can be concluded from the literature review, costs, availability, search time and walking distance are deemed important aspects when considering a parking location. Next to the user aspects, also the built environment aspects were studied. Studies identified accessibility and safety of the vehicle as important built environment aspects related to parking. During the literature review, these aspects were identified important in the context of deciding on a parking location, however, the studies considered these aspects not in relation to a charging square. It is however relevant to investigate these aspects in relation to charging electric vehicles, since more and more electric vehicles will be owned in the future which need to be able to charge as well. In this way, when the important aspects related to deciding on a charging square are known, these aspects can be taken into account in the future when policy makers have to make decisions on the location for a charging square in the future. In addition, expert interviews were conducted which confirmed the findings mentioned in the literature review related to choosing a charging location. Therefore, several of these factors are included in this study to investigate their relevance in relation to a charging square. For the remainder of this study, the attributes that are suggested to be considered are: costs, walking distance, availability and safety.

Next to the research about important user- and built-environment aspects, the literature review also investigated the stakeholders that are involved in choosing a location for a charging square. In the literature review, important stakeholders were identified as the project developer and governmental parties while less important stakeholders were the charging point manufacturer, car manufacturer and shared mobility provider.

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3. Methodology

Based on the literature review, it was possible to answer the first sub-question and provide insights in the remaining sub-questions. In order to be able to determine user preferences when deciding on a public charging square, a stated choice experiment will be performed in this thesis.

This chapter will extensively describe the methodology that is used in this thesis and consists of the following paragraphs. First, the stated choice method will be introduced (section 3.1). After the method has been introduced, the context in which this study is performed will be elaborated (section 3.2). Next, this chapter will present how the data is being collected (section 3.3 and 3.4) and finally the analysis methods that are used will be described (section 3.5).

3.1. Stated Choice Experiment

To determine the user preferences when deciding which public charging square to use in a residential area, preferences regarding the different attributes of a public charging square need to be measured. To measure preferences, two different approaches can be taken as is shown in figure 5. The first approach is to perform a revealed preference/choice experiment, the second approach is to perform a stated preference/choice experiment (Hensher, Rose, & Greene, 2015).

A revealed choice experiment uses past/revealed behavior of the respondents to derive the utility and weights of the attributes and therefore relies on the actual choices made (Abdullah, Markandya, & Nunes, 2011; Boyle, 2003; Kemperman, 2000).

In a stated choice experiment, the respondents are presented with controlled hypothetical situations from which a choice decision has to be made (Hensher et al., 2015). In these hypothetical situations, respondents make trade-offs between the different attributes and levels and decide which option is preferred (Rose & Bliemer, 2009; van den Broek-Altenburg & Atherly, 2020).

As is visible in figure 5, the stated based experiment has two different approaches, an approach for measuring choice and an approach for measuring preferences. Measuring preferences can be further subdivided into, a decompositional and compositional approach. The aim of the decompositional approach is to predict the individuals' preferences and choices based on their response in a controlled environment while in a compositional approach respondents first evaluate the levels of each attribute and then indicate the importance of each attribute (Kemperman, 2000).

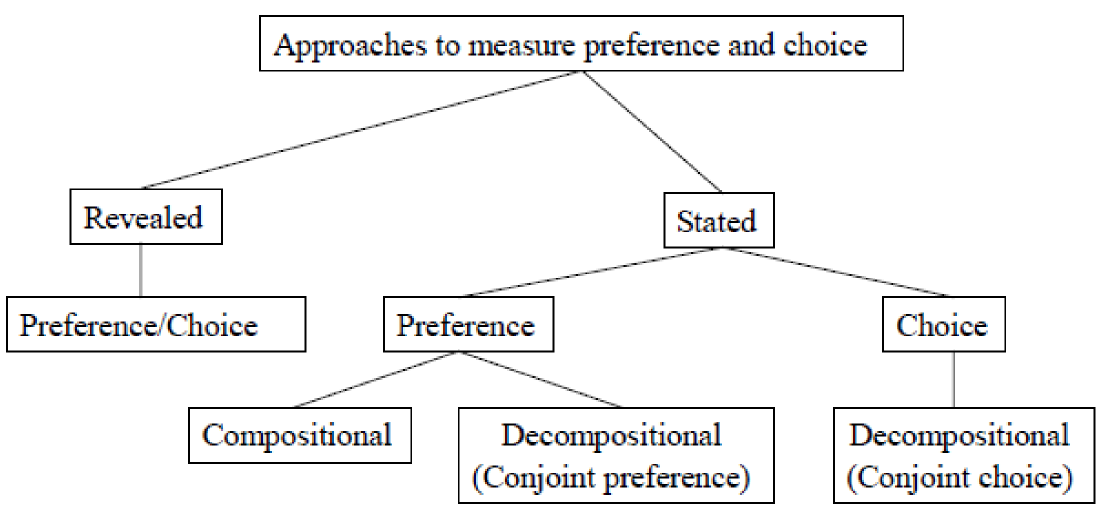

Figure 5. Approaches to measure preference and choice (Kemperman, 2000)

According to Hensher et al. (2015) and Louviere, Hensher, & Swait (2000), stated choice modelling can be used to analyze the preference for new, non-existing situations. Deciding which public charging square to use is considered a new, non-existing situation since there are limited public charging squares available. Since there are only a few charging squares in the Netherlands, deciding on which charging square to use is a hypothetical question as it is likely that respondents did not have to make such a decision in real life yet. Additionally, there are relatively few electric vehicles on the road (compared to the total vehicle pool) and currently the largest part of electric vehicle user's charges near their home instead of using a public charging location (Lee, Chakraborty, Hardman, & Tal, 2020). Furthermore, since stated choice modeling allows to use hypothetical choice options, the researcher can completely determine the included attributes and levels in detail. Consequently, a stated choice experiment will be conducted in this thesis.

In order to be able to set-up a stated choice experiment, Hensher et al. (2015) summarized the process into the steps shown in figure 6. The first step in setting up a stated choice experiment is to refine the overall problem definition. Once the problem has been refined, the different alternatives, attributes and their corresponding levels can be identified in step two. Subsequently, in step three, a decision about the experimental design of the stated choice experiment must be made.

The most common decision that has to be made is whether to use a full factorial design or a fractional factorial design. In a full factorial design, all possible combinations of attributes and levels are used, while a fractional factorial design only uses a selection of all possible combinations (Hensher et al., 2015; Rose & Bliemer, 2009). The decision about which type of design is used in this study can only be made after the attributes and corresponding levels have been determined since these determine the total number of possible combinations.

After a decision about the design is made, the experimental design can be generated. Next, the attributes and levels can be allocated to the design columns resulting in different alternatives. Once the different alternatives have been created, the different choice sets will be generated. When alternatives have been allocated to choice sets, the choice sets can be presented to respondents. Usually, by distributing a questionnaire.

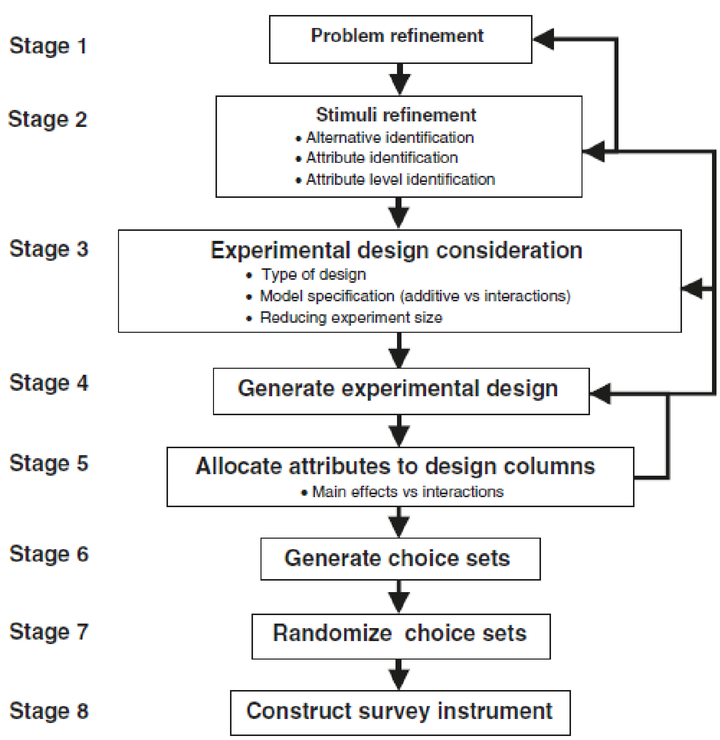

Figure 6. Steps in a stated choice experiment (Hensher et al., 2015)

3.1.1. Attributes and corresponding levels

This sub-section will describe the different attributes and levels that are used in this study. Since part of the problem is more or less similar to finding a suitable parking spot, and the existing literature already studied this aspect, the included parking attributes are based on the literature. The parking attributes included in this study are supplemented with attributes that are important for charging electric vehicles since this study wants to identify user preferences when deciding on a public charging location given the presence of various charging squares for electric vehicles. Next to the attributes regarding parking and charging, the choice sets also include one attribute related to the urban environment. Since every choice set is presented in a context situation, two context related attributes are included (elaborated in more detail in section 3.2).

If large numbers of attributes are included in a stated choice experiment, a possible consequence is biased model estimations (Hensher, 2006). To prevent this, only nine different attributes (including the context attributes) are included in this study. Mangham, Hanson, & McPake (2009) indicated that the number of attributes should be limited to ten in order to guarantee that all attributes are taken into account by the respondent.

The choice sets that are presented to each respondent include two different charging alternatives and a "none-choice". During the experiment, the "none-choice" can be chosen by the respondent if neither one of the two presented charging alternatives would be chosen in the context in which the choice task has to be made. Table 2 presents an overview of all attributes (including the two context related attributes) and the corresponding levels used to create the different alternatives. Next, an explanation of the attributes and how the different attributes are constructed is given.

Table 2. Overview of the attributes and their corresponding levels

Related to	Attributes	Levels
Context	The range that needs to be charged	50/100/150 kilometers
	Available time to charge	There is one hour available to charge There are four hours available to charge There are eight hours available to charge
Parking	Walking distance	50/150/250 meters
	Supervision on charging location	The vehicle is left unattended at the charging location The vehicle is visible from the (surrounding) dwelling(s) The area is monitored through CCTV
	Move vehicle within	30 minutes after the battery is completely charged 2 hours after the battery is completely charged The car does not need to be moved
Charging	Type of charger	Only slow chargers Only fast chargers Both slow chargers as well as fast chargers
	Charge certainty	75%/85%/95%
	Costs	€0.25/€0.40/€0.55 per kWh (for slow charging)
		€0.60/€0.75/€0.90 per kWh (for fast charging)
Urban environment	Alternative functions for parking	Nothing changes More greenery Facilities for sport and exercise

The range that needs to be charged: This attribute indicates the range that needs to be charged in order to be able to drive to the next destination. The range is given at the moment the vehicle arrives at the charging square. In order to present the respondents with a realistic range, it is assumed that respondents drive a middle-class electric vehicle (with an average range of 310 kilometers (Milieu centraal, 2022b)) that has a remaining battery percentage of 15/35/50%. There is chosen to only present the range that needs to be charged to the respondent so that it does not matter what the total range of the respondent's vehicle is (small/medium/large).

Available time to charge: This variable indicates the amount of time that is available to charge the battery before departing to the next destination where it is not allowed to arrive late. One hour available to charge the battery is based on being home for a short amount of time between two appointments while the level of four hours available to charge is based on coming home from work during the day and having an appointment in the evening. The final level, having eight hours to charge, is based on coming home in the evening and not having to leave until the next day.

Walking distance: This attribute indicates the walking distance between the charging square and the dwelling. The average acceptable walking distance between a dwelling and a parking location is 150 meters (Netherlands Institute for Transportation Policy Analysis, 2018). To determine the other two levels of this attribute 100 meters has been subtracted/added to the average acceptable distance. There has been chosen for 100 meters subtraction/addition since smaller differences will be hard to differentiate for respondents. The levels can be referred to as the vehicle is parked in the street (50 meters), in the neighborhood (150 meters) or in the district (250 meters).

Supervision on charging location: The literature indicated that safety is an important aspect for parking and charging an electric vehicle. Therefore, this attribute has been included. Since this thesis is investigating public charging squares, it is not possible to use a fence or other kind of barrier to increase the safety levels (Schneider, 2022). It is allowed to use CCTV under the Dutch law in order to guaranty safety of the user and vehicle in public spaces (Autoriteit Persoonsgegevens, 2022). Therefore, one level is that CCTV provides the security for the charging square. Since the public chargers will be located in an urban residential environment, the second level indicates that the charging square is visible from the (surrounding) dwelling(s). This level, therefore, indicates social control in the environment. Since it is not always possible to provide supervision, the final level provides no supervision.

Move vehicle within: In order to prevent electric vehicles from parking at a charging point when the vehicle is not being charged, policy measures can be implemented. In this thesis, two measures will be tested as well as not having to relocate the electric vehicle after completely charging the battery. Not having to relocate the vehicle is included since charging squares can implement smart charging techniques. In this way, if an electric vehicle is still connected to the charging point while the battery is completely charged, the charging capacity for that vehicle is reduced and increased for the other electric vehicles. The first measure is that the electric vehicle needs to be relocated within 30 minutes of completely charging the electric vehicle. After 30 minutes, the owner risks a fine of €95. The second measure is that the electric vehicle needs to be relocated within two hours of completely charging the battery of the electric vehicle, also with a risk of the same fine after two hours.

Electric vehicles indicate how much time is needed to charge their battery. In this way, drivers roughly know when their vehicle needs to be relocated. Since it is possible to receive a message on a mobile phone when the electric vehicle is completely charged and needs to be moved, these timeframes are considered realistic.

Type of charger: In general, there are two ways to charge an electric vehicle, slow charging, and fast charging. A middle-class electric vehicle needs on average 15 kWh to be able to drive 100 kilometers (ANWB, 2022d). This means that charging 100 kilometers in range using a slow charger takes around 1.5 hours (assuming an 11 kW charger) and around 5 minutes for a fast charger (assuming a 200 kW charger).

Charge certainty: High demand for electricity can result in overloading the electricity grid, resulting in more time needed to charge an electric vehicle. This attribute, therefore, indicates how certain it is to charge 100 kilometers in 1.5 hours for slow charging and in 5 minutes for fast charging. Since charging squares are able to implement new charging techniques, it is possible to have a higher charge certainty compared to individual charging points when the electricity grid is overloaded. Implementing charging techniques on a charging square will be more cost effective compared to implementing the same techniques for each individual charging point. The three presented levels are based on different charging techniques that already exist and can increase the reliability of the expected charging time.

The first level is based on the current way of charging with a high uncertainty at peak moments (75% certainty), the second level is based on smart charging. Smart charging reduces the amount of energy used to charge to prevent overloading the system. In this way, the electric vehicle is still being charged, only at a slower rate and therefore has a smaller uncertainty (85% certainty). The final level is based on a micro grid which has a high reliability of meeting the expected charging times (95% certainty) because a micro grid is able to produce and store electricity on-site and use it when it is needed the most (Schneider Electric, 2023).

Costs: In this thesis, the costs of parking are not considered and only the costs of charging are included. Parking costs are not considered since residents of urban environments are able to acquire a parking permit if there would be paid parking and are therefore not influenced by the different parking tariffs. The costs of charging are given in € per kWh and are differentiated for slow charging and fast charging. This differentiation is made since fast charging requires higher initial investment costs compared to slow charging (ANWB, 2022a). The presented tariffs are based on the current prices (reference date November 2022) that have to be paid when using existing public charging points in the Netherlands.

Alternative functions for parking: Since electric vehicles will be charged on a charging square, fewer vehicles will be parked in the street. This results in a lower demand for parking spaces in the street, and therefore alternative functions can be located on the locations which otherwise would have been parking spaces. In this thesis, two new purposes will be tested as well as the possibility that nothing changes. The two new purposes will be that parking spaces are replaced by greenery or that parking spaces are replaced by facilities for sports and exercise. Both these measures can be implemented on an individual parking space as well as the combined space of the parking spaces that are repurposed. If individual chargers would be located near parking spaces, the demand for parking in the street would not reduce and it is not possible to provide alternative functions in the street.

3.1.2. Experimental design

As has been mentioned, a decision has to be made about whether to use a full factorial design or a fractional factorial design. In order to be able to determine which design is going to be used, the number of unique combinations needs to be determined. In a full factorial design, all 19,683 combinations (nine attributes with three levels) would be included. However, due to practical reasons it is not possible to include all 19,683 combinations and ask every respondent to indicate their preference for every combination. Hence, a fractional factorial design will be used in this thesis.

In order to be able to set-up the fractional factorial design, it is needed to select a series of unique choice options to be included in the design. According to Hensher et al. (2015), an orthogonal design needs to be used. Orthogonality means that all attributes are statistically independent of each other (Allen, 2017; Frost, 2022; Hensher et al., 2015). To create an orthogonal design, every attribute level must appear an equal amount of times in the fractional factorial design (Hensher et al., 2015). The statistical software Ngene (Choice-metrics, 2021) has been used in this thesis to create the fractional factorial design. In Appendix A the fractional factorial design is shown including the Ngene syntax used to generate the design.

After the fractional factorial design was created, the output was tested for orthogonality. The results showed that the created design is orthogonal and thus can be used to create the different alternatives. In the fractional factorial design shown in Appendix A, each line shows one complete choice set including two context variables (column 1 & 2) and all attributes for alternative A (column 3-9) and B (column 10-16) excluding the type of charger. The context variables apply to both alternatives, while alternative A and B are unique. There is chosen to create the alternatives including the context variables at once in Ngene since otherwise alternative A will have a different context compared to alternative B making it impossible and illogical to combine both alternatives in one choice task.

Next to the included variables in the experimental design, type of charger (slow, fast, or both) is also included in the stated choice experiment. The type of charger has not been included in the experimental design since the type of charger (slow, fast, or both) determines which price range has to be presented in each alternative. If the alternative only has a fast charger, the costs for slow charging are not shown in the experiment and therefore coded as zero. If the experimental design would be created including the type of charger, alternatives with only fast chargers will also have cost levels for slow charging. By coding the cost levels of slow charging zero, a non-orthogonal design would be created. Therefore, the type of charger has been used in a different way in the experimental design.

The created experimental design was used for the unique combinations of all charger types (slow-slow, slow-fast, slow-both, fast-fast, fast-both, both-both) included in the study. By using the created experimental design six times, the column for the costs of slow charging is not used if the alternative only provides fast charging and vice versa. In this way, the design remains orthogonal. Since the fractional factorial design consists of 81 choice sets (Appendix A), and the experimental design has been used six times, the final experimental design consists of 81 * 6 = 486 unique choice sets. The 486 different choice sets are built up by using the same fractional factorial design for each of the six different combinations of chargers (slow-slow, slow-fast, slow-both, fast-fast, fast-both, both-both).

All different choice sets were tested to see if the alternatives were not identical. This is important since it is considered as irrelevant to make a choice between two identical alternatives. Unfortunately, there were some identical alternatives and therefore the levels were shuffled for some attributes while still maintaining orthogonality in order to create alternatives which are not identical.

3.2. Context of the study

As has been mentioned in section 3.1.1, context related attributes are included in this study. This means that every respondent will be presented with a hypothetical situation in which the choice task has to be made. Before the respondent is presented with the different choice tasks, an introduction about the procedure and topic is given. The introduction makes sure that respondents know in which context the choice task has to be made. In the introduction, the respondent is made aware of the fact that the presented alternatives consist of multiple charging points and therefore are in fact charging squares. Next, an explanation is given to the respondent about the context with an overview of all attributes and levels. The context in which the respondents must answer each choice task is as follows: "*Imagine that you have to leave by car within **1, 4 or 8 hours**, but you still need to charge the electric vehicle for **50, 100 or 150 kilometers**. Which of the presented charging locations do you choose?*"

There is chosen to only vary the available amount of time to charge the electric vehicle and the range that needs to be charged. Changing more variables in the context would increase the burden on the respondent and might decrease the ability to imagine the presented situation. In order to make sure respondents are able to imagine themselves in the context, the levels used are made as reasonable as possible.

Each respondent is presented with twelve choice tasks which all have to be evaluated individually. In this study, every choice task presented to the respondent will have a different context, but the two presented alternatives in a single choice task always have to be evaluated in the same context. There is chosen to use one context which is the same for both alternatives as comparing the two alternatives is otherwise impossible.

3.3. Pilot study

Before the questionnaire was finalized, a pilot study was conducted in order to optimize the questionnaire for the respondents. In the pilot study, respondents were asked to comment on the content (is the questionnaire clear and understandable) as well as the layout (is the questionnaire esthetically appealing and not too complex). During the pilot study, all questions were entered in the same way as would be the case in the final questionnaire. Only the number of choice tasks presented to the respondents during the pilot study was reduced to six. There was chosen to only present six choice tasks as the intention of the pilot study was to test if everything was clear, and respondents understood what needed to be done. The purpose was not to collect any data. In the final questionnaire each respondent is presented with twelve choice tasks, an amount which was collectively considered to be acceptable by the respondents of the pilot study. According to Bridges et al. (2011) and Mangham et al. (2009), there will be a higher burden on the respondents if the number of choice tasks exceeds sixteen.

The questionnaire was tested among several persons in different age categories with different backgrounds, both males and females. After every response, the author spoke to the respondent to get feedback on the questionnaire. The received feedback was immediately implemented in the questionnaire to test with the next respondent. If respondents would give contradictory feedback, it was decided to use the general opinion of all pilot testers. Overall, some minor adoptions were made to the questionnaire but in general all pilot testers concluded that the questionnaire was clear and not too complex. After the pilot study, the questionnaire was submitted to the Ethical Review Board of the Eindhoven University of Technology which approved the questionnaire on January 5th, 2023.

3.4. Description of data collection method

To collect the data, an online questionnaire was constructed in LimeSurvey (2023) that consisted of three parts. The first part of the questionnaire consisted of selection criteria that needed to be met by the respondent in order to proceed to the second part of this questionnaire. The second part of the questionnaire was the stated choice experiment in which respondents must indicate which of the presented alternatives is preferred. If neither of the options is preferred, the "none-choice" could be chosen. The third and final part of the questionnaire consisted of socio-demographic questions in order to test for representativeness after data collection. Below a small elaboration is given about each of the three parts. The questionnaire as presented to the respondents is shown in Appendix B.

3.4.1. Selection criteria

In order to acquire reliable responses, two exclusion criteria are included in this study. The first exclusion criterion is whether the respondent has a driver's license. The second exclusion criterion is the number of kilometers driven in the last twelve months. The respondent is excluded from the study if they do not possess a driver's license. If the respondent owns a driver's license but has driven zero kilometers in the last twelve months, the respondent is also excluded from this study.

These two selection criteria were chosen since now all respondents have made at least one parking decision in the last twelve months and are therefore considered to be able to project themselves into the context of this study. There is chosen to not exclude respondents that drive a petrol vehicle since these respondents will have to adopt an electric vehicle in the future and in order to choose a suitable location, their responses are also needed. Additionally, the number of electric vehicle drivers is limited and only allowing electric vehicle drivers to participate, could result in biased results. In addition to the selection criteria, additional questions were included where respondents could indicate where they park their car at the home side, and if they drive in an electric vehicle. In this way, it is possible to detect differences between electric vehicle drivers and non-electric vehicle drivers. These questions were not used to exclude respondents from the study.

3.4.2. Stated choice experiment

In the stated choice experiment every respondent was presented with twelve different choice tasks, two for each combination of chargers (slow-slow, slow-fast, slow-both, fast-fast, fast-both, both-both). The stated choice experiment included all attributes mentioned in section 3.1.1. Below in figure 7, an example is given of a choice task that has been presented to the respondents. The example shows the combination of the context in which the decision has to be made and the two charging location alternatives with their corresponding levels for the seven attributes. Since the questionnaire is distributed among Dutch respondents only, the questionnaire was created in Dutch. In total 486 different choice tasks have been created and since only twelve are presented to a single respondent, the choice tasks are randomly assigned to respondents.

*Stel, u moet **over 4 uur** weg met uw auto, maar u moet uw auto nog voor **150-kilometer bijladen**. Welke oplaadlocatie zou u kiezen? Als u geen van beide oplaadlocaties zou willen gebruiken, kies dan voor "Geen van beide".

	Laadlocatie 1	Laadlocatie 2
Type laadpunt	Alleen langzaam laders	Zowel langzaam laders als snelladers
Kosten langzaam laden	€0,55 per kWh	€0,40 per kWh
Kosten snelladen	-	€0,60 per kWh
Loopafstand	150 meter (in de buurt)	50 meter (in de straat)
Laadzekerheid	95%	75%
Toezicht op laadlocatie	Geen toezicht	Vanuit de (omliggende) woning(en)
Auto verplaatsen binnen	De auto hoeft niet verplaatst te worden	2 uur nadat de accu vol is
Wat komt er extra voor terug?	Meer groen	Geen veranderingen

Laadlocatie 1

Laadlocatie 2

Geen van beide

Klik hier voor de toelichting op de variabelen

Figure 7. Example of a choice task

3.4.3. Socio-demographic questions

In order to test if the collected data matches any population in the Netherlands, several socio-demographic related questions were included at the end of the questionnaire. The socio-demographics are not only collected to test for representativeness, but also to be able to investigate different sub-groups within the dataset. The levels used in this part of the questionnaire are based on levels commonly used to collect socio-demographic information. In this way, the sample can be compared to the "Nationaal Laadonderzoek" in order to see if there is a match between both samples. The "Nationaal Laadonderzoek" is a study among Dutch electric vehicle drivers related to the adoption of electric vehicles, charging behavior, and smart charging (Netherlands Enterprise Agency et al., 2022). The socio-demographic questions included in the questionnaire are related to gender, age, four-digit zip code, educational level, household composition and income.

There is chosen to include the socio-demographic questions at the end of the questionnaire to reduce the number of questions that needed to be answered before reaching the choice tasks. If too many questions had to be answered before reaching the choice tasks, respondents might be inclined to stop participating or give false answers. Additionally, including the socio-demographic questions at the end of the questionnaire reduces the risk of respondents moving out during the experiment since no personal information has been provided yet (Van der Waerden, 2022)[14]. Additionally, since socio-demographic questions are easy to answer, they were included at the end as well.

[14] Personal communication, 2022

3.4.4. How is the data collected?

To obtain respondents for this study, the online questionnaire is distributed among as many potential respondents as possible in several ways. In order to evaluate every choice set at least one time, forty-one different respondents are needed (486/12 = 40.5). However, for more reliable results, every choice set needs to be evaluated more than once and therefore more respondents are needed. To acquire as many respondents as possible, the link to the questionnaire is published on social media, among friends and family through direct messaging, e-mailed directly to potential respondents and data collection partners and distributed through door-to-door advertising. By using several ways to distribute the questionnaire, the aim is to acquire a representable sample. After approval by the Ethical Review Board of the Eindhoven University of Technology on January 5th, 2023, the data collection started on January 9th, 2023. Data was being collected until February 1st, 2023.

There was chosen to create an online questionnaire since distributing the questionnaire over the internet is easier compared to physical distribution. Using the internet enables the researcher to reach many potential respondents with only one post. Additionally, using an online questionnaire is less time and cost consuming compared to distributing a physical questionnaire (Lefever, Dal, & Matthíasdóttir, 2007; Schmidt, 1997). Another benefit of using an online questionnaire is that the respondent is able to answer the questionnaire when it suits the respondent, there is no time pressure (Debois, 2017; Evans & Mathur, 2018; MWM2, 2023). A third benefit that will be mentioned here is that it is possible to make certain parts of the online questionnaire mandatory, so respondents are not able to skip these questions, something which is not possible with a physically distributed questionnaire (Debois, 2017). Finally, by distributing a questionnaire online, the answers that are given by the respondents will be entered directly into the database while physically distributed questionnaires need to be entered manually into the database by the researchers, increasing the risk of a typing error (MWM2, 2023; QuestionPro, 2022). However, the invitation to participate in the questionnaire was not only distributed over the internet. The questionnaire was also distributed by physically handing out QR-codes with a direct link to the questionnaire among potential respondents in order to acquire a representable sample. At the end of the questionnaire, every respondent had the possibility to share the questionnaire in their own network. The intention of the researcher was to reach more potential respondents and increase the representativeness of the sample.

In order to acquire more respondents, companies related to electric vehicle charging were contacted. In Appendix C, an overview is given of all companies that were contacted in this thesis and if they were willing to help distribute the questionnaire. Some companies were not willing to share the questionnaire with their customers, but they were (sometimes) willing to share the questionnaire among their own employees to help acquire more responses.

3.5. Analysis methods

In order to analyze the collected data, the dataset must be prepared first. When preparing the dataset, incomplete responses are removed. Once the dataset is prepared, the data can be coded. In order to analyze the data, this study will use effect coding. The socio-demographics of the dataset are analyzed using IBM SPSS Statistics 27 (IBM, 2023) and in order to estimate the Multinomial Logit model and Latent Class model Nlogit6 (Econometric Software Inc., 2016) will be used.

3.5.1. Descriptive analysis

In order to be able to describe the socio-demographics of the respondents that participated in this study, questions regarding gender, age, four-digit zip code, household composition and income were included at the end of the questionnaire. The descriptive analysis will show what type of respondent participated in the questionnaire. Additionally, by comparing the sample to the "Nationaal Laadonderzoek" it is possible to identify if this sample matches the sample of the "Nationaal Laadonderzoek". Because of the measurement level of the variables, a Chi-Square goodness of fit test will determine if the samples match (Statistics How To, 2023).

3.5.2. Effect coding

As mentioned, this study applies effect coding to analyze the results. An overview of all variables and how they were coded is shown in Appendix D. In section 3.5.2.1 the effect coding of the main variables included in this study will be elaborated and section 3.5.2.2 will elaborate on the coding of the included context effects.

3.5.2.1. Coding of the main variables

Since all main variables in the stated choice experiment have three levels, the same coding scheme can be applied. Table 3 shows the coding scheme that has been used for the variables containing three levels.

Table 3. Effect coding scheme for three level attributes

	e1	e2
Level 1	1	0
Level 2	0	1
Level 3	-1	-1

According to effect coding, the base level receives a value of minus one (-1) for each variable (Hensher et al., 2015). In this study, the third level is set as the base level and coded accordingly. One of the reasons why there is chosen for effect coding is because this method, compared to an alternative coding scheme like dummy coding, will provide a unique value for the utility (Hensher et al., 2015). By assigning a minus one value to the base level, it is possible to determine which level has a larger impact on the utility (Hensher et al., 2015).

The only variable which is coded differently is the variable "Type of charger". For this variable, the coding scheme in table 4 has been used. There has been chosen to use this coding scheme because the interpretation becomes simpler. If a type of charger is present, it is coded with a zero (0) while if the type of charger is not present, the level is coded with minus one (-1). In this way, if both type of chargers are present, both effect coding values are zero (0) and the utility of the charging square will be the highest since if either of the type of chargers is not present at a location, and coded as minus one (-1), the utility will decrease. There is chosen for this scheme since having fewer type of chargers to choose from will result in a decrease in overall utility.

Table 4. Effect coding scheme for three level variable "Type of charger"

	e1	e2
Only slow chargers	0	-1
Only fast chargers	-1	0
Both type of chargers	0	0

3.5.2.2. Coding of the context effects

In section 3.5.2.1 the effect coding of the main variables was described, and this section will focus on the coding of the context effects. The first context variable included in this thesis is the range that needs to be charged and the second context variable is the available time to charge. For both context variables the same coding scheme has been used as was used for the other variables included in this study (see table 3). In Appendix D, the effect coding scheme of both context variables is shown. In both context variables, the third level is also used as the base level and therefore, since effect coding is used, the base level of both context variables has a minus one value (Hensher et al., 2015).

In order to be able to estimate parameter values for the context variables, the effect coded values of the context variable and main effect variables were multiplied. Below, an example is given on how the context effects are included in this thesis. In the example, the context effects for all ranges that have to be charged with all different cost levels of slow charging are presented. Based on Appendix D, the effect coding schemes of the two variables are again presented in table 5.

Table 5. Effect coding schemes for all "Range" levels and all "Cost" levels for slow charging

Context (range)		
	X11	X12
50 kilometers	1	0
100 kilometers	0	1
150 kilometers	-1	-1

Costs slow charging		
	X41	X42
€0.25 per kWh	1	0
€0.40 per kWh	0	1
€0.55 per kWh	-1	-1

Since the process of creating the context effects is equal for every variable, the process of creating the context variable is only presented for the three range levels with the three cost levels of slow charging in table 6.

Table 6. Context effect between the three range levels and the three cost levels for slow charging

The effect of cost within different contexts				
	X141	X142	X151	X152
	X11 * X41	X11 * X42	X12 * X41	X12 * X42
50 kilometers - €0.25 per kWh	1	0	0	0
50 kilometers - €0.40 per kWh	0	1	0	0
50 kilometers - €0.55 per kWh	-1	-1	0	0
100 kilometers - €0.25 per kWh	0	0	1	0
100 kilometers - €0.40 per kWh	0	0	0	1
100 kilometers - €0.55 per kWh	0	0	-1	-1
150 kilometers - €0.25 per kWh	-1	0	-1	0
150 kilometers - €0.40 per kWh	0	-1	0	-1
150 kilometers - €0.55 per kWh	1	1	1	1

3.5.3. Multinomial logit analysis

During the stated choice experiment, every respondent decided twelve times on their preferred charging location. To analyze discrete choice behavior, a Multinomial Logit model (MNL) is used in many occasions (Hensher et al., 2015). This model assumes that each respondent chooses the charging location which results in the highest utility and therefore acts rational (Cascetta, 2009; Hensher et al., 2015). In order to choose the alternative which results in the highest utility, trade-offs have to be made by the respondent. These trade-offs are made between the different attributes and the corresponding levels included in each choice task.

The utility that each alternative produces can be divided into two parts, the structural utility and the random utility or error term. Structural utility can be observed while random utility cannot be observed. The total utility is defined by equation (3.1) (Train, 2003).

$$U_{iq} = V_{iq} + \varepsilon_{iq} \qquad (3.1)$$

Where U_{iq} is the total utility of alternative *i* for individual *q*; V_{iq} is the structural utility calculated by equation (3.2) and ε_{iq} is the random utility or error term.

$$V_{iq} = \sum_{n} \beta_n * X_{inq} \qquad (3.2)$$

Where β_n is the weight of attribute *n* and X_{inq} is the score of the alternative *i* on attribute *n* for individual *q*.

The MNL model is used to calculate the probability that an alternative will be chosen (Hensher et al., 2015). The probability will always be a value between zero and one for each alternative in the choice set, summing to one for all attributes combined.

Equation (3.3) shows how to determine the probability that an alternative will be chosen.

$$P_{iq} = \frac{e^{V_{iq}}}{\sum e^{V_{iq}}} \tag{3.3}$$

Where P_{iq} is the probability that alternative *i* is chosen by individual q and V_{iq} is the structural utility

In order to test if the MNL model has an accurate prediction, the model's goodness-of-fit is tested. McFadden's Rho-Square (ρ^2) will have a value between zero and one. To test the goodness-of-fit of a MNL model, McFadden's Rho-Square value is calculated by equation (3.4). A value between 0.2 and 0.4 for McFadden's Rho-Square indicates a perfect fit of the model (McFadden, 1977).

$$\rho^2 = 1 - \frac{LL(\beta)}{LL(0)} \tag{3.4}$$

Where $LL(\beta)$ is the log-likelihood of the estimated model and $LL(0)$ is the log-likelihood of the null model. The log-likelihood of the estimated model is calculated by equation (3.5).

$$LL(\beta) = \sum_q \sum_i y_{iq} \ln{(P_{iq})} \tag{3.5}$$

Where y_{iq} is one if alternative *i* was chosen by individual *q* and otherwise zero; ln() is the natural logarithm and P_{iq} is the probability that individual *q* will choose alternative *i*.

The log-likelihood of the null model can be calculated by multiplying the number of choices with the natural logarithm of $\frac{1}{3}$ since there are only three choice options in each choice task (alternative 1, alternative 2, and the none-choice).

3.5.4. Latent class models

Next to the MNL model estimation, a latent class (LC) model will be estimated. LC models try to identify different groups within the sample data based on their preferences (Aflaki, Vigod, & Ray, 2022; Hagenaars & McCutcheon, 2002). Based on the LC model estimation results, hidden patterns in de sample can be discovered (Weller, Bowen, & Faubert, 2020). Groups identified by LC models share the same choice behavior and can therefore be referred to as latent groups or classes (Weller et al., 2020).

To decide on the best number of classes used in the LC model estimation, the Bayesian Information Criterion (BIC) is often used (Bauer & Curran, 2021; Magidson & Vermunt, 2004). The BIC is expressed by equation (3.6).

$$BIC = -2LL + \ln(N)\,M \tag{3.6}$$

Where LL is the log-likelihood, *N* is the sample size and *M* is the number of parameters. If multiple models are compared, Magidson & Vermunt (2004) state that a lower BIC value is preferred.

3.6. Conclusion

This chapter described the theoretical background of a stated choice experiment extensively and concludes that it is indeed a suitable method to identify user preferences when deciding on a public charging square in urban environments. This is concluded since stated choice modelling can be used to analyze the preference for new, non-existing situations. Next to the theoretical background, the attributes and context used in this study were elaborated on. In total, nine different attributes were included in the stated choice experiment, all with three unique levels. In order to set up the experiment, all attributes and corresponding levels were included in a fractional factorial experimental design created by Ngene. This resulted in 486 unique choice sets of which each respondent was randomly presented with twelve choice sets during the data collection period. Not only the twelve choice sets were presented to a respondent. Respondents were also presented with questions used as selection criteria and questions regarding their socio-demographics. In order to collect the data needed for the analysis, this chapter has elaborated on the data collection methods used.

Not only has this chapter described the theoretical background of the stated choice experiment and the final setup of the experimental design, this chapter also described the setup of the questionnaire and how the data was collected. Additionally, the statistical analysis methods that are going to be used in the remainder of this thesis were described. In the next chapter, the results of the descriptive analysis, Multinomial Logit model and Latent Class model will be presented.

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4. Results

In this chapter, the results of the data collection and analysis methods described in chapter three will be presented. This chapter will start with the results of the descriptive analysis. After the descriptive results have been presented, this chapter will show the results of the Multinomial Logit model and the Latent Class model.

4.1. Descriptive analysis

After the data collection period of almost one month (January 9th until February 1st, 2023), the number of responses in the dataset was considered sufficient since the dataset contained N = 672 responses and for several days the number of new respondents only increased by one or two per day. Since the final dataset contained unusable/invalid responses, the dataset was filtered. In this way, only suitable and valid responses were kept in the dataset. Additionally, since respondents had the possibility to choose the answer option "Other, namely…" and provide an answer outside the provided options for some of the included questions, recoding several responses was required. Appendix E gives a detailed description of the procedure to select useful/valid cases and recode variables in the dataset. By filtering and recoding the variables in the dataset, the collected data is suitable for further analysis. All modifications resulted in a reduction of 135 responses from N = 672 to N = 537 responses.

The final dataset used for the analysis of the MNL and LC models in this thesis contains N = 485 responses. An additional 52 responses were excluded from the dataset since McFadden's Rho² indicated that a model without incomplete responses and without respondents choosing the same (i.e. 1st, 2nd or 3rd) option for each choice set, performed better. These responses were removed since answering the same answer option for each choice set was considered suspicious. The descriptive analysis presented below will be based on the dataset that contains N = 485 responses since this dataset has been used to estimate the MNL and LC models in sections 4.3 and 4.4.

All respondents included in the final dataset have a driver's license and drive more than zero kilometers on a yearly basis since this were the two selection criteria. The majority of the respondents (N = 193) drives between 10,000 – 20,000 kilometers on a yearly basis. Below, the socio-demographic distribution will be elaborated based on the answer options in the questionnaire.

In the sample, **the majority of the respondents were between 45 – 65 years old (N = 209, 43%)**, with 440 respondents (91%) being between 25 – 80 years old. The age categories in the sample ranged from respondents between the age of 15 – 20 years old (N = 1, <1%) and respondents over 80 years old (N = 5, 1%). **376 respondents (78%) in the sample were male and 99 respondents (20%) were female.** The remaining 10 respondents (2%) preferred not to mention their gender or identify as neither a male nor a female.

The highest completed educational level reported in the sample was a "Master (HBO or WO), PhD degree" by 192 respondents (40%). 258 respondents (53%) completed a vocational education, and the remaining 35 respondents (7%) completed their secondary school or preferred not to mention their highest completed educational level.

When asked about the household composition, **the largest group of respondents were classified as a couple (N = 222, 46%), followed by the household composition couple + child(ren) (N = 174, 36%)**. 65 respondents (13%) were classified as a single-person household and 24 respondents (5%) had a different household composition or preferred not to mention their household composition. In the sample, **334 respondents (71%) have an income equal to or higher than €40,000 annually**. The remaining 141 respondents (29%) have a lower income or preferred not to mention their annual income.

Most (64%, N = 309) of the respondents own a private vehicle and 34% (N = 166) indicated to drive a (company) lease car. The remaining 10 respondents (2%) use a different type of transportation or preferred not to indicate this. Each respondent was also asked to indicate where their vehicle is predominantly parked and **63% (N = 304) indicated to park on private property**, 26% (N = 127) uses public parking along the road, 9% (N = 42) uses public parking in a (small) car park/collective parking and the remaining 3% (N = 12) of the respondents park their vehicle in a parking garage.

Each respondent was asked to provide the four digits of their zip code as part about socio-demographic questions. Based on the provided zip codes, figure 8 has been created, which presents the distribution of the respondents across the Netherlands. In the figure, every zip code area which has at least one respondent is marked red. The darker the color, the more respondents participated with that same zip code. As is visible, there is at least one respondent living in each province of the Netherlands, however, the distribution over the provinces is not equal. Most of the zip code areas in the sample are only represented once in the dataset but there are also zip code areas where over five respondents have participated in the study.

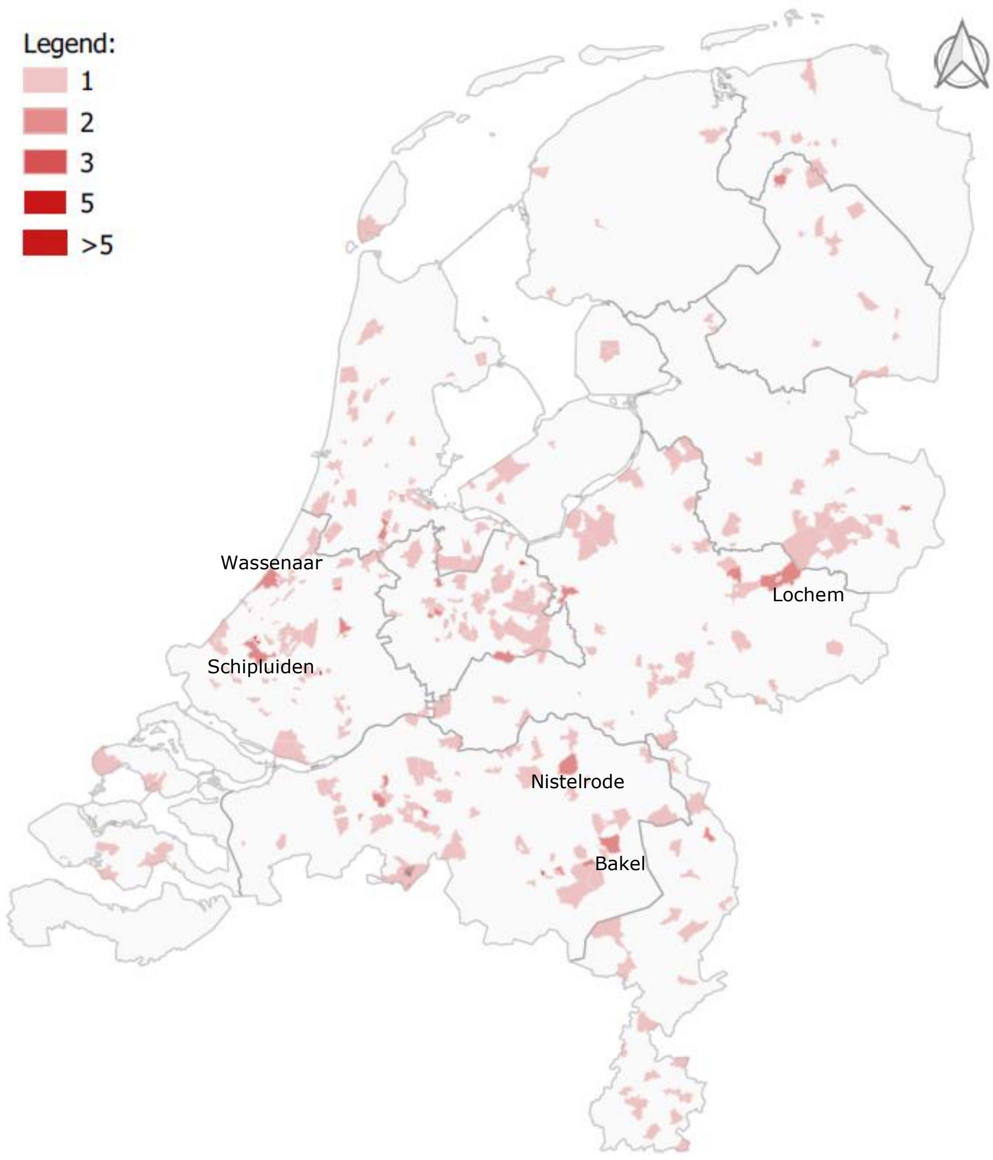

Figure 8. Distribution of respondents across the Netherlands

However, the zip code was not only used to determine the distribution of respondents across the Netherlands. Since this thesis focuses on urban environments, knowing if the respondents live in an urban or rural environment is key. Based on the zip code, the urbanity level has been determined by using publicly available data from the CBS (2023b). 17% (N = 80) of the respondents in the dataset live in an urban environment with over 2,500 addresses per square kilometer (km²). 28% (N = 137) lives in an urban environment with 1,500-2,500 addresses per km² and 21% (N = 103) of the respondents lives in an urban environment with 1,000-1,500 addresses per km². Of the remaining respondents, 19% (N = 92) lives in a rural environment with 500-1,000 addresses per km² and 15% (N = 73) in a rural environment with less than 500 addresses per km². Overall, 66% of the respondents lives in an urban environment making this dataset relevant for this thesis.

Since the electric vehicle is a key aspect in this thesis, every respondent was asked whether or not they drive an electric vehicle. **The majority of the respondents, 75% (N = 362), indicated to drive or at least sometimes drive in an electric vehicle (not including hybrids).** The remaining 25% (N = 123) has not driven an electric vehicle yet. Next to the question about driving an electric vehicle, the respondents also had to indicate whether or not they have the possibility to charge an electric vehicle on private property. 53% (N = 256) of the respondents indicated to have this possibility while the remaining 47% (N = 229) of the respondents do not have this option. Charging an electric vehicle is not only possible near the residence of the respondent, but there also might be the possibility to charge an electric vehicle near the workplace. Of all respondents, 53% (N = 256) indicated to be able to charge an electric vehicle near the workplace, 20% (N = 95) indicated to not have this possibility. The remaining respondents (3%, N = 12) do not know if this possibility exists, or always works from home/is unemployed (25%, N = 122).

Table 7. Descriptive statistics

Variable[15]		Count (N = 485)	Percentage
Gender	Male	376	77.5%
	Female	99	20.4%
	Other/prefer not to say	10	2.1%
Age	Below 25 years	35	7.2%
	25 – 65 years	331	68.2%
	Over 65 years	114	23.5%
	Prefer not to say	5	1.1%
Highest completed education	Vocationally education	106	21.9%
	Theoretically educated	365	75.3%
	Unknown/no completed education/prefer not to say	14	2.8%
Household composition	Single person household	65	13.4%
	Multi-person household without children	222	45.8%
	Multi-person household with children	188	38.8%
	Other/prefer not to say	10	2.0%
Income	<€20,000 euro	14	2.9%
	€20,001 – €40,000 euro	53	10.9%
	>€40,001 euro	344	70.9%
	Prefer not to say	74	15.3%
Urbanity level	Urban environment	217	44.7%
	Not urban/rural environment	103	21.2%
	Rural environment	165	34.1%

[15] The table presents the classes that have been used in the LC membership analysis.

4.2. Representativeness of the sample

To test if the sample of this study fits the population investigated by the Dutch National Charging study, results of the "Nationaal Laadonderzoek 2021" have been used to compare the sample to (Netherlands Enterprise Agency, Vereniging Elektrische Rijders, & ElaadNL, 2021a). The "Nationaal Laadonderzoek" is a study among Dutch electric vehicle drivers related to the adoption of electric vehicles, charging behavior, and smart charging (Netherlands Enterprise Agency et al., 2022). Below, table 8 presents the result of the representativeness analysis.

In order to test if the samples match, a Chi-Square test is used (Frost, 2023). A Chi-Square test is conducted to reveal if the difference between the observed data count and the calculated expected count is caused by a correlation between the variables or due to chance (University of Southampton, 2023). The observed counts and percentages are based on the collected data, while the expected counts and percentages are generated by using the results of the "Nationaal Laadonderzoek 2021". The expected percentages are determined by grouping the results of the "Nationaal Laadonderzoek" into the same categories as the dataset. Once the percentages are determined, the expected count is calculated by multiplying the expected percentage with the total count in the dataset. The residual value is the difference between the observed and expected count. In order to determine the Chi-Square value, the sum is taken of all residuals squared divided by the expected count for all categories. The closer the residual value is to zero, the better the match between both observed and expected counts will be.

Table 8. Representativeness of the sample compared to the "Nationaal Laadonderzoek"

Category		Observed		Expected		Residual	Chi-Square	p-value
		Count	%	Count	%			
Gender	Male	376	78%	437	92%	-61	106.436	.000
	Female	99	20%	38	8%	61		
Highest completed education	Vocationally educated	106	23%	125	27%	-19	3.859	.049
	Theoretically educated	365	77%	346	74%	19		
Household composition	Single person household	65	14%	38	8%	27	25.068	.000
	Multi-person household without children	222	47%	214	45%	8		
	Multi-person household with children	188	40%	223	47%	-35		
Income	<€40,000 euro	67	14%	58	12%	9	5.624	.060
	>€40,000 euro	344	71%	366	76%	-22		
	Prefer not to say	74	15%	61	13%	13		
Urbanity level[16]	Urban environment with over 2,500 addresses per km²	80	16%	114	24%	-34	15.349	.004
	Urban environment with 1,500-2,500 addresses per km²	137	28%	132	27%	5		
	Urban environment with 1,000-1,500 addresses per km²	103	21%	86	18%	17		
	Urban environment with 500-1,000 addresses per km²	92	19%	81	17%	11		
	Rural environment	73	15%	71	15%	2		

[16] Compared to data of the CBS (2023b)

Before the representativeness results are further elaborated, it has to be noted that all participants of the "Nationaal Laadonderzoek 2021 (N = 2,204)" drive an electric vehicle while the results of the current study are also based on response from fossil-fuel drivers. The choice was made to still compare the data of this study to the "Nationaal Laadonderzoek" since both studies are centered around charging electric vehicles. Additionally, in the future, current fossil-fuel drivers will need to switch to an electric vehicle. It could be argued that the Dutch National Travel survey (CBS, 2023a) would be a better dataset for comparison, however, since the Dutch National Travel survey focusses on developments in travel behavior of the Dutch population and the electric vehicle is not a key aspect in the Dutch National Travel survey, there is chosen to not use this dataset for comparison. Furthermore, **it is stated here that the test for representativeness is conducted to see if both samples match or if the sample of this study is a specific group of individuals**.

As is visible, relatively more females have participated in this study compared to the "Nationaal Laadonderzoek" (20% compared to 8% respectively). However, this study is just like the "Nationaal Laadonderzoek" dominated by male respondents. This indicates that males might be more interested in this topic compared to females. Just as in the "Nationaal Laadonderzoek", the respondents in the sample are highly educated with a bachelor's or master's degree (77% compared to 74% respectively). In the sample of this study, more respondents have completed a master's degree compared to a bachelor's degree, something which is the other way around in the "Nationaal Laadonderzoek". However, **according to the Chi-Square test results, the distribution of gender ($p < .001$) and highest completed education ($p = .049$) differ between the "Nationaal Laadonderzoek" and the collected data**.

Looking at the household composition and the income distribution between the sample and the "Nationaal Laadonderzoek", most respondents in both datasets have an income higher than €40,000 annually (71% compared to 76% respectively) and mainly consist of a multi-person household (87% compared to 92% respectively). **The results of the Chi-Square test show that the distribution among the household composition differs between the "Nationaal Laadonderzoek" and the dataset ($p < .001$). The distribution among the income levels is, according to the Chi-Square test, similar in the "Nationaal Laadonderzoek" and the collected data ($p = .060$).**

Based on the descriptive analysis, 66% of the respondents live in an urban environment. However, in order to test if the distribution of the respondents across the different urbanity levels is comparable to the distribution in the Netherlands, the dataset is compared to data provided by the CBS since the "Nationaal Laadonderzoek" did not include this data sufficiently for comparison. As is visible from the results, **the distribution of respondents over the different urbanity grades is not similar to the actual distribution in the Netherlands ($p = .004$)**. This is because fewer participants that live in an urban environment with over 2,500 addresses per km² participated in this study compared to the expected number of respondents for this urbanity grade. Additionally, a lot of respondents that participated in this study live in an urban environment with 1,000-1,500 addresses per km² compared to the expected distribution.

Therefore, **overall, the sample collected in this study is considered not to be in line with the sample of the "Nationaal Laadonderzoek"**. Additionally, the sample is also not considered to represent the whole Netherlands because **educated males with a high income are overrepresented in the dataset**. **Since the current electric vehicle drivers have the best experience with the current infrastructure and know what is currently lacking and needs to be improved, the results of the presented analyses in sections 4.3 and 4.4 are still considered useful since almost 75% of the respondents in this study drive or at least sometimes drive an electric vehicle.** The results will help determine suitable locations for public charging facilities in residential environments in order to provide charging solutions for everyone in the future.

4.3. Multinomial logit model

As described in the methodology, a MNL analysis will be conducted. This section will describe the estimation results of the MNL model. The MNL model is used to predict the probability that an alternative will be chosen. Table 9 shows the results of the final MNL model that has been estimated in this study.

In order to estimate this model, insignificant context parameters were first stepwise removed from the model and finally, several context effects were completely excluded from the MNL model. Several context effects were ultimately excluded as the results of these context effects were considered doubtful. In the end, **only context effects for the constant, type of charger, costs of slow charging and having to relocate the vehicle were included in the model**. Section 3.5.3 presented how the contexts effects were included in this study.

4.3.1. Main effects MNL model

In this section, the results of the main effects in the MNL model will be elaborated. This section will only describe the results of the final estimated MNL model. Appendix F shows the output of the original MNL model and Appendix G shows the steps taken to stepwise remove insignificant parameters from the MNL model in Nlogit. Appendix H shows the results of the reduced MNL model before several context effects were completely excluded from the model. The MNL model containing all parameters (shown in Appendix F) has a McFadden's Rho² value of 0.268, and after removing the insignificant context parameters and completely excluding several context effects **the model has a McFadden's Rho² value of 0.259** (shown in table 9).

Since both values are roughly the same and between 0.2 and 0.4, this model is considered to have a perfect fit (McFadden, 1977). Even though McFadden's Rho² decreases by .009 for the reduced MNL model which excluded several context effects, the overall model performance is better since the included context effects in the reduced model are all significant at the 5% level while in the original model only 14 out of 68 included context effects were significant at the 5% level. Additionally, the results of the context effects are now acceptable where this was not the case before several context effects were completely excluded. That the overall model performance of the reduced model is better is confirmed by the calculations of the BIC value using equation (3.6). The BIC value of the original model is 10,100.15 while the reduced model has a lower BIC value (9,688.80) which is preferred when comparing multiple models (Magidson & Vermunt, 2004). Additionally, all signs in the model are as expected and several main parameters are significant as well.

Table 9. Overview of the estimation results for the reduced MNL model

Variable	Coefficient
Constant	-1.97218***
Main effects	
Slow chargers present	.87343***
Fast chargers present	.32680***
€0.25 per kWh (slow)	.45084***
€0.40 per kWh (slow)	.04090
€0.60 per kWh (fast)	.49003***
€0.75 per kWh (fast)	-.03917
Charge certainty 75%	-.21413***
Charge certainty 85%	.00439
50 meters walking distance	.29849***
150 meters walking distance	.03812
30 minutes after the battery is completely charged	-.19209***
2 hours after the battery is completely charged	-.07070**
The vehicle is left unattended at the charging location	-.12723***
The vehicle is visible from the (surrounding) dwelling(s)	.02741
Nothing changes	-.06890**
More greenery	.07510**
Context effects	
50 kilometer - Slow charger	.34035***
50 kilometer - Fast charger	-.44040***
There is one hour available to charge - Constant	-.23002***
There is one hour available to charge - Slow charger	-.60860***
There is one hour available to charge - Fast charger	1.02821***

There are four hours available to charge - Fast charger	-.32598***
There is one hour available to charge - €0.25 per kWh	-.16847***
There is one hour available to charge - 30 minutes after the battery is completely charged	.15496***
Model performance	
LL(B) LL(0) Rho²	-4,736.039 -6,393.924 0.259
***, **, * => Significance at 1%, 5%, 10% level.	

The value of the constant presented in table 9 is -1.972 which indicates that on average the utility of the "none-choice" alternative is 1.972 units less than that of the other alternatives in the choice sets. It means that **respondents are in general more likely to choose one of the two presented alternatives over the "none-choice" alternative**.

In order to have a better overview of the main effects presented above, figure 9 has been created to show the main parameters graphically. Additionally, below figure 9, the results of table 9 will be elaborated in more detail. When interpreting the results presented in table 9, it has to be taken into account that a different effect coding scheme has been used for the type of charger compared to the other included attributes (section 3.5.2). Appendix I shows a more detailed view of the results presented in figure 9.

Due to the coding of the type of charger (0 if present, -1 if not present), the values presented for the type of charger in figure 9 are the inverse of the values in table 9. The inverse has been presented for better readability of the figure because if both types of chargers are present, the part-worth utility of the type of charger is zero for that location. If either of the type of chargers is not present (coded as minus one) the part-worth utility of that location decreases by 0.87343 * -1 = -0.87343 for a slow charger not being present and with 0.32680 * -1 = -0.32680 when a fast charger is not present. Below figure 9 an elaboration is given of the main effects.

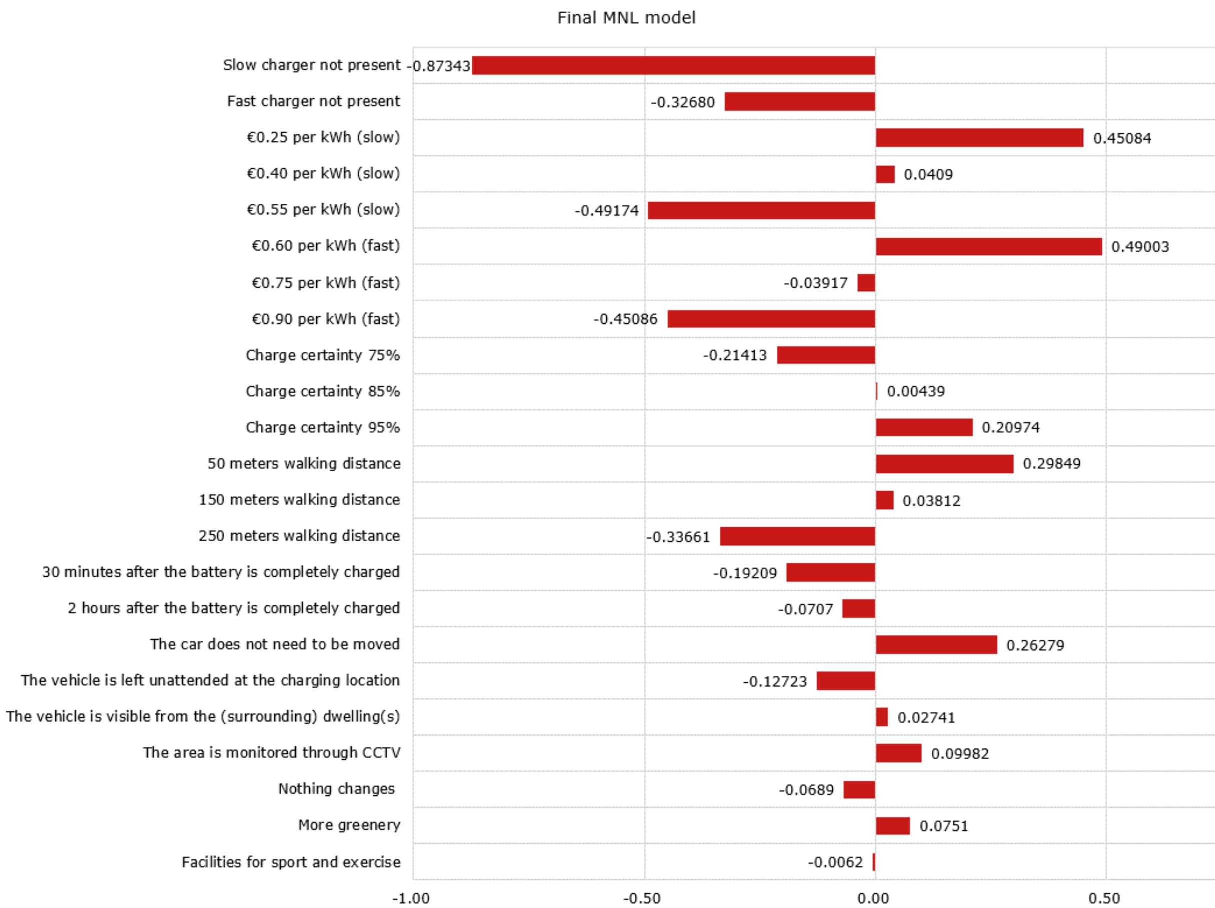

Figure 9. Graphical representation of the part-worth utilities of the main effects

Type of charger: If both slow and fast chargers are present at a public charging square, the utility of the alternative is the highest as the two corresponding dummy variables are zero, but once a slow charger is not present, the utility of that location decreases by 0.87343 while for fast chargers not being present, the utility decreases only by 0.32680 (all else equal). Therefore, this indicates that in residential areas, the population that is represented by the sample prefers the slow charger over the fast charger when considering a public charging square in residential environments. In general, people are for longer periods of time in their residential environment and therefore may have more time to recharge the battery of the electric vehicle. However, utility is highest if both types of chargers are available.

Costs: Both the effect of costs for slow charging as well as the costs for fast charging have the expected effect on the overall utility. If the costs decrease, the utility increases for that location (all else equal). Since the part-worth utility values for costs are not close to zero, they have a large effect on the overall utility of the location and need to be carefully taken into consideration. Since predominantly private vehicle owners (64%) have participated in this study, this is a logical result as private vehicle owners have to pay the costs themselves.

Charge certainty: Charge certainty also has a significant effect on the overall utility of a public charging square. Additionally, as expected, the participants of this study value a location with more certainty higher than a location with less certainty.

Walking distance: The shorter the walking distance from home to the public charging square, the higher the utility of the location becomes (all else equal). In the literature review, the identified maximum acceptable walking distance was around 150 meters (Netherlands Institute for Transportation Policy Analysis, 2018). In this thesis a walking distance of 150 meters has a part-worth utility of almost zero. Longer walking distances result in a negative impact on the utility, while shorter distances have a positive impact on the overall utility if all else remains equal. This indicates that it is preferred to have the charging square at close walking distances. Therefore, public charging should preferably be provided at a maximum walking distance of 150 meters, but it is better to create public charging locations at shorter distances from the residences.

Move vehicle within: Since one of the frustrations of electric vehicle drivers is not having a charger available when arriving at a charging location, for example, due to a completely charged electric vehicle that is not moved by its owner (mkb brandstof, 2023), this study implemented a financial incentive so the owner of the electric vehicle being charged would move the electric vehicle once the battery has been completely charged. As is visible from the part-worth utility results, both measures where the electric vehicle needs to be relocated have a negative impact on the overall utility (all else equal). Only when the electric vehicle can be parked near a charger as long as the user wants, a positive impact on the overall utility is found. This implies that the respondents are reluctant to move their electric vehicle once the battery is completely charged, which was also shown in the literature review by Philipsen, Schmidt, Van Heek, & Ziefle (2016). However, since it is a political decision made by the government to implement or not implement a financial incentive, it is not always possible to fulfill the wishes of the users.

Supervision on charging location: As is visible, the type of supervision does not have a major impact on the location decision for publicly charging an electric vehicle as all part-worth utilities are fluctuating around zero. Only if the vehicle is left unattended at a public charging square, the part-worth utility effect is negative. Both remaining attribute levels have a positive effect on the overall utility of a charging square regarding the supervision. However, monitoring the area through CCTV will result in a larger positive effect on the overall utility compared to the location only being visible from the (surrounding) dwellings.

Alternative functions for parking: Since charging will be provided at a centralized location, fewer parking spots are needed in the street. This is because some of the electric vehicles will have to charge for a longer period of time and as a result, these electric vehicles will not be parked in the street but on the charging square. Therefore, the empty parking spaces in the street can be repurposed. In the questionnaire this was communicated to the respondent as “What comes in return?”. In order for something to come in return, it is needed to remove something first. Therefore, respondents are in fact made aware that empty parking spaces are removed from the street and repurposed into something new. Based on the results, this sample will value a charging location with multiple charging points higher if greenery will be placed on the parking spots that can be repurposed. Having facilities for sport and exercise on the repurposed parking spots has a slightly negative effect on the overall utility, while if the parking spots are not repurposed, the overall utility of the charging location decreases the most (all else equal). However, this effect is only marginal on the total utility value of a charging location compared to the more important attributes.

4.3.2. Context effects MNL model

Above, the main effects have been presented, however, several significant context effects were also included in the final MNL model. In the original MNL model context effects were included for all main variables. However, in the final MNL model, only context effects for the constant, type of charger, cost (slow) and having to relocate the vehicle once the battery is completely charged were included. The results of the estimated context effects before excluding several context effects from the final model are shown in Appendix H.

In general, the results of the context effects have to be interpreted as follows. If there is a positive effect for the given context situation, the overall utility of that location will increase (all else equal). In contrast, if there is a negative effect for the given context, the overall utility of the location will decrease in the given context. The estimated parameters for the different context levels are presented in table 9. Since there are two context variables included in this thesis, the overall effect of the attribute level in the different contexts will be presented in figures and elaborated. The presented figures below are included in more detail in Appendix I.

As mentioned, context effects were also estimated for the constant. Based on the results, the context of having one hour available to charge has a significant effect at the 5% level. Due to the coding of the context variable for the available time to charge, the context effect presented in table 9 not only has an impact on the context situation where there is one hour available to charge, but also on the context situation where there are eight hours available to charge. Since having eight hours available to charge is coded as minus one (-1), the effect in this situation is equal to -0.23002 * -1 = 0.23002. Based on the significant context effect (-0.23002), **respondents are most likely to choose one of the alternatives over the "none-choice" if the presented context includes one hour available to charge**. As is visible in figure 10, in all context situations, respondents are more likely to choose one of the two alternatives over the "none-choice" alternative.

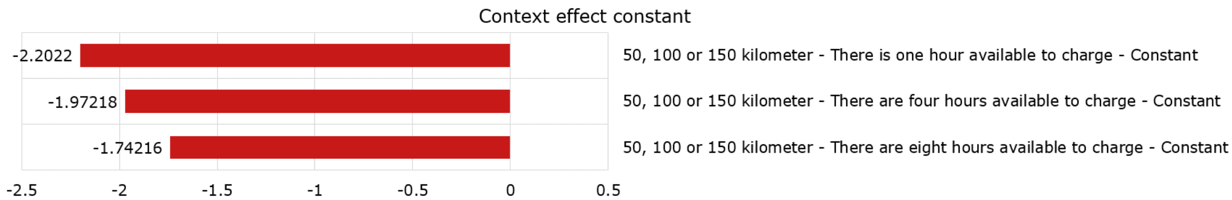

Figure 10. MNL path-worth utility of the context effects for the constant

Considering the results of the context effects in relation to the type of charger, presented in figure 11, **the population represented by the sample of this study prefers a slow charger at the charging location in most of the presented contexts**. This is stated because the utility of a charging location decreases for all context situations where a slow charger is not present except for one. The context where 150 kilometers in range needs to be charged within one hour and a slow charger is not present at the charging location results in a positive effect on the overall utility. This is a logical result since in this context it is essential to have a fast charger. Not having slow chargers at a location means that the location only has fast chargers.

Additionally, **if the context situation requires a fast charger at the public charging location since otherwise the range could not be charged within the available time but the public charging location does not have a fast charger, large negative effects are found**. This is a logical result since respondents need the fast charger in these context situations in order to charge the range in the available time. Finally, there are three context results where a positive effect on the overall utility is found if a fast charger is not present. In all these contexts, the range that needs to be charged within the available time can easily be charged by a slow charger. Since the main MNL results already showed that the respondents of this sample prefer a slow charger at the location, this is a logical finding.

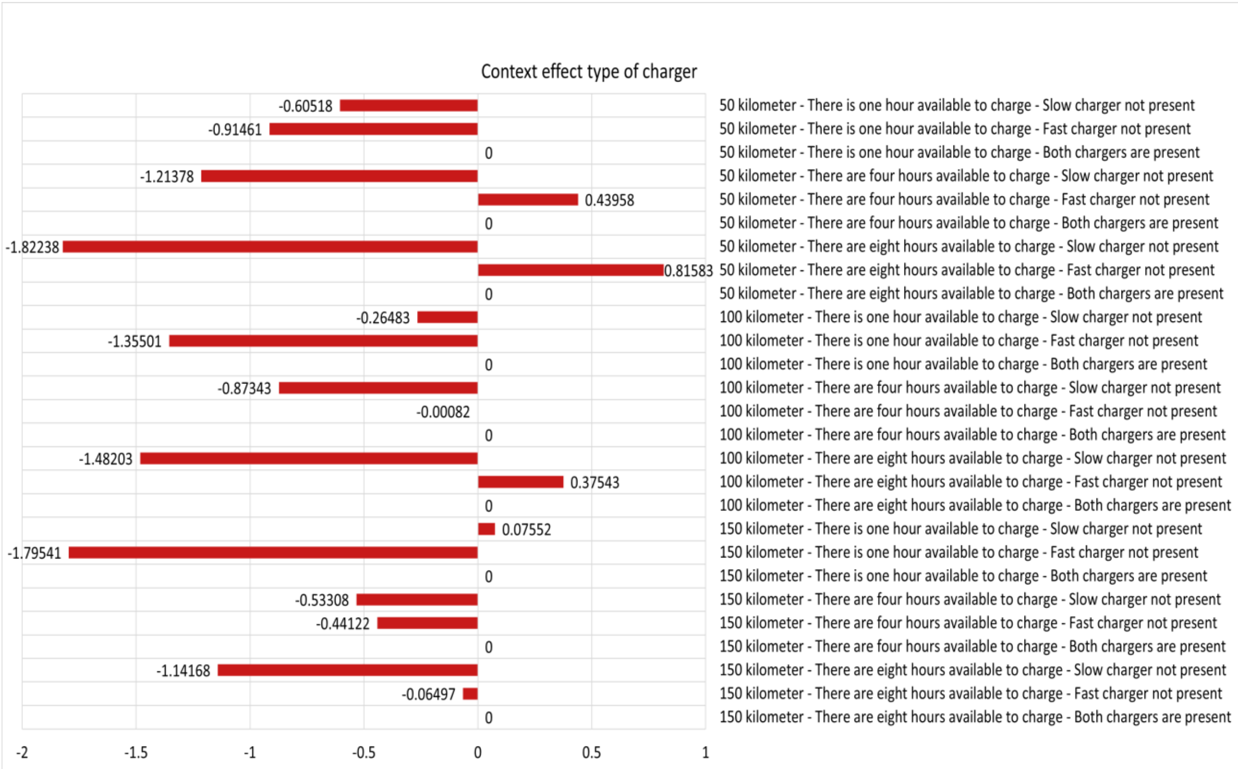

Figure 11. MNL path-worth utility of the context effects for the type of charger

The context effects of the costs for slow charging are presented in figure 12. As is visible from the results, **lower costs are preferred in every context situation included in the model**. If the costs increase, the utility of a charging location decreases. Additionally, based on the results of the context effects presented in figure 12, it can be concluded that **with increasing available time to charge, the impact of the costs becomes larger**. This finding makes sense since the respondents will have more time available to search for a cheaper location while still having enough time to charge the range.

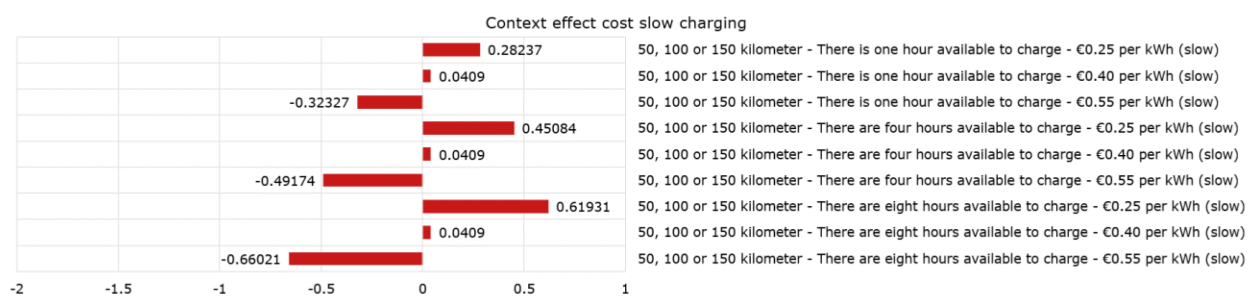

Figure 12. MNL path-worth utility of the context effects for the cost of slow charging

The final context effect that was included in the final MNL model is related to having to relocate the vehicle once the battery is completely charged. According to the results presented in figure 13, **not having to relocate the vehicle will result in a positive effect on the overall utility in all context situations**. This indicates that no matter the context, respondents are reluctant to move their electric vehicle. The moment that there are more hours available to charge, having to relocate the vehicle within 30 minutes after completely charging the electric vehicle will results in the largest decrease of the overall utility in all context situations. This makes sense since the probability that the battery is completely charged within the available time increases, and therefore also the probability increases that the vehicle needs to be relocated. Since the results showed that the respondents are reluctant to move their vehicle, the larger negative effects are logical.

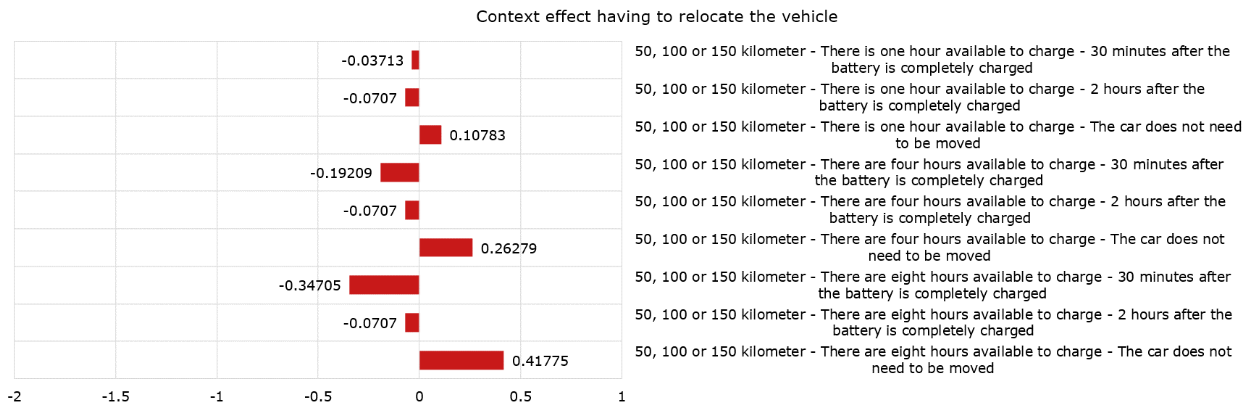

Figure 13. MNL path-worth utility of the context effects for having to relocate the electric vehicle

4.4. Latent class analysis

After the MNL models were estimated, LC models were estimated. LC models are used to check for the existence of different clusters (or classes) of respondents based on their preferences for the included attributes. Given a preset number of classes, Nlogit estimates the parameter values (of a MNL model) for the respondents in each class. In addition to that, Nlogit also estimates class-membership functions. Actually, this is a logistic regression model, predicting the probability that a respondent belongs to each of the classes, using the socio-demographics as explanatory variables. This study used the socio-demographics as explanatory variables; however, other variables could also have been used. Table 7 presented the classes that have been used in the LC class membership analysis. Table 7 includes the “Prefer not to say” category, however, this category is only shown for completeness. In the LC class membership analysis, the “Prefer not to say” class is modeled as zero (0) and therefore not taken into account during the LC class membership analysis. The socio-demographics are effect coded in order to be included in the LC models. Appendix J shows the effect coding scheme for the different socio-demographic classes. Again, just as in the effect coding scheme for the MNL model, the level that has been used as the base level is coded as minus ones (-1). Since the MNL models were first estimated with all variables and finally with significant context effects only (section 4.3), the LC models will be estimated for both approaches.

4.4.1. Estimated LC models

Since LC analysis can be carried out with different classes, several models have been estimated. In total five LC models have been estimated. Two LC models have been estimated where all variables were included. Additionally, two LC models have been estimated based on the reduced MNL model where the main effects were included, and several context effects were excluded from the model. Equation (3.6) has been used to determine the best number of classes.

Since all class membership parameter values of the LC model with the lowest BIC value were insignificant at 10% (excluding the constant), a fifth LC model with two classes based on the reduced MNL model without the class membership parameters has been estimated. Excluding the class membership parameters from the model resulted in the lowest BIC value (9,056.35). As a result, this model is ultimately chosen and elaborated below. In Appendix K1 – K5, the results of all five LC model estimations are shown.

Table 10. BIC-values for LC model estimation with two and three classes in the complete and reduced MNL model

Model	Classes	Log-Likelihood	Sample size (*N*)	Number of parameters (*M*)	BIC
Equivalent of complete MNL model	2	-4,206.04891	5,820	181	9,981.20
	3	No reliable model could be estimated			
Equivalent of reduced MNL model	2	-4,293.94157	5,820	61	9,116.70
	3	-4,195.48850	5,820	97	9,231.88
Final LC model	2	-4,307.11564	5,820	51	9,056.35

4.4.2. Main effects LC model

Since the final LC model with two classes excluding the class membership variables (Rho² = 0.326) has the lowest BIC value, it is not possible to elaborate on socio-demographic differences between the two classes. Even though it is not possible to identify why someone is in a specific class, there are still group differences between the classes since the respondents are grouped based on their preferences. The average class probability is 86% for class one and 14% for class two. Table 11 shows the MNL results of the final LC model estimation for class one and two. Appendix K5 shows the steps taken in Nlogit to get to the output presented in table 11.

Table 11. Overview of the estimation results of the two class LC model

Variable	Coefficients class one	Coefficients class two
Constant	-3.21585***	.46348***
Attributes		
Slow chargers present	1.04303***	.65966***
Fast chargers present	.39218***	.07224
€0.25 per kWh (slow)	.50064***	.48356***
€0.40 per kWh (slow)	.05377	-.14938
€0.60 per kWh (fast)	.57217***	.28754***
€0.75 per kWh (fast)	-.06189	-.02715
Charge certainty 75%	-.25710***	-.03296
Charge certainty 85%	.01161	-.08746
50 meters walking distance	.32178***	.28138***
150 meters walking distance	.05150	-.08074
30 minutes after the battery is completely charged	-.22834***	-.12174
2 hours after the battery is completely charged	-.06358*	-.11518
The vehicle is left unattended at the charging location	-.12850***	-.13970
The vehicle is visible from the (surrounding) dwelling(s)	.03182	-.00041
Nothing changes	-.08476**	-.07149
More greenery	.10520***	-.02718
Context effects		
50 kilometer - Slow charger	.35743***	.45787***
50 kilometer - Fast charger	-.52690***	-.24837
There is one hour available to charge - Constant	.01099	-.77170***
There is one hour available to charge - Slow charger	-.79962***	-.24188
There is one hour available to charge - Fast charger	1.17940***	.99832***
There are four hours available to charge - Fast charger	-.37883***	-.22849
There is one hour available to charge - €0.25 per kWh	-.18925***	-.24024**
There is one hour available to charge - 30 minutes after the battery is completely charged	.20352***	.01893
Model performance		
LL(B)	-4,307.11564	
LL(0)	-6,393.92352	

Rho²	0.326
***, **, * => Significance at 1%, 5%, 10% level.	

In table 11, the value of the constant for both class one and class two are presented. Class one has a constant value of -3.216 while class two has a constant value of 0.463. Based on the values of the constant, **respondents in class one are in general more likely to choose one of the two presented alternatives over the "none-choice" alternative, while respondents in class two are more likely to choose the "none-choice" alternative.** In order to have a better overview of the differences between the main effects in both classes presented above, figure 14 shows the MNL parameter coefficients for class one and class two graphically. Appendix L shows the figure in more detail.

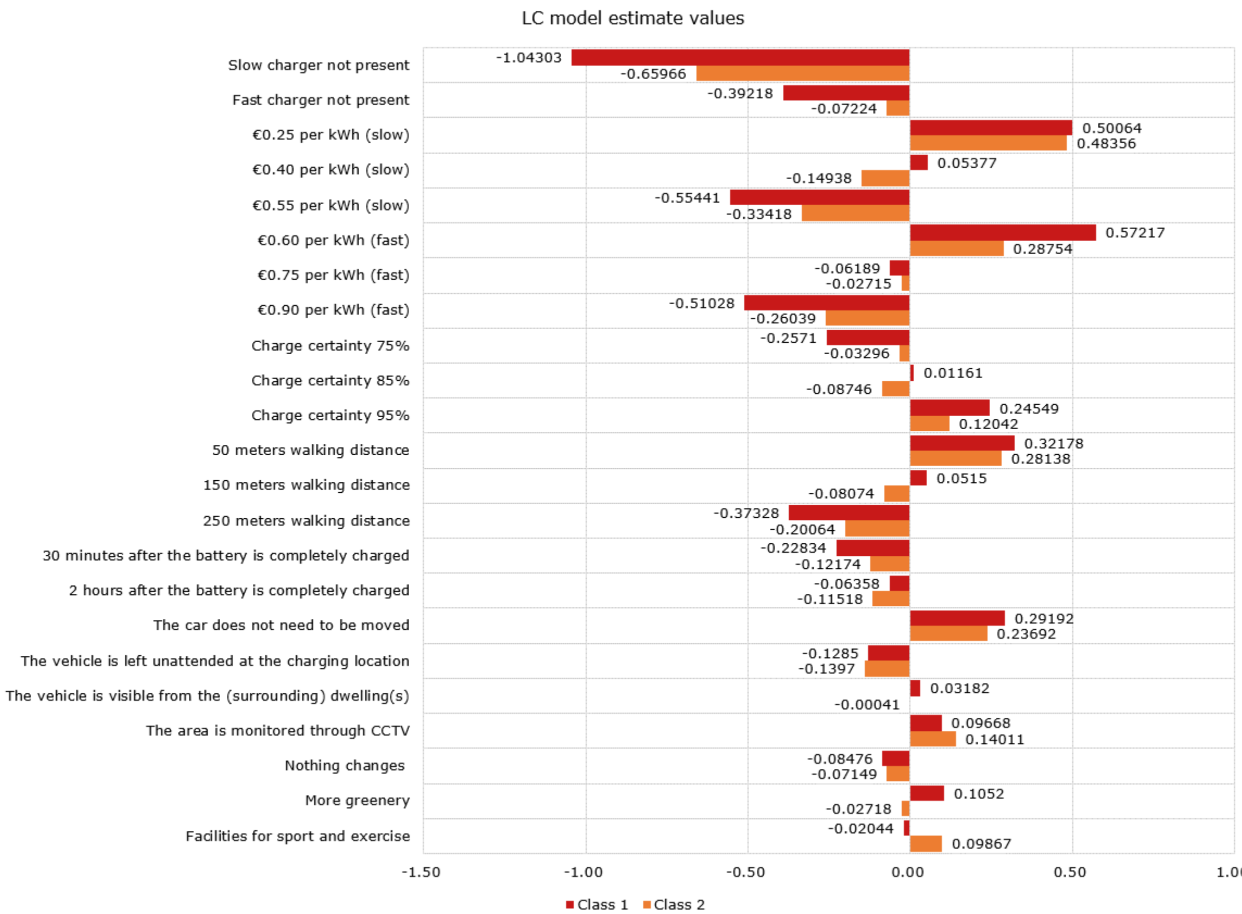

Figure 14. Graphical representation of the part-worth utilities in LC the model estimation

Comparing the coefficients of class one and two in table 11, it has to be noted that most of the parameters in class one are significant at the 5% level while in class two, the constant and only four of the main attribute parameter values are significant at the 5% level. Even though class two has more insignificant parameter values, comparing both models on all parameters is still considered useful. A possible explanation for the fact that class two has mainly insignificant MNL parameters at the 5% level could be that the respondents grouped into class two are less interested in publicly charging electric vehicles, which might be indicated by the positive constant as well. Alternatively, considerably less respondents belong to the second class, generally generating less significant parameters.

Type of charger (slow): Due to the coding of the type of charger (0 if present, -1 if not present), the values as presented in figure 14 are the inverse of the values in table 11. In both classes, the parameter value for a slow charger is significant at the 5% level. Once a slow charger is not present in either of the classes, the overall utility of the location decreases. For class one, the utility decreases with 1.04303 while for class two the overall utility decreases with 0.65966. This indicates that respondents grouped in class one value a slow charger at the public charging square more compared to the respondents in class two.

Type of charger (fast): Comparing the parameter values of a fast charger being present, the overall utility of a charging location decreases with 0.39218 if a fast charger is not present for class one (all else equal). For class two, the results show that if a fast charger is not present at a location the overall utility decreases by 0.07224 (all else equal). However, since the value for class two is insignificant, no robust conclusion can be drawn for this variable on the overall utility of class two.

Costs: In both classes, the effect of the costs on the overall utility is as expected. If the costs decrease, the overall utility increases for a location in both classes (all else equal). Next to that, the part-worth utility values of the costs levels in both classes are not close to zero and therefore have a large impact on the overall utility. For class two, the impact on the overall utility is smaller compared to class one since the values of class two are closer to zero compared to class one.

Charge certainty: As the results present, charge certainty has a significant effect on the overall utility of a charging square for class one. For class two, the effect on the overall utility is more limited since the part-worth utility values are close to zero. In class one, the results are as expected since the utility increases with increasing charge certainty (all else equal). For class two however, the overall utility will first slightly decrease with increasing charge certainty before it increases with the highest charge certainty. It has to be noted that only for class one the parameter values are significant at a 5% level while for class two the values are insignificant.

Walking distance: Comparing the effect of the walking distance on the overall utility, the effect is again as expected for both classes. An increasing walking distance will result in a decrease in the overall utility (all else equal). In both classes, a walking distance of 150 meters has a part-worth utility very close to zero. Considering the part-worth utility results of 150 meters walking distance, results show that for respondents in class two this distance already results in a decrease in utility while for respondents in class one there is still a slight positive effect on the overall utility. Additionally, class one assigns a higher part-worth utility (0.32178) to a location within 50 meters walking distance compared to class two (0.28138).

Move vehicle within: Based on the results, having to relocate the electric vehicle once the battery is completely charged has a negative impact on the overall utility in both classes (all else equal). Only when the electric vehicle does not need to be relocated by the owner once the battery is completely charged, a positive effect on the overall utility is found. This implies that the respondents in both classes are reluctant to move their electric vehicle once the battery is completely charged. Nevertheless, it is a political decision made by the governmental parties to implement or not implement a financial incentive. It must be noted that all parameter values for class two are insignificant at the 5% level.

Supervision on charging location: In both classes, the type of supervision on the charging location does not have a major impact on the overall utility (all else equal). This is concluded since the part-worth utility values of both classes are close to zero. For class one, having the electric vehicle visible from the (surrounding) dwellings results in a slight increase in the overall utility while class two has a small decrease. In both classes, having CCTV supervision near the charging location will result in a positive effect on the overall utility (all else equal).

Alternative functions for parking: If nothing changes in the street due to providing centralized charging locations, the overall utility decreases for both classes. For class one, greenery as an alternative function for parking is preferred over facilities for sport and exercise. For class two, facilities for sport and exercise as an alternative for parking are preferred over more greenery, although these parameters are insignificant.

4.4.3. Context effects LC model

Just like the MNL model included several context effects, the final LC model estimation included the same context effects as the final MNL model estimation. Below, the different context effects for class one and class two are elaborated. Of the graphs used to elaborate the different context effects, a more detailed figure is included in Appendix L.

The context effect was also estimated for the constant in both classes (figure 15). In class one, the constant has a value of -3.21585 and the context effect is 0.01099, which is insignificant at the 5% level and therefore can be ignored. In class two, the context effect of having one hour available to charge was significant at the 5% level. This means that due to the coding, just like the MNL model, this context effect also influences the context situation of having eight hours available to charge.

In class two, the constant has a value of 0.46348 which indicates that in class two, respondents are more inclined to choose the "none-choice" alternative over the two presented alternatives. However, if the context would include one hour available to charge (context effect is equal to -0.77170) respondents in class two are also more likely to choose one of the two alternatives over the "none-choice" alternative. If there is more time available to charge the electric vehicle, respondents in class two are still more likely to choose the "none-choice" alternative.

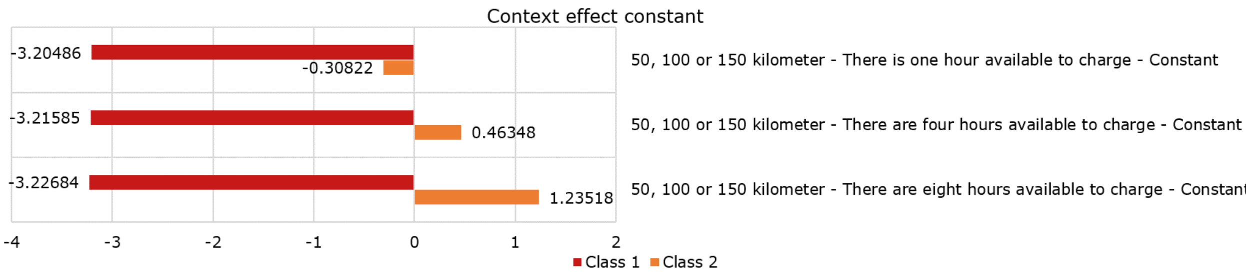

Figure 15. LC part-worth utility of the context effects for the constant

Based on the results of the context effects related to the type of charger, **both classes prefer a public charging location that has a slow charger present** as is visible in figure 16. Again, just as in the MNL model, not having a slow charger decreases the utility of the location more compared to not having a fast charger at the charging location. Additionally, not having a fast charger when it is only possible to charge the given range in the available time with a fast charger, results in a large decrease in utility for both classes. Just as in the MNL model, if the given range can be easily charged with a slow charger, respondents assign a positive utility value to a location which does not provide any fast chargers. In addition, the results show that in some of the context situations there is a large difference between the part-worth utility values of class one and class two.

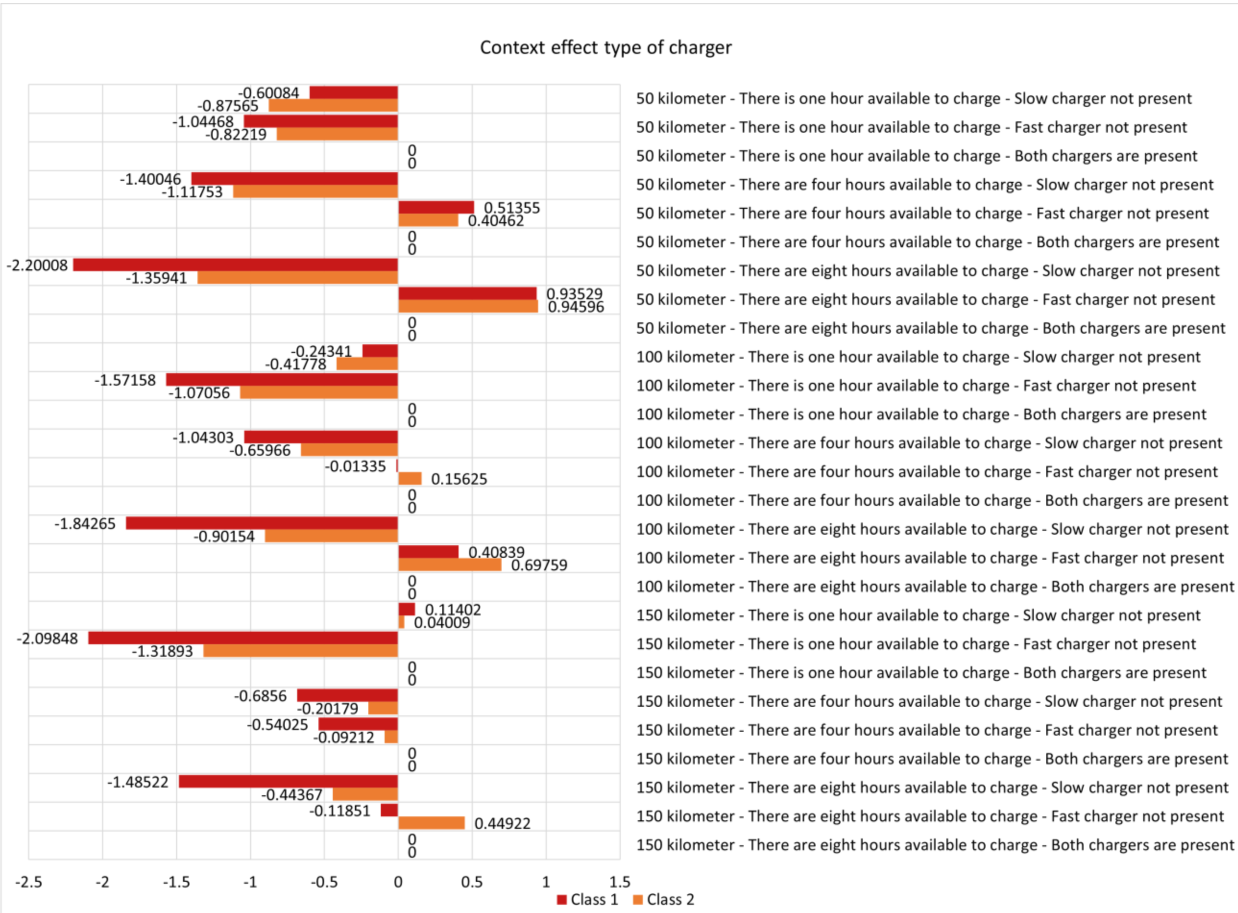

Figure 16. LC part-worth utility of the context effects for the type of charger

The costs of slow charging have the expected effect on the overall utility of a public charging location in the different contexts for class one and class two as is visible in figure 17. **In both classes, the lower the costs are, the higher the overall utility of a charging location will be in all different contexts included in this thesis** (all else equal). The positive effect on the overall utility for the lowest cost level is almost equal for class one and class two while the effect of the highest cost level has a larger negative value for class one compared to class two.

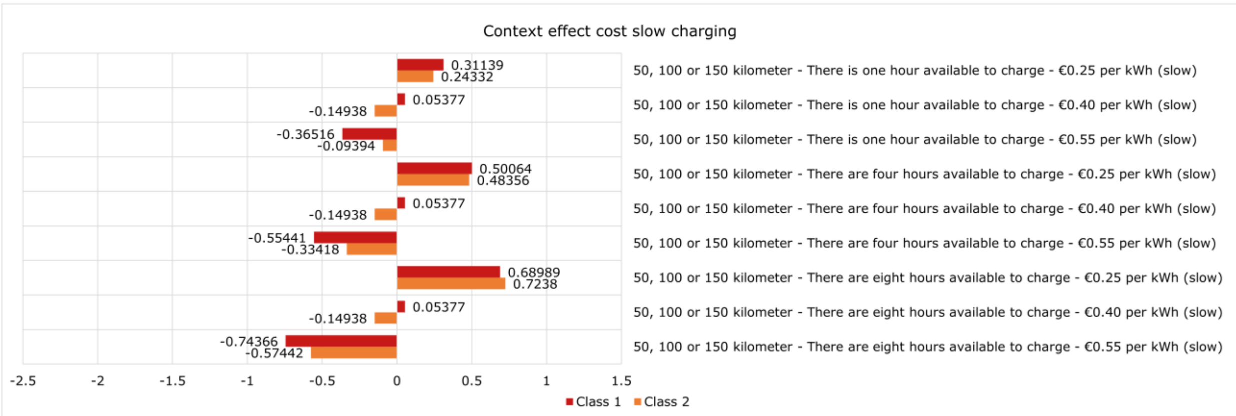

Figure 17. LC part-worth utility of the context effects for the cost of slow charging

As is visible from the results, **both measures that implement a financial incentive to move the electric vehicle have a negative impact on the overall utility for both classes in the different contexts** as is shown in figure 18 (all else equal). Only when the electric vehicle does not need to be relocated by its owner and can be parked near a public charger as long as the users wants, a positive impact on the overall utility is found for class one and class two. This implies that both classes in this sample are reluctant to move their electric vehicle once the battery is completely charged. The effect on the overall utility is larger for class one compared to class two. **This indicates that the respondents in class one are more reluctant to move their electric vehicle compared to the respondents in class two.** However, it is a political decision made by the governmental parties to implement or not implement a financial incentive**.**

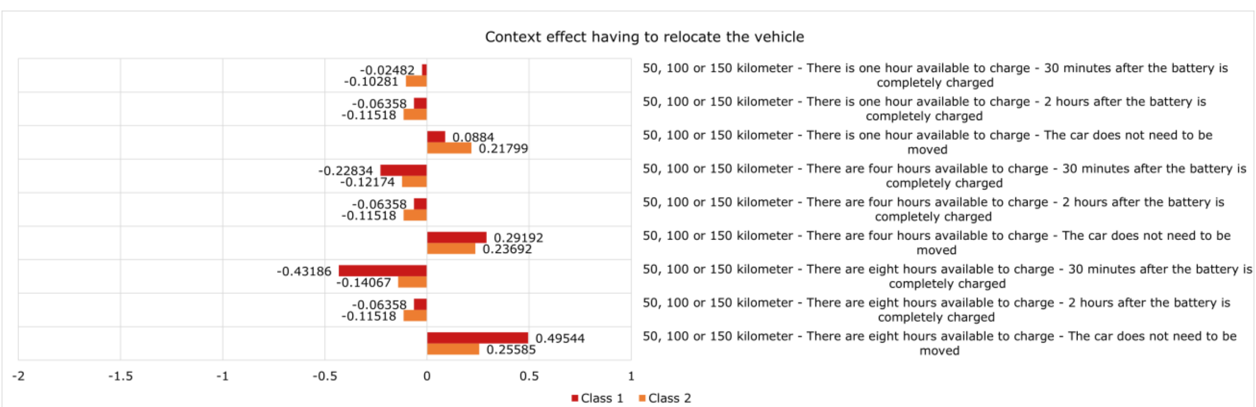

Figure 18. LC part-worth utility of the context effects for having to relocate the vehicle

4.5. Conclusion

This chapter has presented the results of the data collection and the analysis methods described in chapter three. Based on the results of the representativeness, the collected data is considered not representable for a larger population since educated males with a high income are overrepresented in the dataset. However, since 75% of the respondents drive or at least sometimes drive an electric vehicle and the current electric vehicle drivers have the best experience with the current infrastructure and knows what is currently lacking and needs to be improved, the dataset was still considered useful for the MNL and LC model estimations.

The results of both the MNL as well as LC models based on the collected data, showed that a slow charger is preferred over a fast charger in residential environments. However, if both types of chargers are present, the highest utility was found. Furthermore, the findings showed that if the costs of either slow charging or fast charging increases, the utility of that location rapidly decreases. In addition, charging locations within 150 meters will result in an increase of the overall utility while larger walking distances result in a decrease of the overall utility if all else remains equal. The remaining variables in order of importance are having to relocate the vehicle, charge certainty, alternative functions for parking and supervision at the public charging location.

In addition, several context effects were also included in the model estimations and ultimately, only context effects were estimated for the constant, type of charger, cost (slow) and having to relocate the vehicle once the battery is completely charged. Overall, the context effects included in this study showed that the range that needs to be charged does not seem to play a role on the overall context effects.

Next to the MNL model, this study also estimated several LC models. After multiple estimations, the LC model based on the final MNL model excluding the class membership variables performed the best. In the final model, two classes were estimated, and the class probability is 86% for class one and 14% for class two. Since the final LC model did not include any socio-demographic variables, it was not possible to identify what makes a respondent belong to either of the created classes.

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5. Practical application of the results

This chapter will use the results presented in chapter four to demonstrate the practical application of the results. There is chosen to use the MNL results in this chapter since the MNL parameters in the LC model of class one (which contained 86% of the dataset) were in line with the MNL model estimates. Additionally, since the final LC model estimation did not include any class membership variables, and it was therefore not possible to statistically identify why a respondent belongs to class one or class two, the MNL results are considered more useful for this chapter.

The intention of this chapter is to show that the results presented in chapter four have a practical purpose and can be used in a design tool to determine suitable locations for public charging squares in residential environments. The practical application of the results will be demonstrated on a development of Dura Vermeer Vastgoed. The first part of this chapter will briefly introduce the development. After the introduction of the development, assumptions made in order to demonstrate the practical application are mentioned and finally, the identified potential public charging locations are analyzed based on the results of chapter four.

5.1. Introduction to TudorPark

The development which has been selected to show the practical application of the results is called "TudorPark". TudorPark is a development of Dura Vermeer Vastgoed which started back in 2013 and is located on the southside of Hoofddorp in the municipality Haarlemmermeer (Dura Vermeer, 2023a, 2023b). Once the whole development of TudorPark is complete, approximately 1,350 new dwellings in a variety of sizes, types and appearances will be realized. Due to the wide range of different types and sizes of dwellings, TudorPark offers a home for different types of households. Figure 19 shows the location of TudorPark in Haarlemmermeer. Since TudorPark is an integrated area development where also the public parking facilities have to be realized by Dura Vermeer, it is considered a suitable development to assess the intended tool.

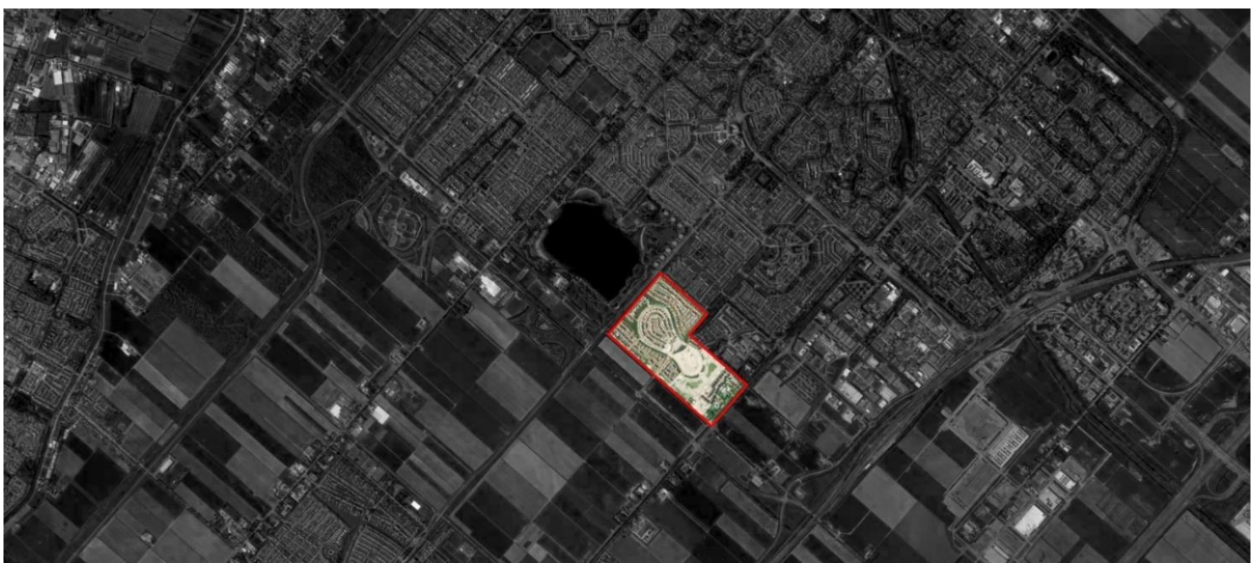


Figure 19. Location of TudorPark in Haarlemmermeer (adopted from Google Earth (2023))

In order to have a good overview of the layout of the development, figure 20 shows the complete urban plan of TudorPark. In the design of TudorPark, the loop provides access throughout the whole area and therefore, it is also the main road in the development. Along the loop public parking is realized, but a key aspect of TudorPark is that public parking is also provided by creating several clustered parking locations directly connected to the main road. By creating public parking clusters, fewer parking spaces needed to be realized along the street, creating space for other functions.

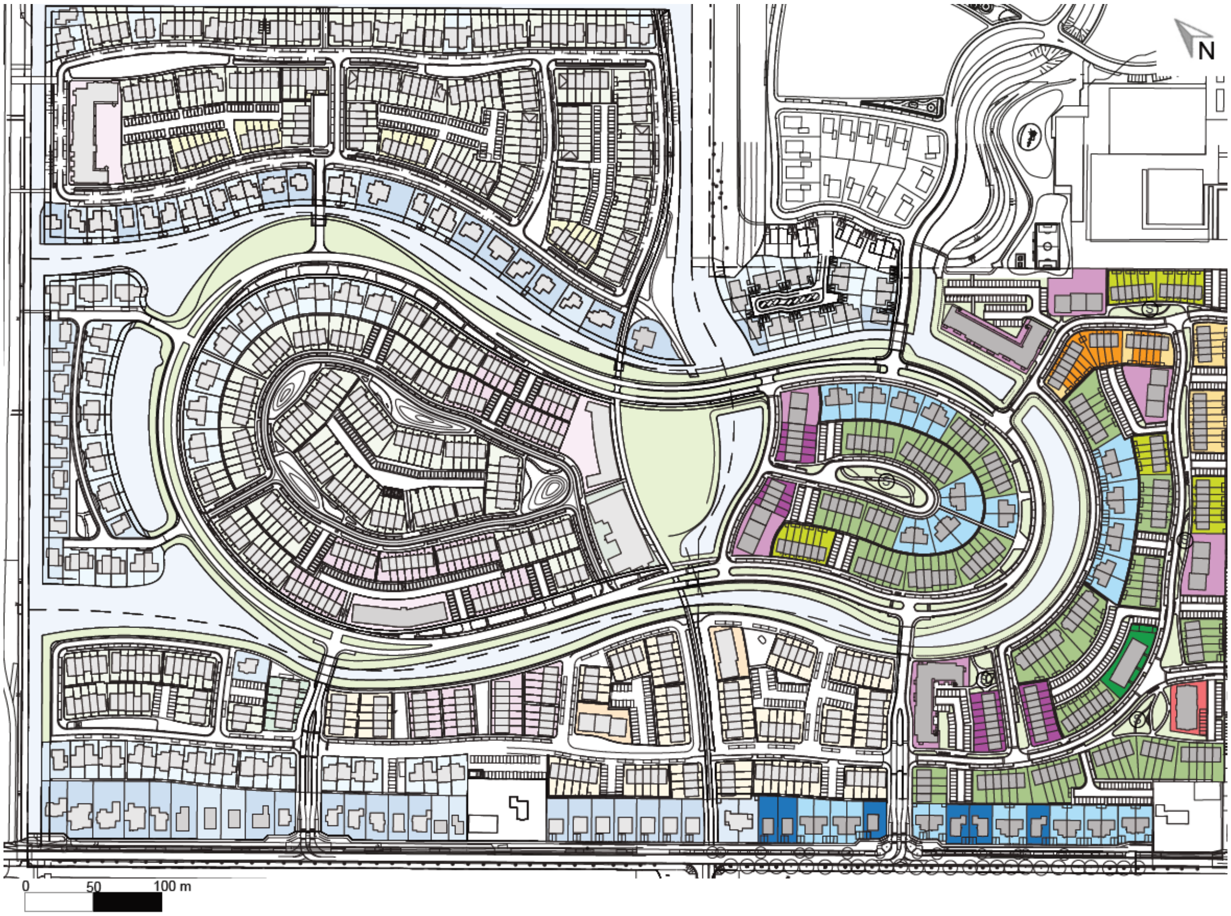


Figure 20. The urban plan of TudorPark

As mentioned, the development started back in 2013 and therefore, parts of the development are already inhabited, and the surrounding public space is already completed. Currently (April 2023), the final phase of the development is under development. This chapter will focus on the area which still has to be constructed in order to demonstrate that the results of this thesis can be used in a design tool in future developments. Figure 21 gives a more detailed view of the area of the development on which this chapter focuses which is located on the east side of the urban plan. Additionally, several of the parking clusters are indicated in figure 21.

Since the representative analysis showed that the dataset is not representable for the "Nationaal Laadonderzoek" (section 4.2), and the socio-demographics of TudorPark can only be roughly estimated, the assumption is made that for the remainder of this chapter the composition of the residents in TudorPark is equal to the composition of the respondents in the dataset. As a result, it is assumed that the preferences of the respondents are in line with the preferences of the residents in TudorPark.

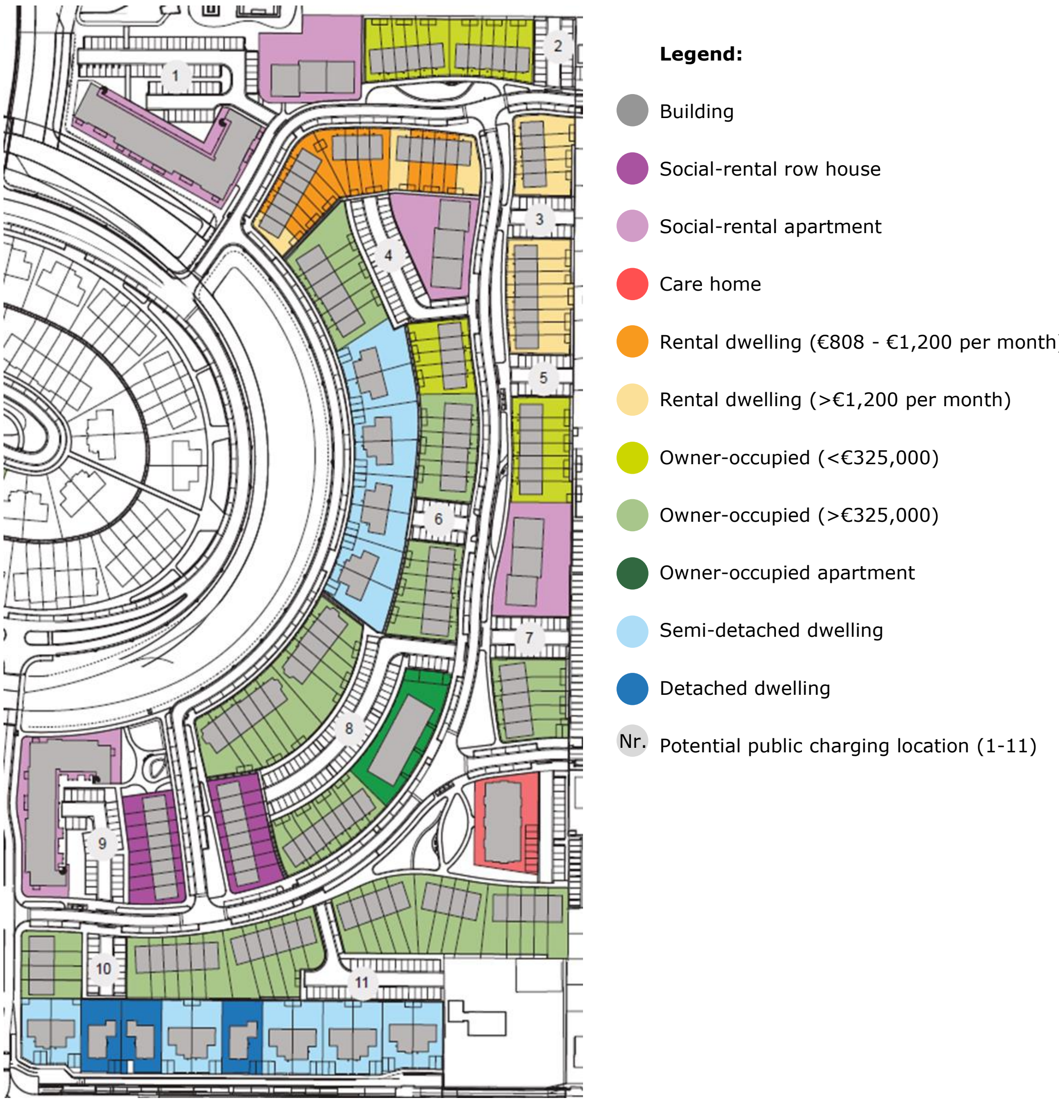


Figure 21. Focus area and potentially identified public charging locations within the area development

Within the area development, several public parking clusters are identified, and section 5.4 will determine the probability of choosing between two of the identified public parking clusters based on the results of chapter four. In total, eleven potential public charging locations have been identified in the area development which all have been indicated on figure 21 by numbers 1 – 11. Before presenting the results of the practical application, section 5.2 will elaborate on assumptions that have been made in order to show the practical application.

5.2. Assumptions for analyzing the identified public charging locations in TudorPark

Before analyzing all the identified potential public charging locations, it is needed to elaborate on five assumptions that have been made in addition to the assumption that the preferences of the residents in TudorPark do not differ significantly from the preferences of the respondents in the dataset.

The assumptions mentioned below are made to be able to properly analyze the different potential sites. Based on the assumptions made, section 5.4 shows the practical application of the results in a design tool when not yet everything is known and thus different scenarios can be evaluated.

1) Semi-detached and detached dwellings in the development have the possibility to park (and therefore charge) on private property, therefore these dwellings are not taken into consideration when determining the number of dwellings within the acceptable walking distance from the public charging location. The owners of these dwellings are more likely to install a private charger instead of using public charging locations.
2) Visitors might need to use public chargers but since these visitors are not daily/frequent users of the public charging locations in TudorPark, visitors are not taken into account. Besides, the respondents that participated in the questionnaire were asked to answer the questions from a resident's perspective and not a visitor's perspective. Since the possibility exists that visitors have different preferences, and these preferences are therefore unknown, it is assumed that visitors will have enough remaining range to drive home and therefore do not need to use the public chargers.
3) Next to that, there are also apartment complexes in the development and in order to determine if the dwellings in the apartment complex are within 50/150/250 meters walking distance from a public charging square, the distance is measured from the main entrance of the apartment complex for all apartments in the same complex.
4) Furthermore, the assumption is made that for 2030, every social-rental dwelling demands 0.01 public chargers. For the normal rental dwellings, it is assumed that there will be a demand for 0.20 public chargers for every dwelling (1.4 * 15% = 0.21). Per owner-occupied apartment, a demand for 0.35 public chargers is assumed (1.2 * 30% = 0.36) and for the owner-occupied row houses a demand for 0.45 public chargers is assumed per dwelling (1.5 * 30% = 0.45).

   This differentiation in demand for public chargers is made since several different dwelling types are constructed as is indicated on figure 21 and every dwelling type will have a different parking demand now, and in the future. The difference in parking demand is caused by the differences in economic and social backgrounds of the residents occupying the different types of dwellings. The current parking demand in TudorPark is estimated based on Goudappel & Provincie Zuid-Holland (2023) who have created a tool to show the actual car ownership per type of dwelling in every district of the Netherlands. This tool does however not take into account future developments in for example car possession and shared mobility since it is about the current actual car ownership. In Toolenburg Zuid, the district in which TudorPark is located, the current car ownership per dwelling type based on Goudappel & Provincie Zuid-Holland (2023) is as follows (only car ownership for the relevant types of dwellings without private parking in this development are shown):
   - 0.6 parking spaces per social-rental apartment
   - 1.4 parking spaces per rental row house
   - 1.2 parking spaces per owner-occupied apartment
   - 1.5 parking spaces per owner-occupied row house

   It is expected that car possession will keep increasing up until 2040 (Ministry of Infrastructure and Water Management, 2021) and that new technological developments related to mobility (i.e. shared mobility or self-driving cars) are expected to be limited up to 2040 (Hilbers et al., 2020). Meanwhile, the adoption rates of electric vehicles are likely to increase after 2030, but the rate of adoption is surrounded by great uncertainty (Hilbers et al., 2020). Therefore, due to this great uncertainty and the expected limitation in technical developments, this chapter does not look beyond 2030.

   According to Corpeleijn, Huur & Energie Consult, EVConsult, Vigleco, & VBTM Advocaten (2020), it is expected that 15% of the tenants and 25% of the total Dutch population will drive an electric vehicle in 2030. Since the Netherlands has 8.1 million households (CBS, 2023b), and 70% of the Dutch households have a privately owned dwelling (Nederlandse Vereniging van Banken, 2023), 30% of the owner-occupied dwellings will drive an electric vehicle in 2030.

   Based on the parking demand per dwelling type of Goudappel & Provincie Zuid-Holland (2023) and the expected percentage of electric vehicle possession, the following numbers are assumed for the demand for public chargers per dwelling type.
   - 0.01 public chargers per social-rental apartment
   - 0.20 public chargers per rental row house

- 0.35 public chargers per owner-occupied apartment
- 0.45 public chargers per owner-occupied row house

The demand for public chargers above is geared towards 2030 since the adoption rate of electric vehicles after 2030 is too uncertain. Yet, it has to be noted that in the future it is expected that more and more electric vehicles will be owned. However, not every electric vehicle driver currently needs to charge on a daily basis and as new innovations will increase the range with the same battery size in the future, there is also no need for a charging point for every electric vehicle in the future. Additionally, not all residents will possess an electric vehicle in 2030.

In the future, the tenants of social-rental dwellings will drive electric vehicles as well, but potential electric vehicle drivers are waiting for affordable second-hand electric vehicles since currently the prices of electric vehicles are too high (even including subsidy) (Automotive-online, 2023). In addition, the prices of lithium-ion batteries even increased in 2022 making the electric vehicle even more expensive, however, it is expected that the prices for electric vehicle batteries will slowly start to decrease after 2024 (Autoweek, 2023; Van der Weerd, 2022). If the prices of electric vehicles keep on decreasing after 2024, the electric vehicle will become more affordable for the larger population.

5) It has to be taken into account that there is a difference between the actual walking distance (also called city-block distance or Manhattan distance) and the distance measured along the shortest direct line (also called the Euclidean line). Since this study will use a buffer around the charging location to determine the number of dwellings within 50/150/250 meters walking distance, the Euclidean distance has to be reduced. The distance is reduced in order to take into account the fact that it is usually not possible to walk in a straight line from the dwelling to the charging location.

   Since the structure in TudorPark is not similar to a city-block structure, it is not possible to use the ratio between the city-block distance and the Euclidean distance. Therefore, after several measurements, it is assumed that the difference between the actual walking distance and the shortest straight line is 15%. Therefore, the maximum acceptable walking distance becomes 150 meters * (100% - 15%) = 127.5 meters. The preferred walking distance of 50 meters is also reduced and becomes 42.5 meters. Finally, 250 meters walking distance becomes 212.5 meters.

5.3. Distribution of public chargers without using the MNL model

As has been described in section 2.6, currently, drivers of electric vehicles have to apply for a new public charging point in order for the municipality to realize a public charging point. This means that the current method for locating public chargers is not proactive but reactive. This also applies to the development of TudorPark where no public chargers are included in the urban plan and the municipality only realizes new public chargers once an inhabitant has applied for one. Since the project area considered in this chapter is not yet inhabited, it is not possible to use the applications filed at the municipality to determine the demand locations for public chargers. Therefore, the tool of Goudappel & Provincie Zuid-Holland (2023), the type of dwellings surrounding each of the identified sites and the assumptions described in section 5.2 are used in order to determine the potential distribution for public chargers over the eleven identified public charging sites in TudorPark in 2030. Additionally, in order to determine the potential distribution of public chargers based on general insights, an assumption is made about which of the eleven sites will be used by the residents of a building block. Based on general insights, the potential demand for public chargers at the eleven sites is shown in table 12.

Table 12. Distribution of public chargers over the eleven identified sites based on general insight

Site	Number of public chargers
Site 1	1
Site 2	5
Site 3	1
Site 4	8
Site 5	3
Site 6	4
Site 7	2
Site 8	14
Site 9	1
Site 10	4
Site 11	9

5.4. Distribution of public chargers by using the MNL model

The results presented in section 5.3 do not take into account user preferences and are solely based on the demand for parking and the estimated possession of electric vehicles in 2030. This might result in public chargers being located where there is no demand for public chargers or where users are not willing to use them. Based on the results of this study, it is possible to take user preferences into account and determine the probability of choosing between two public charging locations for each block of dwellings.

In reality, a resident of TudorPark has the possibility to choose between all of the eleven sites at once, however, when determining the probability to choose a site in this chapter, it is only possible to take into account two sites at the same time. This is the case since the results of this study are based on a stated choice experiment in which only two alternative locations and a "none-choice" were presented to a respondent. Hence, the constant value is based on two alternative charging locations and a "none-choice". Including more alternative charging locations in the stated choice experiment would result in a different value for the constant and therefore different probability results. Thus, it is not possible to determine the probability of choosing a charging location when considering more than two locations at the same time in this chapter. If the "none-choice" probability is high, it is likely that one of the remaining nine public charging locations which have not been considered in the probability calculation is used or a charging location outside TudorPark is used. The higher the probability for a site is, the more likely that site is chosen to charge an electric vehicle.

5.4.1. Site characteristics

For the remainder of this chapter, there is chosen to determine the probabilities for site eight and site eleven since section 5.3 indicated that these two sites will have the largest demand for public chargers. The indicated blocks on figure 22 are taken into account when determining the probabilities. These blocks are selected based on general insights used to determine the demand for public chargers in section 5.3. All the indicated blocks are within 50 meters walking distance from one of the two sites without having to cross a street. However, before the probabilities of choosing between sites eight and eleven are going to be calculated (section 5.4.2), the site characteristics will be described. Since all sites still have to be developed, it is assumed that they are currently equal in characteristics.

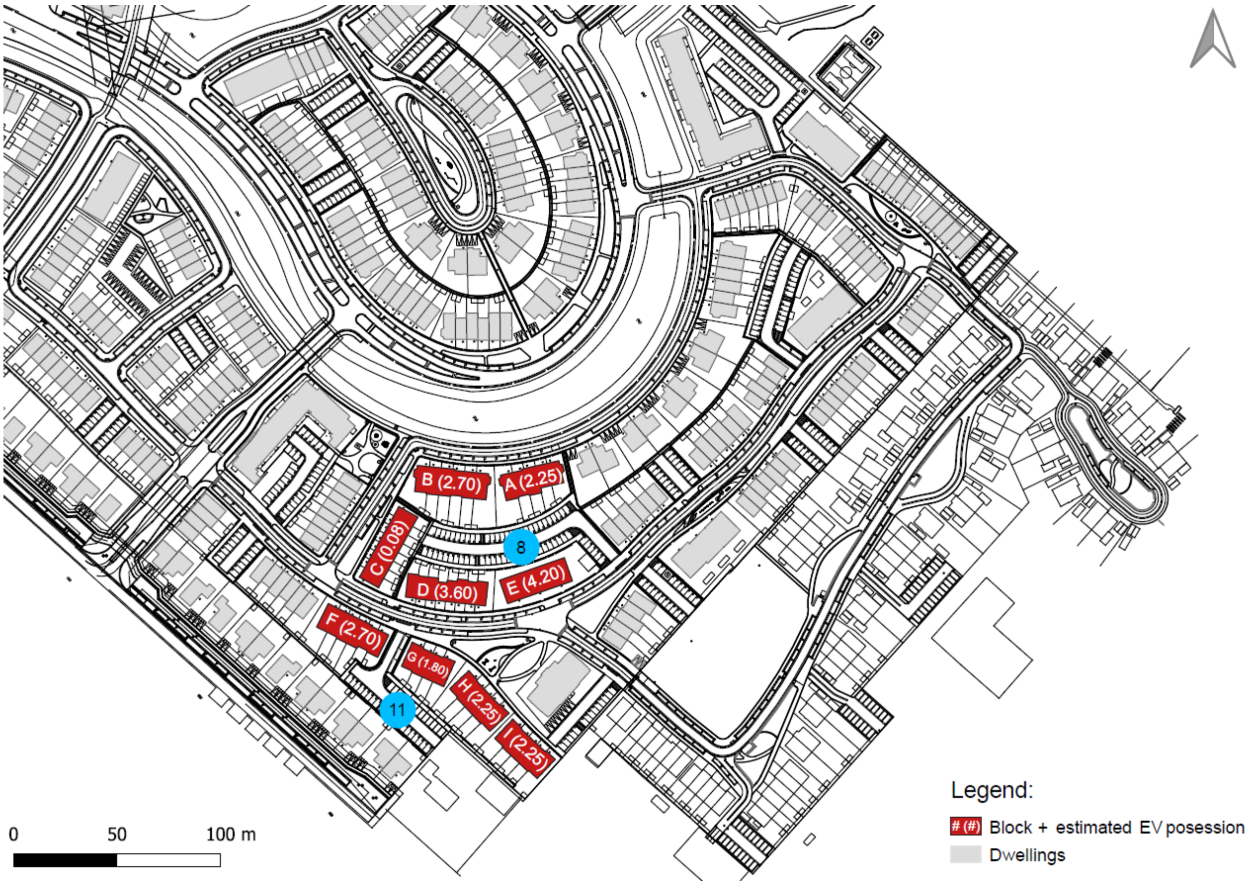
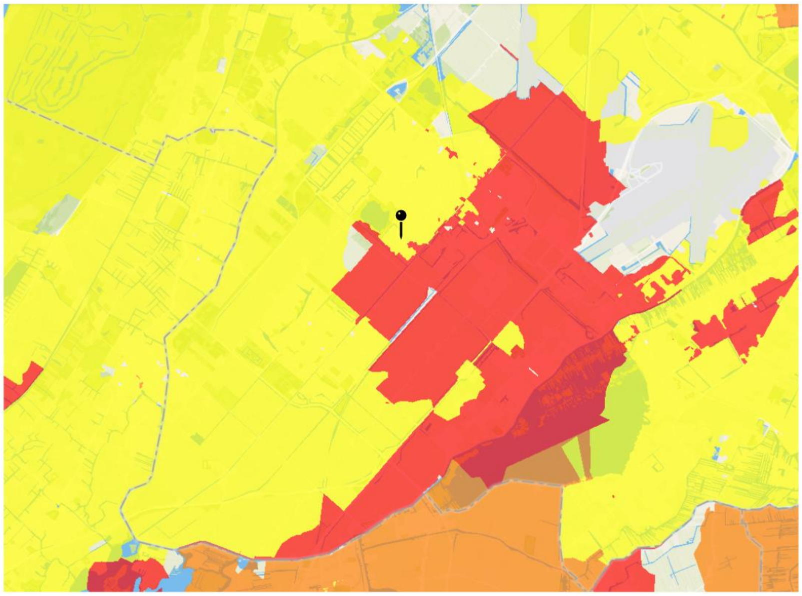


Figure 22. Considered building blocks plus the estimated electric vehicle possession per block

Type of charger: Based on the results of the MNL model presented in chapter four, slow chargers are much more preferred in residential neighborhoods compared to fast chargers. Even though the main effect results of the MNL model in chapter four showed that having both slow chargers as well as fast chargers at the charging location results in the highest overall utility, it is assumed that in this scenario all sites will only provide slow charging. This assumption is made in order to reduce the impact on the power grid.

Costs: As mentioned in chapter four, costs have a major impact on the location decision when deciding on a charging location. The costs of charging at a public charging location are determined by the provider of the public charger, the location of the public charger as well as the charging card provider (Vermeulen, 2023). Since it is possible to charge an electric vehicle at any public charging point using any type of charging card, the electric vehicle owner is able to choose the charging card provider that best matches their needs. Therefore, since only the location of the public charger is known, and the provider of the charging point as well as the charging card used are unknown, it is assumed that the costs of slow charging are equal to €0.40 per kWh for all locations.

Charge certainty: Netbeheer Nederland (2023) has created a map indicating the available capacity for all regions in the Netherlands. Figure 23 shows the power grid capacity map for Hoofddorp and its surroundings. The development location of TudorPark is indicated by the pin on the figure and as is visible, the development area is completely located in the yellow area. According to Netbeheer Nederland (2023), this means that there is only a limited capacity available on the power grid for new connections. This means that it is likely not possible to acquire a new large connection to the grid or expand current connections and therefore it is not possible to locate public chargers everywhere. Since there is limited grid capacity available in TudorPark, all sites will be realized with load balancing to reduce the impact on the grid. Consequently, all sites have a charge certainty of 85%.



Legend:

- (yellow) Limited grid capacity available.
- (orange) Temporarily no grid capacity available pending the outcome of the congestion management study.
- (red) No grid capacity available and congestion management cannot be applied.

Figure 23. Power grid capacity map for Hoofddorp and its surroundings (Netbeheer Nederland, 2023)

Having to relocate the vehicle: Since the eleven sites are all located in the same district, it is likely that if the municipality would enforce a financial incentive policy for having to relocate the electric vehicle once the battery is completely charged, this policy is likely to apply to all identified potential charging locations. This is stated because the area considered in this chapter is too small for having different policies on this topic. Since the actual policy is unknown, it is assumed that on all sites the electric vehicle does not need to be relocated after the battery is completely charged.

Supervision on charging location: Since the sites have not been developed yet, CCTV supervision could be realized on all sites which was the preferred level by the respondents in this study. However, realizing CCTV will induce extra costs, and therefore, it is assumed that the only method of supervision is “visible from the (surrounding) dwellings”. Based on the location of all sites in the urban plan of TudorPark, all sites are visible from (surrounding) dwellings.

5.4.2. Probability calculation

Based on the description of the charging square characteristics, it is possible to determine the utility that each site will generate for the different building blocks and the corresponding probability of choosing site eight, site eleven or neither of the sites. Below in tables 13, 14 and 15, the probabilities of selecting site eight, site eleven or neither of the sites in the different contexts that were included in this study are shown for each building block indicated in figure 22. Appendix M shows the intermediate results.

Since it is unknown in which context each individual electric vehicle driver will make a decision, it is assumed that each time, all drivers living in the considered building blocks will make the decision in the same context. This is of course far from reality since every individual electric vehicle driver will make a decision in a different context. In reality, it could be the case that one electric vehicle driver has to make a decision when the driver has four hours available and needs to charge 50 kilometers, while at the same time, another electric vehicle driver has one hour available and needs to charge 150 kilometers in range. Taking into account individual context situations for every electric vehicle driver would make the probability calculations too complex for the purpose of this chapter and therefore, it is assumed that all electric vehicle drivers made a decision in the same context.

Table 13. Probability of choosing site eight, eleven or neither when having one, four or eight hours available and having to charge 50 kilometers in range

	50 kilometers in one hour			50 kilometers in four hours			50 kilometers in eight hours		
	Site 8	Site 11	Neither	Site 8	Site 11	Neither	Site 8	Site 11	Neither
Block A	59%	31%	9%	63%	34%	3%	62%	33%	4%
Block B	52%	40%	8%	55%	42%	3%	54%	42%	4%
Block C	52%	40%	8%	55%	42%	3%	54%	42%	4%
Block D	52%	40%	8%	55%	42%	3%	54%	42%	4%
Block E	52%	40%	8%	55%	42%	3%	54%	42%	4%
Block F	40%	52%	8%	42%	55%	3%	42%	54%	4%
Block G	40%	52%	8%	42%	55%	3%	42%	54%	4%
Block H	40%	52%	8%	42%	55%	3%	42%	54%	4%
Block I	45%	45%	9%	48%	48%	3%	48%	48%	4%

Table 14. Probability of choosing site eight, eleven or neither when having one, four or eight hours available and having to charge 100 kilometers in range

	100 kilometers in one hour			100 kilometers in four hours			100 kilometers in eight hours		
	Site 8	Site 11	Neither	Site 8	Site 11	Neither	Site 8	Site 11	Neither
Block A	56%	30%	14%	62%	33%	5%	61%	32%	7%
Block B	50%	38%	12%	54%	42%	4%	53%	41%	6%
Block C	50%	38%	12%	54%	42%	4%	53%	41%	6%
Block D	50%	38%	12%	54%	42%	4%	53%	41%	6%
Block E	50%	38%	12%	54%	42%	4%	53%	41%	6%
Block F	38%	50%	12%	42%	54%	4%	41%	53%	6%
Block G	38%	50%	12%	42%	54%	4%	41%	53%	6%
Block H	38%	50%	12%	42%	54%	4%	41%	53%	6%
Block I	43%	43%	14%	48%	48%	5%	47%	47%	7%

Table 15. Probability of choosing site eight, eleven or neither when having one, four or eight hours available and having to charge 150 kilometers in range

	150 kilometers in one hour			150 kilometers in four hours			150 kilometers in eight hours		
	Site 8	Site 11	Neither	Site 8	Site 11	Neither	Site 8	Site 11	Neither
Block A	56%	30%	14%	62%	33%	5%	61%	32%	7%
Block B	50%	38%	12%	54%	42%	4%	53%	41%	6%
Block C	50%	38%	12%	54%	42%	4%	53%	41%	6%
Block D	50%	38%	12%	54%	42%	4%	53%	41%	6%
Block E	50%	38%	12%	54%	42%	4%	53%	41%	6%
Block F	38%	50%	12%	42%	54%	4%	41%	53%	6%
Block G	38%	50%	12%	42%	54%	4%	41%	53%	6%
Block H	38%	50%	12%	42%	54%	4%	41%	53%	6%
Block I	43%	43%	14%	48%	48%	5%	47%	47%	7%

Based on the probabilities presented in tables 13, 14 and 15 and the assumed possession of electric vehicles per dwelling type, the demand for public chargers per site in each context situation is shown in figure 24. According to figure 24, site eight will have a slightly higher demand for public chargers compared to site eleven. Based on the results, site eight has an average demand for eleven public chargers and site eleven has an average demand for ten public chargers if a location decision has to be made between sites eight and eleven. Taking into account user preferences therefore results in a different distribution of public chargers compared to the demand determined in section 5.3.

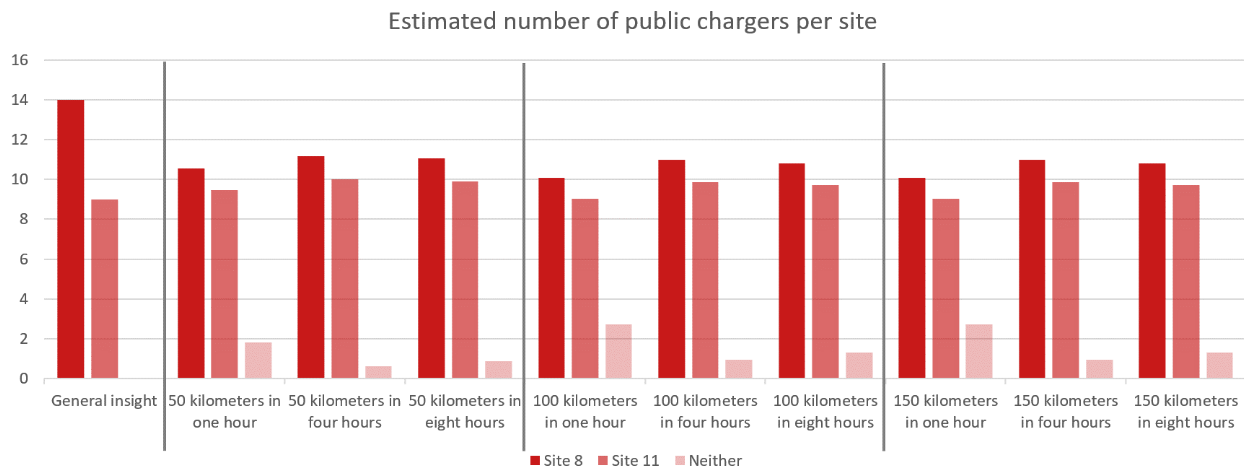


Figure 24. Demand for public chargers per site in different contexts

5.4.3. A different scenario

When designing an urban plan and determining the location of the public chargers, it might be the case that fewer public chargers can be located on a charging square, or that public charging squares have different characteristics. If this is the case, urban planners can determine the demand for each of the locations by recalculating the probabilities to choose between the two locations.

If for example site eleven would be connected to a micro grid instead of only having load balancing to reduce the impact on the grid, the charge certainty of site eleven increases to 95% certainty. Since site eleven will have a higher charge certainty, the demand for public chargers in each of the context situations changes. Figure 25 presents the new demand for public chargers based on the new characteristics of both sites.

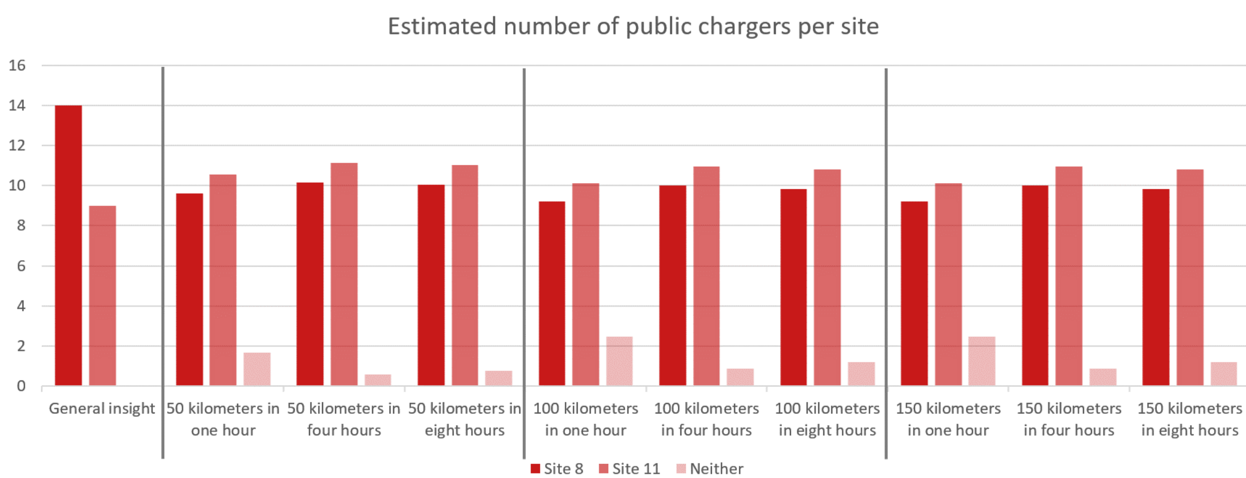


Figure 25. Demand for public chargers per site in different contexts in a different scenario

Compared to the situation where both charging squares had the same characteristics, site elven now has a higher demand for public chargers in all of the context situations due to the increased charge certainty. On average, site eleven will have a demand for eleven public chargers and site eight will have a demand for ten public chargers. Comparing this scenario to the determined demand when assuming general insights, site eleven has a higher demand and site eight has a considerably lower demand.

Since the procedure described above is the same for all remaining building blocks/different combinations of locations/different site characteristics these will not be elaborated on any further. This is because this chapter was about showing that the results have a practical application.

5.5. Conclusion

The goal of this chapter was to demonstrate the practical application of the results on a development of Dura Vermeer Vastgoed. Concluding this chapter, it can be stated that the results of chapter four indeed have a practical application and are able to help determine the probability that a charging square is chosen. However, in order to be able to show the practical application, several assumptions have been made throughout this chapter and these assumptions need to be verified before using the results in practice. In reality it might be the case that several of the assumptions differ which will result in different outputs.

Furthermore, the results of the practical application have shown that by using the results presented throughout this thesis, the demand for public chargers per site differs compared to the demand estimated based on general insights. Therefore, the results of this thesis are able to help provide a better distribution of public chargers over the residential environment. Additionally, urban planners are able to recalculate the probabilities of choosing between different sites if the characteristics of the sites change. By changing the characteristics, it is possible to evenly distribute the number of public chargers over the development area.

Overall, it can therefore be concluded that the results yield a practical application and are able to provide useful results for practice when taking into account the assumptions and limitations of this thesis (elaborated in chapter six).

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6. Discussion and conclusion

In this chapter, the presented results will be discussed and used to answer the main research question:

"Which user preferences are most important to be included in a tool that evaluates locations for charging squares in metropolitan areas?"

This study was carried out since the expected increase in the number of electric vehicles will result in a higher demand for public charging locations in urban environments where residents have fewer options to charge on private property. The expected acceleration of electric vehicle adoption means that it is needed to think about future public charging possibilities now. In this way, the adoption of electric vehicles will not be halted by the lack of public chargers. In order to provide public charging in an efficient way, this thesis argued to use public charging squares which consist of multiple charging points (each with one or more charging ports) with a shared grid connection located at a single location which is publicly accessible. This thesis argued to use a public charging square since it has several benefits compared to individual public charging points, like lower impact on the grid, easier to find, easier to install and maintain and future proof (NKL Nederland, 2021a).

When deciding on a suitable location for a public charging square, several important stakeholders are involved according to the stakeholder analysis. The project developer is the most important stakeholder involved in the location decision if the charging square needs to be realized in a new area development. However, since not every charging square will be realized in a new area development, a project developer is not always involved. Another important stakeholder which is always involved is the electric vehicle owner. The electric vehicle owner needs to be taken into consideration throughout the entire decision process since in the end, they need to use the charging square.

The stakeholders with the highest decision power are the governmental parties because they are responsible for assuring that the development is in line with the current regulations and therefore have the possibility to withhold a permit if this is not the case. Additionally, only governmental parties can assign locations where public charging facilities can be realized in the land-use plan. Another stakeholder with a high decision power in the ultimate location decision for public charging squares are the power grid operators. Power grid operators are responsible for assuring the continuity of the power grid by controlling the network and capacity on the grid. Therefore, if the electricity grid is too congested, an application for a new connection can be rejected by this stakeholder. The governmental parties as well as the power grid operators have a limited interest in the location as long as the policies that are in place are met.

Not only the stakeholders have an impact on the location decision for public charging squares, also the user preferences and built environment aspects influence the location decision. Based on the literature, costs, availability, search time and walking distance are deemed important aspects when considering a parking location from an user's perspective. The most important consideration from an user's perspective are the costs. In addition, if the public charging square is located too far from the residence, electric vehicle drivers are unwilling to use it. A maximum acceptable walking distance between the dwelling and parking location is 150 meters in residential environments according to the literature (Netherlands Institute for Transportation Policy Analysis, 2018). In order to select a suitable location, aspects like accessibility, safety of the vehicle, and grid capacity also have to be taken into account as these built environment aspects influence the suitability of the location for a charging square as well. Since the literature identified important user and built environment aspects but did not consider these aspects in relation to deciding on a public charging square, these aspects were investigated since more and more electric vehicles will be owned in the future. This study therefore investigated the importance of the different aspect by conducting a stated choice experiment among Dutch respondents.

This thesis considered a stated choice experiment as a suitable method for analysis since stated choice modelling is able to analyze the preference for new, non-existing situations. Deciding on which public charging square to use is considered a new, non-existing situation since currently there are only a limited number of public charging squares available. Since there are only a few charging squares in the

Netherlands, deciding on which charging square to use is a hypothetical question as it is likely that respondents did not have to make such a decision in real life yet.

The results of this study are based on 485 unique responses collected through an online distributed questionnaire using Limesurvey. Since excluding responses which chose the same option for every choice set or only partially completed the stated choice experiment resulted in an increased model fit for the MNL model, there was chosen to exclude these responses. Excluding these responses was considered valid since partially completing the stated choice experiment or answering the same answer option for each choice task was considered suspicious.

Once the final dataset was created through recoding and only selecting useful responses, the representativeness analysis showed that there is no match between the collected data sample and the data sample of the "Nationaal Laadonderzoek". Even though educated males with a high income are dominantly present in both datasets, the samples are not a match. The reason for this is that the distribution of gender, highest completed education level and household composition differ too much between both datasets. The only variable on which a statistically significant match was found was the income distribution. Additionally, the dataset of the "Nationaal Laadonderzoek" only included responses from Dutch electric vehicle drivers while this study also has taken responses from fossil-fuel drivers into account. However, since 75% of the respondents drive or at least sometimes drive an electric vehicle and the current electric vehicle drivers have the best experience with the current infrastructure and knows what is currently lacking and therefore needs to be improved, the dataset was still considered useful for the MNL and LC model estimation.

In the MNL model estimation, the coefficients of the different parameters included in the stated choice experiment and their corresponding significance level have been estimated. According to the results presented in chapter four, respondents were more likely to choose one of the presented alternatives in the stated choice experiment over the "none-choice" alternative. The MNL model estimation showed that costs, charge certainty, walking distance and having to relocate the vehicle have a significant impact on the location choice. The only two main effects which did not seem to have a significant impact on the overall utility were the supervision of the public charging location and the alternative function for parking.

Based on the MNL results, slow chargers are preferred over fast chargers when considering a public charging square in residential environments. Of the remaining variables included in the stated choice experiment, the cost of charging is considered to be the most dominant variable influencing a location choice. If the costs of either slow charging or fast charging increases, the utility of that location rapidly decreases. For both cost attributes, the level with the lowest cost had the largest positive impact on the overall utility (all else equal). This was in line with the expectations since the literature already indicated that costs are a dominant variable influencing parking choice (Chakraborty et al., 2019; Chaniotakis & Pel, 2015; Golias et al., 2002; Hassine et al., 2022; Hilvert et al., 2012; Ibeas et al., 2014; Kobus et al., 2012; Litman & Burwell, 2006). One of the possible explanations for the fact that costs are such a dominant variable in this study is because the majority of respondents in this study have a privately owned vehicle. This means that the respondents in this sample mainly have to pay for the costs of charging themselves, and this could have resulted in the fact that cost is the most important variable.

The second most important aspect according to the results of the MNL model is the walking distance between the public charging square and the residence. Based on the results, the user wants to have the public charging square as close as possible to the residence in order to reduce the walking distance. In the literature, 150 meters walking distance was identified as the maximum acceptable walking distance in residential environments (Netherlands Institute for Transportation Policy Analysis, 2018) and this study showed that having the public charging square at around 150 meters walking distance seems not to influence the overall utility. Having a public charging square closer to the residence has a positive impact on the overall utility of the public charging square while longer walking distances have a negative impact. The remaining variables in order of importance are having to relocate the vehicle, charge certainty, alternative functions for parking and supervision at the public charging location.

Next to the MNL analysis, also several LC models were estimated in order to check for the existence of different clusters (or classes) of respondents in the dataset. Given a preset number of classes, Nlogit was used to estimate the parameter values for the respondents in each class. In total five different LC models were estimated, and the LC model which did not include the class membership variables and several context effects turned out to be the best estimation based on the BIC value.

Ultimately, the reason why the class membership variables were excluded from the LC model was because the class membership variables were all insignificant at the 10% level except for the constant variable. Possibly, if another categorization would have been used during the data collection period, other groupings could have been used for the socio-demographics in the LC model estimation that might resulted in significant class membership variables.

Since the final LC model did not include any class membership variables, it was not possible to identify what makes a respondent belong to either of the created classes. Class one contained 86% of all respondents while class two contained the remaining 14% of the respondents. Since class two is a relatively small class compared to class one, this possibly caused the statistical insignificance of the class membership results. Furthermore, almost all parameter values estimated by the LC model for class two were insignificant, likely as a result of the small class, while in class one, the results were comparable to the final MNL model which excluded several context effects. Since class one contains 86% of the dataset, finding comparable MNL estimates for this class in the LC model estimation is logical.

Finally, the results of the MNL model estimation were used to show the practical application in a design tool. In order to be able to show the practical application, eleven potential sites were identified in TudorPark, a development of Dura Vermeer Vastgoed. The practical application showed that the presented results are indeed able to determine which of the identified locations will have the highest potential demand for public chargers. Therefore, the practical application showed that the results presented in this thesis can be used in a design tool to determine the probability that a resident chooses between two public charging squares if potential sites have been identified. Additionally, if the urban planners have to make decisions on how to increase the probability that a location is chosen, the results of this thesis can be used as well. Therefore, it can be concluded that the results yield a practical application and are able to provide useful results for practice when taking into account the assumptions and limitations of this thesis.

The findings presented in this thesis should be considered given the following limitations:

- First, after the sample was collected and the dataset was analyzed, the representative analysis showed that the sample is not representative. Therefore, the results are not directly generalizable for a larger population. Furthermore, this study has not taken into consideration any special requirements for the disabled in society.
- Second, in this study only unique combinations of the type of chargers were included in the stated choice experiment instead of including all possible combinations. A possible consequence of this is that if the first presented alternative was sufficient for the respondent, the second alternative was not evaluated anymore. The combinations fast-slow, both-fast, both-slow were not included in order to reduce the burden on the respondent. Next to that, the order of presenting the unique charger combinations was the same for every respondent and only the 81 choice sets for each unique combination of chargers were randomized in Limesurvey.
- A third limitation of this study is that in order to reduce the size of the model, this study only included two context effects. Interaction effects between the main attributes and higher order interactions were not considered in this thesis.
- A fourth limitation that has to be mentioned is the fact that in order to show the practical application of the results, it was needed to make several assumptions which might differ in reality.
- A final limitation that will be mentioned is that the behavioral change needed in order to use a public charging square instead of parking right in front of the home has not been taken into account in this study.

In order to solve the first limitation, future researchers can extend the data collection period or involve a data panel which has a representative population for the entire Dutch population in order to make the results generally applicable. Additionally, future studies should take into account specific requirements for the disabled and other minority groups. By including more respondents in the study, it is also possible to split the stated choice experiment into multiple parts with only a selection of charger combinations. This will decrease the burden on the respondent while at the same time including all possible combinations of chargers in a random order. Future researchers are encouraged to include (higher order) interaction effects to find potential new relations which were not discovered in this study. Additionally, since visitors of a residential environment might have different preferences compared to the residents of the same residential environment, future researchers should consider to also focus on visitors since the respondents that participated in this study were asked to answer the questions from a resident's perspective and not a visitor's perspective. Likewise, future studies should take a more in depth look into the assumptions that have been made to show the practical application of the results. In addition, this study included the supervision level "visible from the (surrounding) dwellings" but did not specify this level any further for the respondent. A possible way to better specify this level for the respondent is to indicate from where in the dwelling the charging square is visible and whether or not the visibility is (un)obstructed. Therefore, to take into account different types of supervision from a dwelling (is it visible from the back side, front side or only along the dwelling) future studies should specify this level more in order to determine potential differences in the part-worth utility. Finally, the final limitation can be solved by performing a new study, which is completely focused on the behavioral change that is needed to use a public charging square and the adoption of those locations.

Overall, the results presented throughout this study are consistent with several studies mentioned in the literature review. The studies mentioned in the literature review had identified several important aspects regarding the location decision when deciding on a public parking location but did not consider these aspects in relation to charging an electric vehicle. According to the results of this thesis, the most important considerations from a user's perspective are the costs of charging, followed by walking distance. When users of public charging squares are deciding which location to use, they look for the lowest cost and want the charging square as close as possible to their residence. The lower the charge certainty is at a public charging square, the less likely an electric vehicle driver chooses for that charging square. Additionally, if the electric vehicle needs to be relocated once the battery is completely charged, electric vehicle drivers are reluctant to use that public charging square. The final two aspects, supervision on the charging location and the alternative functions for parking, only marginally influence the location decision for an electric vehicle driver and are therefore the least important aspects that need to be taken into account when deciding on the location for a public charging square.

The results presented throughout this study contribute to the academic knowledge already available related to public charging squares as previous studies only considered the aspects included in this thesis in relation to public parking and did not consider the aspects in relation to public charging squares. This study has provided evidence that there are different aspects that impact the location decision of electric vehicle drivers when deciding on a location to charge their electric vehicle.

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Appendix A – Fractional factorial design

Table 16. Factional factorial design

Choice set	Attribute															
#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
2	-1	-1	0	0	-1	-1	-1	1	0	1	0	0	0	0	1	-1
3	-1	-1	1	1	-1	-1	-1	0	1	0	1	1	1	1	0	-1
4	0	0	-1	-1	-1	0	0	0	0	-1	1	0	-1	-1	0	-1
5	0	0	0	0	-1	0	0	-1	1	1	-1	1	0	0	-1	-1
6	0	0	1	1	-1	0	0	1	-1	0	0	-1	1	1	1	-1
7	1	1	-1	-1	-1	1	1	1	1	-1	0	1	-1	-1	1	-1
8	1	1	0	0	-1	1	1	0	-1	1	1	-1	0	0	0	-1
9	1	1	1	1	-1	1	1	-1	0	0	-1	0	1	1	-1	-1
10	-1	-1	0	-1	0	1	0	0	-1	0	0	-1	-1	1	-1	1
11	-1	-1	1	0	0	1	0	-1	0	-1	1	0	0	-1	1	1
12	-1	-1	-1	1	0	1	0	1	1	1	-1	1	1	0	0	1
13	0	0	0	-1	0	-1	1	1	0	0	-1	0	-1	1	0	1
14	0	0	1	0	0	-1	1	0	1	-1	0	1	0	-1	-1	1
15	0	0	-1	1	0	-1	1	-1	-1	1	1	-1	1	0	1	1
16	1	1	0	-1	0	0	-1	-1	1	0	1	1	-1	1	1	1
17	1	1	1	0	0	0	-1	1	-1	-1	-1	-1	0	-1	0	1
18	1	1	-1	1	0	0	-1	0	0	1	0	0	1	0	-1	1
19	-1	-1	1	-1	1	0	1	1	-1	1	1	-1	-1	0	-1	0
20	-1	-1	-1	0	1	0	1	0	0	0	-1	0	0	1	1	0
21	-1	-1	0	1	1	0	1	-1	1	-1	0	1	1	-1	0	0
22	0	0	1	-1	1	1	-1	-1	0	1	0	0	-1	0	0	0
23	0	0	-1	0	1	1	-1	1	1	0	1	1	0	1	-1	0
24	0	0	0	1	1	1	-1	0	-1	-1	-1	-1	1	-1	1	0
25	1	1	1	-1	1	-1	0	0	1	1	-1	1	-1	0	1	0
26	1	1	-1	0	1	-1	0	-1	-1	0	0	-1	0	1	0	0
27	1	1	0	1	1	-1	0	1	0	-1	1	0	1	-1	-1	0
28	0	-1	1	0	0	0	-1	-1	0	1	0	-1	1	-1	1	0
29	0	-1	-1	1	0	0	-1	1	1	0	1	0	-1	0	0	0
30	0	-1	0	-1	0	0	-1	0	-1	-1	-1	1	0	1	-1	0
31	1	0	1	0	0	1	0	0	1	1	-1	0	1	-1	-1	0
32	1	0	-1	1	0	1	0	-1	-1	0	0	1	-1	0	1	0
33	1	0	0	-1	0	1	0	1	0	-1	1	-1	0	1	0	0
34	-1	1	1	0	0	-1	1	1	-1	1	1	1	1	-1	0	0
35	-1	1	-1	1	0	-1	1	0	0	0	-1	-1	-1	0	-1	0
36	-1	1	0	-1	0	-1	1	-1	1	-1	0	0	0	1	1	0
37	0	-1	-1	0	1	-1	0	0	0	-1	1	-1	1	1	1	-1
38	0	-1	0	1	1	-1	0	-1	1	1	-1	0	-1	-1	0	-1

39	0	-1	1	-1	1	-1	0	1	-1	0	0	1	0	0	-1	-1
40	1	0	-1	0	1	0	1	1	1	-1	0	0	1	1	-1	-1
41	1	0	0	1	1	0	1	0	-1	1	1	1	-1	-1	1	-1
42	1	0	1	-1	1	0	1	-1	0	0	-1	-1	0	0	0	-1
43	-1	1	-1	0	1	1	-1	-1	-1	-1	-1	1	1	1	0	-1
44	-1	1	0	1	1	1	-1	1	0	1	0	-1	-1	-1	-1	-1
45	-1	1	1	-1	1	1	-1	0	1	0	1	0	0	0	1	-1
46	0	-1	0	0	-1	1	1	1	0	0	-1	-1	1	0	1	1
47	0	-1	1	1	-1	1	1	0	1	-1	0	0	-1	1	0	1
48	0	-1	-1	-1	-1	1	1	-1	-1	1	1	1	0	-1	-1	1
49	1	0	0	0	-1	-1	-1	-1	1	0	1	0	1	0	-1	1
50	1	0	1	1	-1	-1	-1	1	-1	-1	-1	1	-1	1	1	1
51	1	0	-1	-1	-1	-1	-1	0	0	1	0	-1	0	-1	0	1
52	-1	1	0	0	-1	0	0	0	-1	0	0	1	1	0	0	1
53	-1	1	1	1	-1	0	0	-1	0	-1	1	-1	-1	1	-1	1
54	-1	1	-1	-1	-1	0	0	1	1	1	-1	0	0	-1	1	1
55	1	-1	0	1	1	1	-1	-1	1	0	1	-1	0	-1	0	1
56	1	-1	1	-1	1	1	-1	1	-1	-1	-1	0	1	0	-1	1
57	1	-1	-1	0	1	1	-1	0	0	1	0	1	-1	1	1	1
58	-1	0	0	1	1	-1	0	0	-1	0	0	0	0	-1	1	1
59	-1	0	1	-1	1	-1	0	-1	0	-1	1	1	1	0	0	1
60	-1	0	-1	0	1	-1	0	1	1	1	-1	-1	-1	1	-1	1
61	0	1	0	1	1	0	1	1	0	0	-1	1	0	-1	-1	1
62	0	1	1	-1	1	0	1	0	1	-1	0	-1	1	0	1	1
63	0	1	-1	0	1	0	1	-1	-1	1	1	0	-1	1	0	1
64	1	-1	1	1	-1	0	0	0	1	1	-1	-1	0	1	0	0
65	1	-1	-1	-1	-1	0	0	-1	-1	0	0	0	1	-1	-1	0
66	1	-1	0	0	-1	0	0	1	0	-1	1	1	-1	0	1	0
67	-1	0	1	1	-1	1	1	1	-1	1	1	0	0	1	1	0
68	-1	0	-1	-1	-1	1	1	0	0	0	-1	1	1	-1	0	0
69	-1	0	0	0	-1	1	1	-1	1	-1	0	-1	-1	0	-1	0
70	0	1	1	1	-1	-1	-1	-1	0	1	0	1	0	1	-1	0
71	0	1	-1	-1	-1	-1	-1	1	1	0	1	-1	1	-1	1	0
72	0	1	0	0	-1	-1	-1	0	-1	-1	-1	0	-1	0	0	0
73	1	-1	-1	1	0	-1	1	1	1	-1	0	-1	0	0	0	-1
74	1	-1	0	-1	0	-1	1	0	-1	1	1	0	1	1	-1	-1
75	1	-1	1	0	0	-1	1	-1	0	0	-1	1	-1	-1	1	-1
76	-1	0	-1	1	0	0	-1	-1	-1	-1	-1	0	0	0	1	-1
77	-1	0	0	-1	0	0	-1	1	0	1	0	1	1	1	0	-1
78	-1	0	1	0	0	0	-1	0	1	0	1	-1	-1	-1	-1	-1
79	0	1	-1	1	0	1	0	0	0	-1	1	1	0	0	-1	-1
80	0	1	0	-1	0	1	0	-1	1	1	-1	-1	1	1	1	-1
81	0	1	1	0	0	1	0	1	-1	0	0	0	-1	-1	0	-1

In order to create the presented design above, Ngene (Choice-metrics, 2021) has been used in this thesis. Below, the syntax used in Ngene to create the design is presented.

```
Design
;alts = alt1, alt2
;rows = 45
;orth = sim
;model:
U(alt1) = b01 +
b2 * Context1[-1,0,1] +
b3 * Context2[-1,0,1] +
b4 * Kosten1[-1,0,1] +
b5 * Kosten2[-1,0,1] +
b6 * Loopafstand[-1,0,1] +
b7 * Veiligheid[-1,0,1] +
b9 * Laadzekerheid[-1,0,1]  +
b10 * Anti[-1,0,1] +
b11 * Terug[-1,0,1] +
b12 * V2Kosten1[-1,0,1] +
b13 * V2Kosten2[-1,0,1] +
b14 * V2Loopafstand[-1,0,1] +
b15 * V2Veiligheid[-1,0,1] +
b17 * V2Laadzekerheid[-1,0,1]  +
b18 * V2Anti[-1,0,1] +
b19 * V2Terug[-1,0,1] +
b20 * Context1 * Kosten1 +
b21 * Context1 * Kosten2 +
b22 * Context1 * Loopafstand +
b23 * Context1 * Veiligheid +
b25 * Context1 * Laadzekerheid +
b26 * Context1 * Anti +
b27 * Context1 * Terug +
b28 * Context1 * V2Kosten1 +
b29 * Context1 * V2Kosten2 +
b30 * Context1 * V2Loopafstand +
b31 * Context1 * V2Veiligheid +
b33 * Context1 * V2Laadzekerheid +
b34 * Context1 * V2Anti +
b35 * Context1 * V2Terug +
b36 * Context2 * Kosten1 +
b37 * Context2 * Kosten2 +
b38 * Context2 * Loopafstand +
b39 * Context2 * Veiligheid +
b41 * Context2 * Laadzekerheid +
b42 * Context2 * Anti +
b43 * Context2 * Terug +
b44 * Context2 * V2Kosten1 +
b45 * Context2 * V2Kosten2 +
b46 * Context2 * V2Loopafstand +
b47 * Context2 * V2Veiligheid +
b49 * Context2 * V2Laadzekerheid +
b50 * Context2 * V2Anti +
b51 * Context2 * V2Terug/

U(alt2) =       b2 * Context1[-1,0,1] +
b3 * Context2[-1,0,1] +
b4 * Kosten1[-1,0,1] +
b5 * Kosten2[-1,0,1] +
b6 * Loopafstand[-1,0,1] +
b7 * Veiligheid[-1,0,1] +
```

```
b9 * Laadzekerheid[-1,0,1]  +
b10 * Anti[-1,0,1] +
b11 * Terug[-1,0,1] +
b12 * V2Kosten1[-1,0,1] +
b13 * V2Kosten2[-1,0,1] +
b14 * V2Loopafstand[-1,0,1] +
b15 * V2Veiligheid[-1,0,1] +
b17 * V2Laadzekerheid[-1,0,1]  +
b18 * V2Anti[-1,0,1] +
b19 * V2Terug[-1,0,1] +
b20 * Context1 * Kosten1 +
b21 * Context1 * Kosten2 +
b22 * Context1 * Loopafstand +
b23 * Context1 * Veiligheid +
b25 * Context1 * Laadzekerheid +
b26 * Context1 * Anti +
b27 * Context1 * Terug +
b28 * Context1 * V2Kosten1 +
b29 * Context1 * V2Kosten2 +
b30 * Context1 * V2Loopafstand +
b31 * Context1 * V2Veiligheid +
b33 * Context1 * V2Laadzekerheid +
b34 * Context1 * V2Anti +
b35 * Context1 * V2Terug +
b36 * Context2 * Kosten1 +
b37 * Context2 * Kosten2 +
b38 * Context2 * Loopafstand +
b39 * Context2 * Veiligheid +
b41 * Context2 * Laadzekerheid +
b42 * Context2 * Anti +
b43 * Context2 * Terug +
b44 * Context2 * V2Kosten1 +
b45 * Context2 * V2Kosten2 +
b46 * Context2 * V2Loopafstand +
b47 * Context2 * V2Veiligheid +
b49 * Context2 * V2Laadzekerheid +
b50 * Context2 * V2Anti +
b51 * Context2 * V2Terug


$
```

Appendix B – Questionnaire

This Appendix shows the final questionnaire as presented to the respondents. Therefore, only twelve out of the 486 different choice sets are presented in this Appendix. Since the questionnaire was only distributed among Dutch participants, the whole questionnaire was written in Dutch.

Onderzoek naar gebruikerswensen elektrisch opladen (± 5 min)

Beste meneer, mevrouw,

Om de klimaatdoelstellingen van de Europese Unie te behalen, heeft Nederland besloten dat vanaf 2030 alle nieuwe auto's emissievrij moeten zijn. Hierdoor zal er een enorme toename zijn in het aantal elektrische auto's waardoor ook de vraag naar oplaadplaatsen zal toenemen.

Deze vragenlijst is onderdeel van mijn afstudeeronderzoek aan de Technische Universiteit Eindhoven waarmee ik inzicht wil krijgen in de aspecten die huidige en toekomstige bestuurders van elektrische auto's belangrijk vinden bij het kiezen van een oplaadplek nabij hun woning.

Het invullen van de vragenlijst zal **ongeveer 5 minuten** duren en is geheel vrijwillig. Alle antwoorden worden anoniem opgeslagen en zullen niet te herleiden zijn tot individuele personen. Naast bestuurders van elektrische auto's worden ook personen die nu (nog) geen elektrische auto rijden uitgenodigd deel te nemen aan dit onderzoek. Hartelijk dank voor uw deelname, en mocht u vragen hebben dan kunt u altijd contact opnemen.

Met vriendelijke groet,

Mark Polet

Master student aan de Technische Universiteit Eindhoven e-mail: m.r.polet@student.tue.nl

Volgende

Privacy verklaring

Ik begrijp dat deelname aan het onderzoek op geheel vrijwillige basis is en ik te allen tijde kan stoppen, of kan weigeren dat mijn gegevens gebruikt mogen worden voor het onderzoek, zonder opgaaf van reden. Als ik mijn medewerking besluit te stoppen tijdens het onderzoek mogen de reeds verzamelde gegevens tot het moment van intrekking gebruikt worden in het onderzoek. Ik geef toestemming om de bij mij verzamelde onderzoeksdata te gebruiken en ik verklaar dat ik voldoende geïnformeerd ben over het onderzoek.

Lees voordat u mee doet hier alle informatie over het onderzoek (klik hier)
(/upload/surveys/472695/files/Informed%20consent%20formulier%20(NL).pdf)

- ○ Akkoord
- ○ Niet akkoord

Selectievragen

Heeft u een rijbewijs?

- ✔ Ja
- ⊘ Nee

Hoeveel kilometer heeft u in de afgelopen 12 maanden gereden in een auto?

- ○ 0 kilometer
- ○ <10.000 kilometer
- ○ 10.001 – 20.000 kilometer
- ○ 20.001 – 30.000 kilometer
- ○ 30.001 – 40.000 kilometer
- ○ >40.000 kilometer

De auto waar u het meest mee gereden heeft is een...
Als u zelf geen auto bezit, beantwoord deze vraag dan hoe de eigenaar de auto bezit

- ○ Auto in privébezit/private lease
- ○ (Lease) auto van de zaak
- ○ Deelmobiliteit auto
- ○ Zeg ik liever niet

Waar parkeert u over het algemeen bij uw huis?

- ○ Op eigen terrein/oprit
- ○ Op een openbare parkeerplaats langs de weg
- ○ Op een openbaar parkeerterrein(tje)/verzamelparkeerplaats
- ○ In een parkeergarage

Rijdt u (wel eens) in een volledig elektrische auto?

- ✔ Ja
- ⊘ Nee

Is uw woning voorzien van een eigen oplaadpunt?

- ✔ Ja
- ⊘ Nee

Heeft u de mogelijkheid om bij uw werk een elektrische auto op te laden?

- ○ Ja
- ○ Nee
- ○ Ik werk altijd vanuit huis/ik heb geen baan
- ○ Weet ik niet

Volgende

Uitleg keuzetaak

In dit deel van de enquête krijgt u enkele keuzetaken waarin we naar uw voorkeur vragen over oplaadlocaties. **Lees onderstaande algemene uitleg goed door.**

In elke keuzetaak vertrekt u vanaf thuis en wilt u niet te laat aankomen bij uw volgende bestemming. Hierbij variëren de beschikbare **tijd om bij te laden (1, 4 of 8 uur)** en **het aantal bij te laden kilometers (50, 100 of 150 kilometer)**. Als het niet mogelijk is om het aantal kilometers bij te laden op genoemde oplaadlocaties dan is er onderweg de mogelijkheid om kort te stoppen bij een snellader voor het laatste stukje bereik.

In elke keuzetaak bestaat de oplaadlocatie uit langzame laadpunten (100 kilometer in ± 1,5 uur), snelle laadpunten (100 kilometer in ± 5 minuten) of een combinatie. Elke oplaadlocatie heeft daarnaast nog 6 kenmerken die kunnen variëren. Op de volgende pagina worden eerst alle kenmerken met bijbehorende niveaus weergegeven voordat u verder gaat naar de eerste keuzetaak. Bij elke keuzetaak kunt u via de toelichtingsknop de uitgebreide uitleg van alle kenmerken raadplegen.

Volgende

Kenmerken en bijbehorende niveaus

Hieronder ziet u een overzicht van alle kenmerken en bijbehorende niveaus:

Kenmerk	Niveau 1	Niveau 2	Niveau 3
Type laadpunt	Alleen langzaam laders	Alleen snelladers	Zowel langzaam laders als snelladers
Kosten langzaam laden	€0,25 per kWh	€0,40 per kWh	€0,55 per kWh
Kosten snelladen	€0,60 per kWh	€0,75 per kWh	€0,90 per kWh
Loopafstand	50 meter (in de straat)	150 meter (in de buurt)	250 meter (in de wijk)
Laadzekerheid	75%	85%	95%
Toezicht op laadlocatie	Geen toezicht	Vanuit de (omliggende) woning(en)	Cameratoezicht
Auto verplaatsen binnen	30 minuten nadat de accu vol is	2 uur nadat de accu vol is	De auto hoeft niet verplaatst te worden
Wat komt er extra voor terug?	Geen veranderingen	Meer groen	Voorzieningen voor sport en beweging

Een korte toelichting op een aantal kenmerken:

- De loopafstand betreft de afstand tussen de oplaadlocatie en uw woning.
- De laadzekerheid geeft aan hoe zeker u ervan kunt zijn dat 100 kilometer wordt bijgeladen in ± 1,5 uur (bij langzaam laden) of in ± 5 minuten (bij snelladen).
- Bij het niet tijdig verplaatsen van de auto nadat de accu vol is riskeert u een boete van €95.

Op de volgende pagina's vragen wij u om **12 keer** een keuze te maken. Na elke keuze gaat u automatisch verder naar de volgende keuzetaak.

Bedenk dat de kenmerken van de oplaadlocaties steeds veranderen en dat ook de bij te laden hoeveelheid kilometers en de beschikbare tijd daarvoor zal variëren.

Volgende

Keuzetaak 1

Stel, u moet **over 8 uur** weg met uw auto, maar u moet uw auto nog voor **50-kilometer bijladen**. Welke oplaadlocatie zou u kiezen? Als u geen van beide oplaadlocaties zou willen gebruiken, kies dan voor "Geen van beide".

	Laadlocatie 1	**Laadlocatie 2**
Type laadpunt	Alleen langzaam laders	Alleen langzaam laders
Kosten langzaam laden	€0,25 per kWh	€0,25 per kWh
Kosten snelladen	-	-
Loopafstand	250 meter (in de wijk)	150 meter (in de buurt)
Laadzekerheid	95%	95%
Toezicht op laadlocatie	Geen toezicht	Vanuit de (omliggende) woning(en)
Auto verplaatsen binnen	30 minuten nadat de accu vol is	De auto hoeft niet verplaatst te worden
Wat komt er extra voor terug?	Geen veranderingen	Geen veranderingen

Laadlocatie 1

Laadlocatie 2

Geen van beide

Klik hier voor de toelichting op de variabelen

Keuzetaak 2

Stel, u moet **over 8 uur** weg met uw auto, maar u moet uw auto nog voor **150-kilometer bijladen**. Welke oplaadlocatie zou u kiezen? Als u geen van beide oplaadlocaties zou willen gebruiken, kies dan voor "Geen van beide".

	Laadlocatie 1	**Laadlocatie 2**
Type laadpunt	Alleen langzaam laders	Alleen langzaam laders
Kosten langzaam laden	€0,25 per kWh	€0,55 per kWh
Kosten snelladen	-	-
Loopafstand	150 meter (in de buurt)	150 meter (in de buurt)
Laadzekerheid	85%	85%
Toezicht op laadlocatie	Vanuit de (omliggende) woning(en)	Geen toezicht
Auto verplaatsen binnen	30 minuten nadat de accu vol is	2 uur nadat de accu vol is
Wat komt er extra voor terug?	Meer groen	Voorzieningen voor sport en beweging

Laadlocatie 1

Laadlocatie 2

Geen van beide

Klik hier voor de toelichting op de variabelen

Keuzetaak 3

Stel, u moet **over 1 uur** weg met uw auto, maar u moet uw auto nog voor **100-kilometer bijladen**. Welke oplaadlocatie zou u kiezen? Als u geen van beide oplaadlocaties zou willen gebruiken, kies dan voor "Geen van beide".

	Laadlocatie 1	**Laadlocatie 2**
Type laadpunt	Alleen langzaam laders	Alleen snelladers
Kosten langzaam laden	€0,40 per kWh	-
Kosten snelladen	-	€0,60 per kWh
Loopafstand	250 meter (in de wijk)	150 meter (in de buurt)
Laadzekerheid	75%	75%
Toezicht op laadlocatie	Cameratoezicht	Cameratoezicht
Auto verplaatsen binnen	De auto hoeft niet verplaatst te worden	2 uur nadat de accu vol is
Wat komt er extra voor terug?	Meer groen	Voorzieningen voor sport en beweging

Laadlocatie 1

Laadlocatie 2

Geen van beide

Klik hier voor de toelichting op de variabelen

Keuzetaak 4

Stel, u moet **over 8 uur** weg met uw auto, maar u moet uw auto nog voor **50-kilometer bijladen**. Welke oplaadlocatie zou u kiezen? Als u geen van beide oplaadlocaties zou willen gebruiken, kies dan voor "Geen van beide".

	Laadlocatie 1	**Laadlocatie 2**
Type laadpunt	Alleen langzaam laders	Alleen snelladers
Kosten langzaam laden	€0,40 per kWh	-
Kosten snelladen	-	€0,75 per kWh
Loopafstand	150 meter (in de buurt)	150 meter (in de buurt)
Laadzekerheid	75%	95%
Toezicht op laadlocatie	Vanuit de (omliggende) woning(en)	Vanuit de (omliggende) woning(en)
Auto verplaatsen binnen	2 uur nadat de accu vol is	2 uur nadat de accu vol is
Wat komt er extra voor terug?	Geen veranderingen	Voorzieningen voor sport en beweging

Laadlocatie 1

Laadlocatie 2

Geen van beide

Klik hier voor de toelichting op de variabelen

Keuzetaak 5

Stel, u moet **over 8 uur** weg met uw auto, maar u moet uw auto nog voor **150-kilometer bijladen**. Welke oplaadlocatie zou u kiezen? Als u geen van beide oplaadlocaties zou willen gebruiken, kies dan voor "Geen van beide".

	Laadlocatie 1	**Laadlocatie 2**
Type laadpunt	Alleen langzaam laders	Zowel langzaam laders als snelladers
Kosten langzaam laden	€0,40 per kWh	€0,25 per kWh
Kosten snelladen	-	€0,90 per kWh
Loopafstand	50 meter (in de straat)	150 meter (in de buurt)
Laadzekerheid	95%	85%
Toezicht op laadlocatie	Cameratoezicht	Geen toezicht
Auto verplaatsen binnen	2 uur nadat de accu vol is	30 minuten nadat de accu vol is
Wat komt er extra voor terug?	Meer groen	Meer groen

Laadlocatie 1

Laadlocatie 2

Geen van beide

Klik hier voor de toelichting op de variabelen

Keuzetaak 6

Stel, u moet **over 8 uur** weg met uw auto, maar u moet uw auto nog voor **100-kilometer bijladen**. Welke oplaadlocatie zou u kiezen? Als u geen van beide oplaadlocaties zou willen gebruiken, kies dan voor "Geen van beide".

	Laadlocatie 1	**Laadlocatie 2**
Type laadpunt	Alleen langzaam laders	Zowel langzaam laders als snelladers
Kosten langzaam laden	€0,25 per kWh	€0,55 per kWh
Kosten snelladen	-	€0,90 per kWh
Loopafstand	150 meter (in de buurt)	250 meter (in de wijk)
Laadzekerheid	95%	85%
Toezicht op laadlocatie	Geen toezicht	Vanuit de (omliggende) woning(en)
Auto verplaatsen binnen	De auto hoeft niet verplaatst te worden	De auto hoeft niet verplaatst te worden
Wat komt er extra voor terug?	Geen veranderingen	Voorzieningen voor sport en beweging

Laadlocatie 1

Laadlocatie 2

Geen van beide

Klik hier voor de toelichting op de variabelen

Keuzetaak 7

Stel, u moet **over 8 uur** weg met uw auto, maar u moet uw auto nog voor **150-kilometer bijladen**. Welke oplaadlocatie zou u kiezen? Als u geen van beide oplaadlocaties zou willen gebruiken, kies dan voor "Geen van beide".

	Laadlocatie 1	**Laadlocatie 2**
Type laadpunt	Alleen snelladers	Alleen snelladers
Kosten langzaam laden	-	-
Kosten snelladen	€0,75 per kWh	€0,90 per kWh
Loopafstand	250 meter (in de wijk)	50 meter (in de straat)
Laadzekerheid	75%	75%
Toezicht op laadlocatie	Vanuit de (omliggende) woning(en)	Vanuit de (omliggende) woning(en)
Auto verplaatsen binnen	De auto hoeft niet verplaatst te worden	2 uur nadat de accu vol is
Wat komt er extra voor terug?	Geen veranderingen	Geen veranderingen

Laadlocatie 1

Laadlocatie 2

Geen van beide

Klik hier voor de toelichting op de variabelen

Keuzetaak 8

Stel, u moet **over 4 uur** weg met uw auto, maar u moet uw auto nog voor **150-kilometer bijladen**. Welke oplaadlocatie zou u kiezen? Als u geen van beide oplaadlocaties zou willen gebruiken, kies dan voor "Geen van beide".

	Laadlocatie 1	**Laadlocatie 2**
Type laadpunt	Alleen snelladers	Alleen snelladers
Kosten langzaam laden	-	-
Kosten snelladen	€0,60 per kWh	€0,75 per kWh
Loopafstand	50 meter (in de straat)	50 meter (in de straat)
Laadzekerheid	75%	75%
Toezicht op laadlocatie	Vanuit de (omliggende) woning(en)	Vanuit de (omliggende) woning(en)
Auto verplaatsen binnen	30 minuten nadat de accu vol is	30 minuten nadat de accu vol is
Wat komt er extra voor terug?	Meer groen	Voorzieningen voor sport en beweging

Laadlocatie 1

Laadlocatie 2

Geen van beide

Klik hier voor de toelichting op de variabelen

Keuzetaak 9

Stel, u moet **over 8 uur** weg met uw auto, maar u moet uw auto nog voor **100-kilometer bijladen**. Welke oplaadlocatie zou u kiezen? Als u geen van beide oplaadlocaties zou willen gebruiken, kies dan voor "Geen van beide".

	Laadlocatie 1	**Laadlocatie 2**
Type laadpunt	Alleen snelladers	Zowel langzaam laders als snelladers
Kosten langzaam laden	-	€0,55 per kWh
Kosten snelladen	€0,75 per kWh	€0,90 per kWh
Loopafstand	150 meter (in de buurt)	250 meter (in de wijk)
Laadzekerheid	95%	85%
Toezicht op laadlocatie	Geen toezicht	Vanuit de (omliggende) woning(en)
Auto verplaatsen binnen	De auto hoeft niet verplaatst te worden	De auto hoeft niet verplaatst te worden
Wat komt er extra voor terug?	Geen veranderingen	Voorzieningen voor sport en beweging

Laadlocatie 1

Laadlocatie 2

Geen van beide

Klik hier voor de toelichting op de variabelen

Keuzetaak 10

Stel, u moet **over 1 uur** weg met uw auto, maar u moet uw auto nog voor **100-kilometer bijladen**. Welke oplaadlocatie zou u kiezen? Als u geen van beide oplaadlocaties zou willen gebruiken, kies dan voor "Geen van beide".

	Laadlocatie 1	**Laadlocatie 2**
Type laadpunt	Alleen snelladers	Zowel langzaam laders als snelladers
Kosten langzaam laden	-	€0,25 per kWh
Kosten snelladen	€0,75 per kWh	€0,90 per kWh
Loopafstand	50 meter (in de straat)	150 meter (in de buurt)
Laadzekerheid	95%	75%
Toezicht op laadlocatie	Vanuit de (omliggende) woning(en)	Cameratoezicht
Auto verplaatsen binnen	2 uur nadat de accu vol is	De auto hoeft niet verplaatst te worden
Wat komt er extra voor terug?	Meer groen	Geen veranderingen

Laadlocatie 1

Laadlocatie 2

Geen van beide

Klik hier voor de toelichting op de variabelen

Keuzetaak 11

Stel, u moet **over 8 uur** weg met uw auto, maar u moet uw auto nog voor **50-kilometer bijladen**. Welke oplaadlocatie zou u kiezen? Als u geen van beide oplaadlocaties zou willen gebruiken, kies dan voor "Geen van beide".

	Laadlocatie 1	**Laadlocatie 2**
Type laadpunt	Zowel langzaam laders als snelladers	Zowel langzaam laders als snelladers
Kosten langzaam laden	€0,55 per kWh	€0,40 per kWh
Kosten snelladen	€0,60 per kWh	€0,90 per kWh
Loopafstand	250 meter (in de wijk)	50 meter (in de straat)
Laadzekerheid	95%	85%
Toezicht op laadlocatie	Vanuit de (omliggende) woning(en)	Cameratoezicht
Auto verplaatsen binnen	30 minuten nadat de accu vol is	2 uur nadat de accu vol is
Wat komt er extra voor terug?	Voorzieningen voor sport en beweging	Geen veranderingen

Laadlocatie 1

Laadlocatie 2

Geen van beide

Klik hier voor de toelichting op de variabelen

Keuzetaak 12

Stel, u moet **over 4 uur** weg met uw auto, maar u moet uw auto nog voor **150-kilometer bijladen**. Welke oplaadlocatie zou u kiezen? Als u geen van beide oplaadlocaties zou willen gebruiken, kies dan voor "Geen van beide".

	Laadlocatie 1	**Laadlocatie 2**
Type laadpunt	Zowel langzaam laders als snelladers	Zowel langzaam laders als snelladers
Kosten langzaam laden	€0,55 per kWh	€0,55 per kWh
Kosten snelladen	€0,75 per kWh	€0,60 per kWh
Loopafstand	250 meter (in de wijk)	150 meter (in de buurt)
Laadzekerheid	85%	85%
Toezicht op laadlocatie	Vanuit de (omliggende) woning(en)	Geen toezicht
Auto verplaatsen binnen	2 uur nadat de accu vol is	30 minuten nadat de accu vol is
Wat komt er extra voor terug?	Voorzieningen voor sport en beweging	Meer groen

Laadlocatie 1

Laadlocatie 2

Geen van beide

Klik hier voor de toelichting op de variabelen

Algemene vragen

Wat is uw geslacht?

- ○ Man
- ○ Vrouw
- ○ Overig/Zeg ik liever niet

Wat is uw leeftijd?

- ○ 15 tot 20 jaar
- ○ 20 tot 25 jaar
- ○ 25 tot 45 jaar
- ○ 45 tot 65 jaar
- ○ 65 tot 80 jaar
- ○ 80 jaar of ouder
- ○ Zeg ik liever niet

Wat zijn de 4 cijfers van de postcode van uw thuisadres?

……………………

Wat is de door u hoogst genoten opleiding?
Of gelijkwaardig internationaal diploma

- ○ Weet niet/Geen opleiding voltooid
- ○ Basisonderwijs
- ○ Vmbo, havo-onderbouw, vwo-onderbouw, mbo1
- ○ Havo, vwo, mbo2-4
- ○ Bachelor (HBO of WO)
- ○ Master (HBO of WO), doctor
- ○ Zeg ik liever niet
- ○ Anders:

Wat is de samenstelling van uw huishouden?

- ○ Eenpersoonshuishouden
- ○ Gehuwd/samenwonend
- ○ Gehuwd/samenwonend + kind(eren)
- ○ 1 oudergezin + kind(eren)
- ○ Zeg ik liever niet
- ○ Anders:

Wat is het bruto jaarinkomen van uw huishouden?

- ○ <10.000 euro
- ○ 10.001 – 20.000 euro
- ○ 20.001 – 30.000 euro
- ○ 30.001 – 40.000 euro
- ○ 40.001 – 50.000 euro
- ○ >50.000 euro
- ○ Zeg ik liever niet

Kunt u via de schuif aangeven hoe vaak u **gemiddeld per week** weer weg moet binnen 1, 4 of 8 uur nadat u thuis bent gekomen?

U bent hooguit 1 uur thuis voordat u weer weg moet/gaat

0 keer per week

U bent 1-4 uur thuis voordat u weer weg moet/gaat

0 keer per week

U bent 4-8 uur thuis voordat u weer weg moet/gaat

0 keer per week

Als u deze vraag niet wenst te beantwoorden kunt u op volgende klikken

Volgende

Laatste vraag

U heeft het einde van de enquête bereikt. Bedankt voor uw tijd! Om uw gegevens te versturen dient u op "**Verzenden**" te klikken. Mocht u inzicht willen in de onderzoeksresultaten dan kunt u op de volgende pagina contact opnemen met de onderzoeker Mark Polet.

Mocht u nog vragen en/of opmerkingen hebben (over ingevulde gegevens, verbeteringen van de enquête, enzovoorts) dan kunt u dat hieronder vermelden:

Verzenden

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Appendix C – Data collection partners

Table 17 shows which of the contacted data partners were willing to help distributing the questionnaire among as many respondents as possible. Some of the partners that were willing to collaborate with this study were only willing to distribute the questionnaire among their employees and not among their customers. Partners had different reasons for doing so but the most common reason for not sharing the questionnaire among their customers was that the company did not want to "over-ask" their customer.

Table 17. Overview of data collection partners

#	Name	Collaborated
1	ANWB	Yes
2	BOVAG	Yes
3	Delta energie	Yes
4	Dura Vermeer Techniek	Yes
5	Dura Vermeer Vastgoed	Yes
6	Elaad	Yes
7	Emodz	Yes
8	EV box	Yes
9	EV Consult	Yes
10	EV solutions	Yes
11	Green caravan	Yes
12	Innovam	Yes
13	Laadpaaldirect	Yes
14	Librijn	Yes
15	Maarten Steinbuch (prof. TU/e)	Yes
16	Nationale Agenda Laadinfrastructuur	Yes
17	NKL Nederland	Yes
18	NL Mobility	Yes
19	Personal network	Yes
20	RAI vereniging	Yes
21	Shell recharge	Yes
22	Stedin	Yes
23	TIM technical recruitment	Yes
24	Vattenfall incharge	Yes
25	Vereniging DOET	Yes
26	Vereniging voor elektrische rijders	Yes
27	viaBOVAG	Yes
28	We Drive Solar	Yes

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Appendix D – Effect coding

Table 18. Overview of effect coding for all attributes including the indication of the X-variable in Nlogit

Related to	Attribute	Levels		e1	e2	
Context	The range that needs to be charged?	Level 1	50 kilometers	1	0	X11
		Level 2	100 kilometers	0	1	X12
		Level 3	150 kilometers	-1	-1	
	Available time to charge	Level 1	One hour available to charge	1	0	X21
		Level 2	Four hours available to charge	0	1	X22
		Level 3	Eight hours available to charge	-1	-1	
Parking	Walking distance	Level 1	50 meters (in the street)	1	0	X71
		Level 2	150 meters (in the neighborhood)	0	1	X72
		Level 3	250 meters (in the district)	-1	-1	
	Supervision on charging location	Level 1	No supervision	1	0	X91
		Level 2	Supervision from (surrounding) dwelling(s)	0	1	X92
		Level 3	CCTV supervision	-1	-1	
	Move car within	Level 1	After 30 minutes once the battery is full	1	0	X81
		Level 2	After 2 hours once the battery is full	0	1	X82
		Level 3	The car does not need to be moved	-1	-1	
Charging	Type of charger	Level 1	Only slow chargers	0	-1	X31
		Level 2	Only fast chargers	-1	0	X32
		Level 3	Both slow chargers as well as fast chargers	0	0	
	Charge certainty	Level 1	75%	1	0	X61
		Level 2	85%	0	1	X62
		Level 3	95%	-1	-1	
	Costs (slow charging)	Level 1	€0.25 per kWh	1	0	X41
		Level 2	€0.40 per kWh	0	1	X42
		Level 3	€0.55 per kWh	-1	-1	
	Costs (fast charging)	Level 1	€0.60 per kWh	1	0	X51
		Level 2	€0.75 per kWh	0	1	X52
		Level 3	€0.90 per kWh	-1	-1	
Urban environment	Alternative function for parking	Level 1	No change	1	0	X101
		Level 2	More greenery	0	1	X102
		Level 3	Facilities for sport and exercise	-1	-1	

Table 19. Overview of context variables in Nlogit for the model estimation

Context variable in Nlogit for the model estimation		**Context variable in Nlogit for the model estimation**	
X111	50 kilometers * Constant	X281	One hour available to charge * Constant
X112	100 kilometers * Constant	X282	Four hours available to charge * Constant
X121	50 kilometers * Only slow chargers	X291	One hour available to charge * Only slow chargers
X122	50 kilometers * Only fast chargers	X292	One hour available to charge * Only fast chargers
X131	100 kilometers * Only slow chargers	X301	Four hours available to charge * Only slow chargers
X132	100 kilometers * Only fast chargers	X302	Four hours available to charge * Only fast chargers
X141	50 kilometers * €0.25 per kWh	X311	One hour available to charge * €0.25 per kWh
X142	50 kilometers * €0.40 per kWh	X312	One hour available to charge * €0.40 per kWh
X151	100 kilometers * €0.25 per kWh	X321	Four hours available to charge * €0.25 per kWh
X152	100 kilometers * €0.40 per kWh	X322	Four hours available to charge * €0.40 per kWh
X161	50 kilometers * €0.60 per kWh	X331	One hour available to charge * €0.60 per kWh
X162	50 kilometers * €0.75 per kWh	X332	One hour available to charge * €0.75 per kWh
X171	100 kilometers * €0.60 per kWh	X341	Four hours available to charge * €0.60 per kWh
X172	100 kilometers * €0.75 per kWh	X342	Four hours available to charge * €0.75 per kWh
X181	50 kilometers * Charge certainty 75%	X351	One hour available to charge * Charge certainty 75%
X182	50 kilometers * Charge certainty 85%	X352	One hour available to charge * Charge certainty 85%
X191	100 kilometers * Charge certainty 75%	X361	Four hours available to charge * Charge certainty 75%
X192	100 kilometers * Charge certainty 85%	X362	Four hours available to charge * Charge certainty 85%
X201	50 kilometers * 50 meters (in the street)	X371	One hour available to charge * 50 meters (in the street)
X202	50 kilometers * 150 meters (in the neighborhood)	X372	One hour available to charge * 150 meters (in the neighborhood)
X211	100 kilometers * 50 meters (in the street)	X381	Four hours available to charge * 50 meters (in the street)
X212	100 kilometers * 150 meters (in the neighborhood)	X382	Four hours available to charge * 150 meters (in the neighborhood)
X221	50 kilometers * After 30 minutes once the battery is completely charged	X391	One hour available to charge * After 30 minutes once the battery is completely charged
X222	50 kilometers * After 2 hours once the battery is completely charged	X392	One hour available to charge * After 2 hours once the battery is completely charged
X231	100 kilometers * After 30 minutes once the battery is completely charged	X401	Four hours available to charge * After 30 minutes once the battery is completely charged
X232	100 kilometers * After 2 hours once the battery is completely charged	X402	Four hours available to charge * After 2 hours once the battery is completely charged
X241	50 kilometers * No supervision	X411	One hour available to charge * No supervision
X242	50 kilometers * Supervision from (surrounding) dwelling(s)	X412	One hour available to charge * Supervision from (surrounding) dwelling(s)
X251	100 kilometers * No supervision	X421	Four hours available to charge * No supervision
X252	100 kilometers * Supervision from (surrounding) dwelling(s)	X422	Four hours available to charge * Supervision from (surrounding) dwelling(s)
X261	50 kilometers * Nothing changes	X431	One hour available to charge * Nothing changes
X262	50 kilometers * More greenery	X432	One hour available to charge * More greenery
X271	100 kilometers * Nothing changes	X441	Four hours available to charge * Nothing changes
X272	100 kilometers * More greenery	X442	Four hours available to charge * More greenery

Appendix E – Recoding variables, selecting useful/valid cases in the dataset

This appendix will describe the revisions that have been made to the raw dataset in order to be able to use the collected data for analysis. The revisions will be elaborated in order of execution.

The first revisions are related removing respondents from the dataset due to several reasons.

1) 27 responses were removed from the dataset since the question regarding the privacy statement was not answered.
2) Additionally, 3 responses were removed from the dataset since these respondents did not agree with the privacy statement.
3) Additionally, 11 responses were removed from the dataset since these respondents did not answer the question regarding the possession of a driver's license.
4) Additionally, 7 responses were removed from the dataset since these respondents did not possess a driver's license.
5) Additionally, 65 responses were removed from the dataset since these respondents did not answer any of the twelve choice sets.
6) Additionally, 19 responses were removed from the dataset since these respondents only answered one or two of the presented choice sets. The threshold value of three to be included in the dataset has been chosen since once a choice task was answered, the respondent automatically proceeded to the next choice task. Answering one or two choice tasks is therefore considered to be caused by randomly clicking one of the answer options.
7) Finally, 3 responses were removed from the dataset due to the following reasons. One respondent indicated in the comment section that the questions were not applicable to the respondent. One respondent has been removed since the respondent indicated in the comment section that the respondent did not understand the choice task. The final response that has been removed is because the respondent indicated in the comment section that this was a test run of one of the data collection partners. Due to the presented comments, it is likely that the answers given are unrealistic and therefore these responses have been removed from the dataset.

After having removed 135 responses from the dataset, the remaining number of responses in the dataset is equal to 537.

Next to the removal of 135 responses from the dataset, several other changes have been made to the raw dataset.

1) Eight changes have been made to the provided answers regarding the zip code.
    a. One respondent answered that their zip code is 0. Since the zip code in the Netherlands needs to have at least four digits, this answer is unrealistic. Since the zip code is only used to determine the urbanity level where the respondent lives, this response has been included in the group with the highest count.
    b. One respondent answered all socio-demographic questions with "Zeg ik liever niet" except for the zip code. Since it is likely that this zip code if not the actual zip code of the respondent, this response has been included in the group with the highest count for the urbanity level as well.
    c. Six respondents answered with an invalid zip code, for example 1234. Since the zip code is only used to determine the urbanity level where the respondent lives, this response has been included in the group with the highest count.
2) Several respondents answered "Overig, namelijk…" regarding the question about their highest completed education level. Below in table 20, an overview is given of the "Overig, namelijk…" responses and how these have been changed.

Table 20. Modifications in the dataset regarding the highest completed education level

Original response	Modified to
Master, 4 dagen werken 1 dag studie (Nyenrode)	Master (HBO of WO), doctor
Lho	Vmbo, havo-onderbouw, vwo-onderbouw, mbo1
2e jaar HBO, propedeuse behaald	Havo, vwo, mbo2-4
Gymnasium	Havo, vwo, mbo2-4
(Blank)	Zeg ik liever niet
5348	Zeg ik liever niet
MTS werktuigbouw	Havo, vwo, mbo2-4
post doctorale studie	Master (HBO of WO), doctor

3) Several respondents answered "Overig, namelijk…" regarding the question about their household composition. Below in table 21, an overview is given of the "Overig, namelijk…" responses and how these have been changed.

Table 21. Modifications in the dataset regarding the household composition

Original response	Modified to
Gedeeld huis (5 personen)	Eenpersoonshuishouden
Samenwonend + prachtige hond :D	Gehuwd/samenwonend
studentenhuis	Eenpersoonshuishouden
Bij ouders	Eenpersoonshuishouden
Studentenhuis	Eenpersoonshuishouden
geregistreerd partnerschap	Gehuwd/samenwonend
gehuwd, volwassen kind (met rijbewijs)	Gehuwd/samenwonend + kind(eren)
huisgenoten	Eenpersoonshuishouden
thuiswonend	Eenpersoonshuishouden
(Blank)	Zeg ik liever niet

4) Since not all participants completed the whole questionnaire, several questions regarding the socio-demographic characteristics were not answered for the remaining responses in the dataset. These blanks have been changed to the "Zeg ik liever niet" option.

Appendix F – MNL results of the original model

In order to estimate the MNL and LC models presented in Appendix F, H & K, Nlogit6 (Econometric Software Inc., 2016) has been used.

Code:

```
Reset $
READ; file = "D:\(…)\Final MNL.csv" $
Create; nalt=3 $

Nlogit
 ; lhs = obsch,nalt
 ; rhs = con,X31,X32,X41,X42,X51,X52,X61,X62,X71,X72,
        X81,X82,X91,X92,X101,X102,X111,X112,X121,X122,X131,X132,X141,
        X142,X151,X152,X161,X162,X171,X172,X181,X182,X191,X192,X201,
        X202,X211,X212,X221,X222,X231,X232,X241,X242,X251,X252,X261,
        X262,X271,X272,X281,X282,X291,X292,X301,X302,X311,X312,X321,
        X322,X331,X332,X341,X342,X351,X352,X361,X362,X371,X372,X381,
        X382,X391,X392,X401,X402,X411,X412,X421,X422,X431,X432,X441,X442
 ; frequencies
$
```

Output:

```
-----------------------------------------------------------------------------
Discrete choice (multinomial logit) model
Dependent variable               Choice
Log likelihood function     -4681.64064
Estimation based on N =    5820, K =  85
Inf.Cr.AIC  =   9533.3 AIC/N =    1.638
---------------------------------------
            Log likelihood R-sqrd R2Adj
ASCs  only  model must be fit separately
               Use NLOGIT ;...;RHS=ONE$
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as frequencies.
Number of obs.=   5820, skipped    0 obs
--------+--------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
   OBSCH|  Coefficient       Error       z    |z|>Z*         Interval
--------+--------------------------------------------------------------------
     CON|   -1.97777***      .05863   -33.74  .0000    -2.09268  -1.86287
     X31|     .87929***      .05961    14.75  .0000      .76246    .99612
     X32|     .34046***      .05897     5.77  .0000      .22488    .45604
     X41|     .37255***      .04342     8.58  .0000      .28745    .45766
     X42|     .11164***      .04250     2.63  .0086      .02834    .19494
     X51|     .49657***      .04387    11.32  .0000      .41058    .58255
     X52|    -.04847         .04219    -1.15  .2507     -.13117    .03423
     X61|    -.21576***      .03939    -5.48  .0000     -.29296   -.13856
     X62|     .02425         .03877      .63  .5316     -.05174    .10025
     X71|     .30166***      .04896     6.16  .0000      .20571    .39762
     X72|     .02622         .04944      .53  .5958     -.07067    .12312
     X81|    -.18187***      .03879    -4.69  .0000     -.25789   -.10584
     X82|    -.10535***      .03842    -2.74  .0061     -.18064   -.03005
```

X91	-.07532	.05317	-1.42	.1566	-.17953	.02889
X92	.00444	.06853	.06	.9483	-.12987	.13875
X101	-.06991*	.04147	-1.69	.0918	-.15118	.01136
X102	.03737	.04020	.93	.3526	-.04142	.11616
X111	.07310	.08206	.89	.3730	-.08773	.23393
X112	-.04192	.08155	-.51	.6072	-.20175	.11791
X121	.33637***	.08489	3.96	.0001	.16999	.50276
X122	-.48666***	.08388	-5.80	.0000	-.65106	-.32227
X131	-.04703	.08238	-.57	.5680	-.20850	.11443
X132	.03156	.08122	.39	.6975	-.12762	.19075
X141	.12233*	.06486	1.89	.0593	-.00478	.24945
X142	.02704	.06272	.43	.6664	-.09589	.14997
X151	-.10954*	.06230	-1.76	.0787	-.23165	.01256
X152	.07176	.06282	1.14	.2533	-.05136	.19488
X161	-.07789	.06124	-1.27	.2034	-.19792	.04213
X162	.03936	.05865	.67	.5022	-.07560	.15431
X171	.07634	.05968	1.28	.2008	-.04063	.19332
X172	-.00993	.05759	-.17	.8631	-.12282	.10295
X181	.01947	.08483	.23	.8185	-.14679	.18572
X182	.03584	.08381	.43	.6689	-.12843	.20011
X191	-.11979	.08078	-1.48	.1381	-.27812	.03855
X192	.18766**	.07502	2.50	.0124	.04063	.33469
X201	.12134	.07719	1.57	.1160	-.02996	.27263
X202	-.05384	.09504	-.57	.5711	-.24011	.13244
X211	.03797	.07784	.49	.6257	-.11460	.19055
X212	-.08256	.07973	-1.04	.3004	-.23883	.07370
X221	-.00073	.05825	-.01	.9900	-.11490	.11343
X222	.07033	.05780	1.22	.2237	-.04295	.18361
X231	-.02107	.05430	-.39	.6980	-.12750	.08536
X232	-.07169	.05382	-1.33	.1829	-.17718	.03381
X241	-.06866	.06142	-1.12	.2636	-.18903	.05171
X242	.21170***	.06072	3.49	.0005	.09269	.33071
X251	.06252	.05951	1.05	.2935	-.05413	.17917
X252	-.31082***	.05965	-5.21	.0000	-.42774	-.19390
X261	.02701	.06449	.42	.6754	-.09939	.15341
X262	.08596	.05604	1.53	.1250	-.02387	.19580
X271	.00290	.06187	.05	.9626	-.11836	.12417
X272	.01373	.05326	.26	.7965	-.09065	.11811
X281	-.23388***	.08438	-2.77	.0056	-.39926	-.06850
X282	-.02213	.08227	-.27	.7880	-.18338	.13913
X291	-.67560***	.08230	-8.21	.0000	-.83691	-.51429
X292	1.00392***	.08560	11.73	.0000	.83615	1.17169
X301	.14486*	.08277	1.75	.0801	-.01737	.30709
X302	-.26671***	.08093	-3.30	.0010	-.42533	-.10808
X311	-.19783***	.05682	-3.48	.0005	-.30919	-.08646
X312	-.01641	.05568	-.29	.7682	-.12554	.09273
X321	.04031	.05576	.72	.4697	-.06898	.14960
X322	.01795	.05419	.33	.7404	-.08826	.12417
X331	.09020	.05819	1.55	.1211	-.02384	.20425
X332	.01169	.05612	.21	.8351	-.09832	.12169
X341	-.07617	.05751	-1.32	.1854	-.18890	.03655
X342	.06059	.05510	1.10	.2715	-.04741	.16858
X351	-.08361	.06030	-1.39	.1656	-.20179	.03458
X352	.02269	.05921	.38	.7016	-.09337	.13874
X361	.12412**	.06049	2.05	.0402	.00557	.24267
X362	-.06325	.05977	-1.06	.2899	-.18039	.05388
X371	.18549***	.06010	3.09	.0020	.06769	.30329

```
    X372|    -.12241**       .05970    -2.05  .0403     -.23941   -.00540
    X381|    -.13951**       .06027    -2.31  .0206     -.25765   -.02138
    X382|     .05723         .06119      .94  .3496     -.06269    .17716
    X391|     .10213         .07425     1.38  .1690     -.04339    .24765
    X392|    -.05396         .07255     -.74  .4570     -.19617    .08824
    X401|    -.02743         .08887     -.31  .7576     -.20161    .14675
    X402|     .07910         .07249     1.09  .2752     -.06298    .22118
    X411|    -.02913         .05734     -.51  .6114     -.14152    .08326
    X412|     .08723         .05700     1.53  .1259     -.02449    .19896
    X421|     .07692         .05545     1.39  .1653     -.03175    .18559
    X422|    -.07633         .05680    -1.34  .1790     -.18766    .03501
    X431|     .10491         .06712     1.56  .1180     -.02663    .23646
    X432|     .01372         .06081      .23  .8215     -.10546    .13290
    X441|    -.11110*        .06664    -1.67  .0955     -.24171    .01952
    X442|     .07659         .05956     1.29  .1984     -.04014    .19332
--------+--------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Feb 22, 2023 at 01:44:38 PM
-----------------------------------------------------------------------------
```

Appendix G – Stepwise removing the insignificant context parameters from the original MNL model

Several steps have been taken to remove the insignificant context parameters of the MNL model in Nlogit and get to the final output. Below the steps are summarized in order of execution. During the process of stepwise removing insignificant context variables, all main effects (X31 – X102) were kept in the model even if these were not significant at the 5% level. The process of stepwise removing insignificant variables continued until all context-effects were significant at the 5% level, or stepwise removing insignificant context variables did not improve the model.

1. The first step was to remove all context variables where the probability that the context variable deviated from 0.0 is higher or equal to 0.3
2. Based on the first step, all context variables where the probability that the context variable deviated from 0.0 was larger than 0.2 were removed.
3. Based on the output of step 2, every context variable where the probability that the context variable deviated from 0.0 was larger than 0.1 were removed again.
4. Based on the output of step 3, every context variable where the probability that the context variable deviated from 0.0 was larger than 0.1 were removed again.
5. Based on the output of step 4, every context variable where the probability that the context variable deviated from 0.0 was larger than 0.1 were removed again.
6. Based on the output of step 5, every context variable where the probability that the context variable deviated from 0.0 was larger than 0.1 were removed again.
7. Based on the output of step 6, every context variable where the probability that the context variable deviated from 0.0 was larger than 0.1 were removed again.
8. Based on the output of step 7, every context variable where the probability that the context variable deviated from 0.0 was larger than 0.05 were removed again. This is because everything the threshold is at the 5% level in this study.

Appendix H – Reduced MNL results where all context effects are significant at 5%

After step 8 in Appendix G, all context-effects are significant at a 5% level. Below the results are shown. In order to acquire these results, the following Nlogit code has been used:

Code:

```
Reset $
READ; file = "D:\(…)\Final MNL.csv" $
Create; nalt=3 $

Nlogit
 ; lhs = obsch,nalt
 ; rhs = con,X31,X32,X41,X42,X51,X52,X61,X62,X71,X72,
        X81,X82,X91,X92,X101,X102,X121,X122,X141,
        X192,X242,X252,X262,X281,X291,X292,X302,
        X311,X371,X372,X381,X391,X431,X441
 ; frequencies
$
```

Output:

```
-----------------------------------------------------------------------------
Discrete choice (multinomial logit) model
Dependent variable               Choice
Log likelihood function     -4705.96313
Estimation based on N =   5820, K =  35
Inf.Cr.AIC  =   9481.9 AIC/N =    1.629
---------------------------------------
            Log likelihood R-sqrd R2Adj
ASCs  only  model must be fit separately
               Use NLOGIT ;...;RHS=ONE$
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as frequencies.
Number of obs.=  5820, skipped    0 obs
--------+--------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
   OBSCH|  Coefficient       Error       z    |z|>Z*         Interval
--------+--------------------------------------------------------------------
     CON|   -1.98869***      .05808   -34.24  .0000    -2.10252  -1.87486
     X31|     .88598***      .05897    15.02  .0000      .77040   1.00156
     X32|     .33756***      .05829     5.79  .0000      .22331    .45180
     X41|     .42282***      .03817    11.08  .0000      .34802    .49763
     X42|     .08019**       .03694     2.17  .0299      .00779    .15260
     X51|     .49881***      .03991    12.50  .0000      .42058    .57704
     X52|    -.06137         .03740    -1.64  .1008     -.13467    .01193
     X61|    -.26308***      .03317    -7.93  .0000     -.32808   -.19808
     X62|     .05818*        .03251     1.79  .0735     -.00553    .12189
     X71|     .37122***      .03535    10.50  .0000      .30194    .44050
     X72|    -.00648         .03508     -.18  .8535     -.07523    .06227
     X81|    -.18258***      .02952    -6.19  .0000     -.24043   -.12473
     X82|    -.10504***      .03089    -3.40  .0007     -.16558   -.04450
```

X91	-.03971	.03485	-1.14	.2546	-.10802	.02860
X92	-.00674	.03189	-.21	.8326	-.06924	.05576
X101	-.05988*	.03180	-1.88	.0597	-.12221	.00244
X102	.08053**	.03181	2.53	.0114	.01819	.14287
X121	.32953***	.06130	5.38	.0000	.20938	.44968
X122	-.44861***	.06287	-7.14	.0000	-.57185	-.32538
X141	.11587***	.04350	2.66	.0077	.03061	.20114
X192	.11014***	.04056	2.72	.0066	.03065	.18964
X242	.12426***	.04431	2.80	.0050	.03742	.21110
X252	-.18404***	.04456	-4.13	.0000	-.27138	-.09671
X262	.10475***	.03284	3.19	.0014	.04038	.16911
X281	-.22805***	.07078	-3.22	.0013	-.36678	-.08933
X291	-.62016***	.07342	-8.45	.0000	-.76407	-.47626
X292	1.01771***	.08120	12.53	.0000	.85856	1.17686
X302	-.31318***	.06628	-4.73	.0000	-.44309	-.18328
X311	-.17668***	.04021	-4.39	.0000	-.25549	-.09786
X371	.13804***	.04748	2.91	.0036	.04499	.23109
X372	-.08743**	.04093	-2.14	.0327	-.16765	-.00721
X381	-.08948**	.04110	-2.18	.0295	-.17004	-.00892
X391	.15609***	.03254	4.80	.0000	.09232	.21986
X431	.16622***	.04321	3.85	.0001	.08153	.25090
X441	-.11186**	.04353	-2.57	.0102	-.19717	-.02654

***, **, * ==> Significance at 1%, 5%, 10% level.
Model was estimated on Feb 22, 2023 at 01:59:59 PM

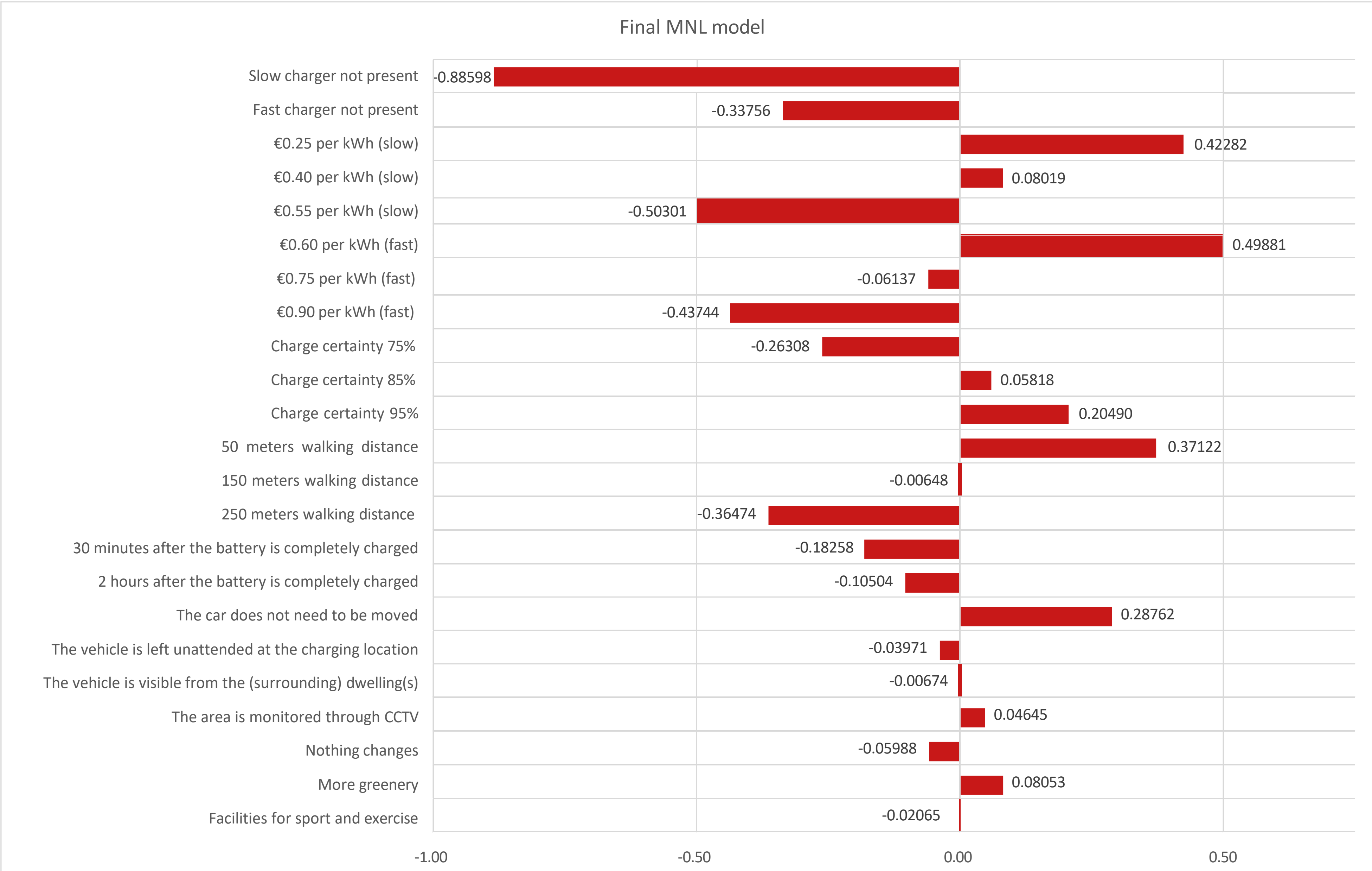

Figure 26. MNL path-worth utility of the reduced MNL model before excluding several context effects

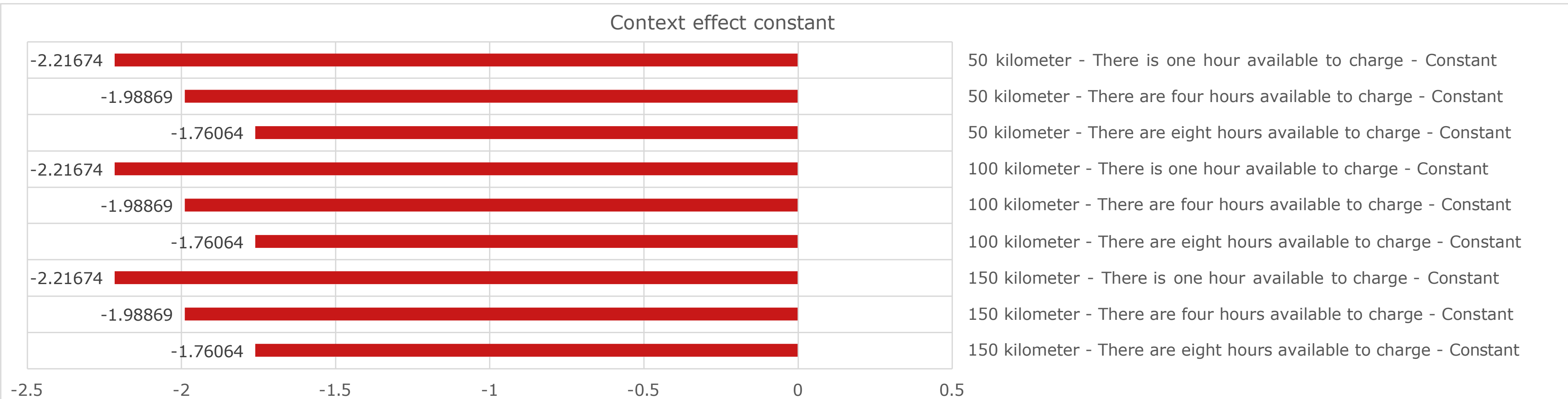

Figure 27. MNL path-worth utility of context effect for the constant of the reduced MNL model before excluding several context effects

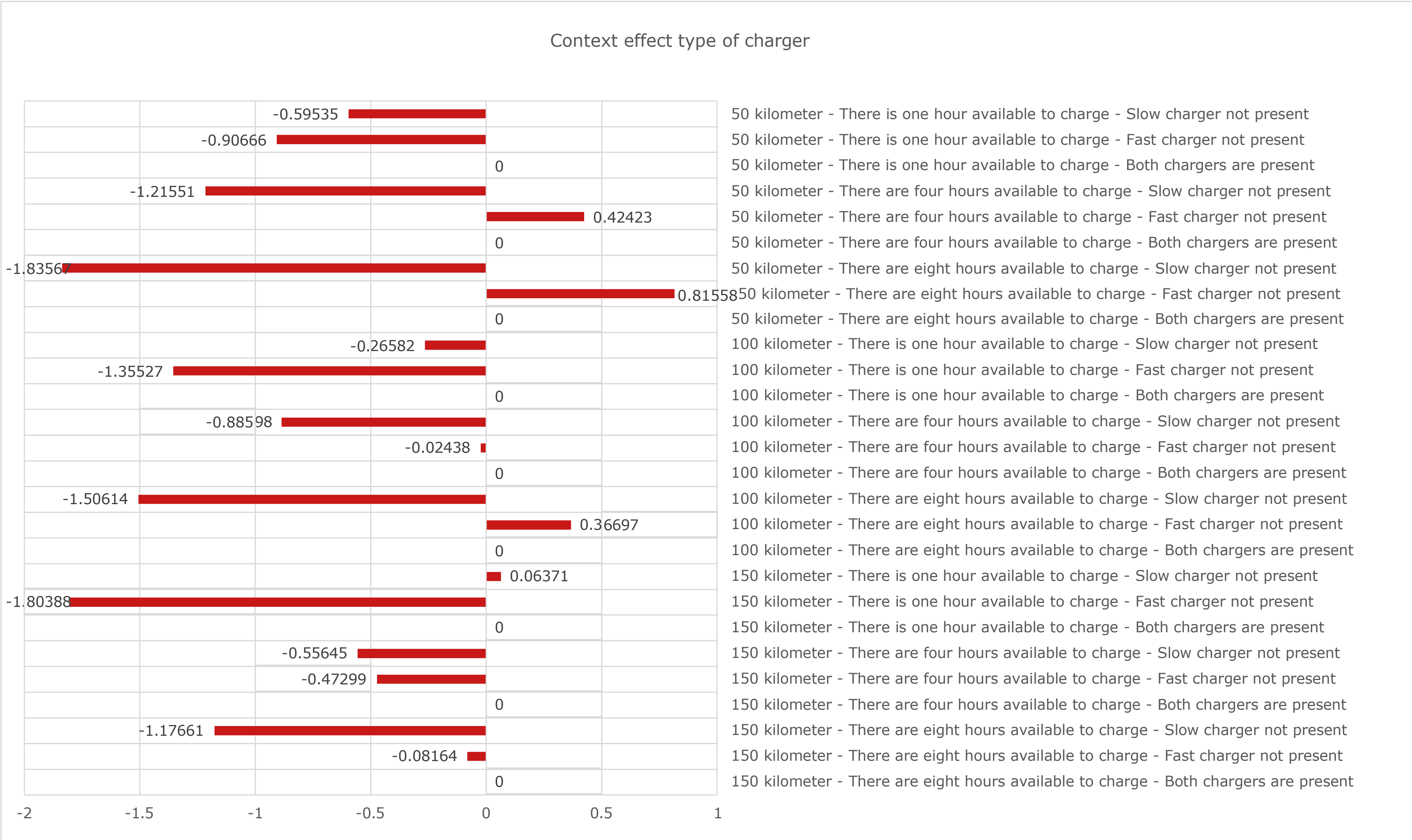

Figure 28. MNL path-worth utility of context effect for the type of charger of the reduced MNL model before excluding several context effects

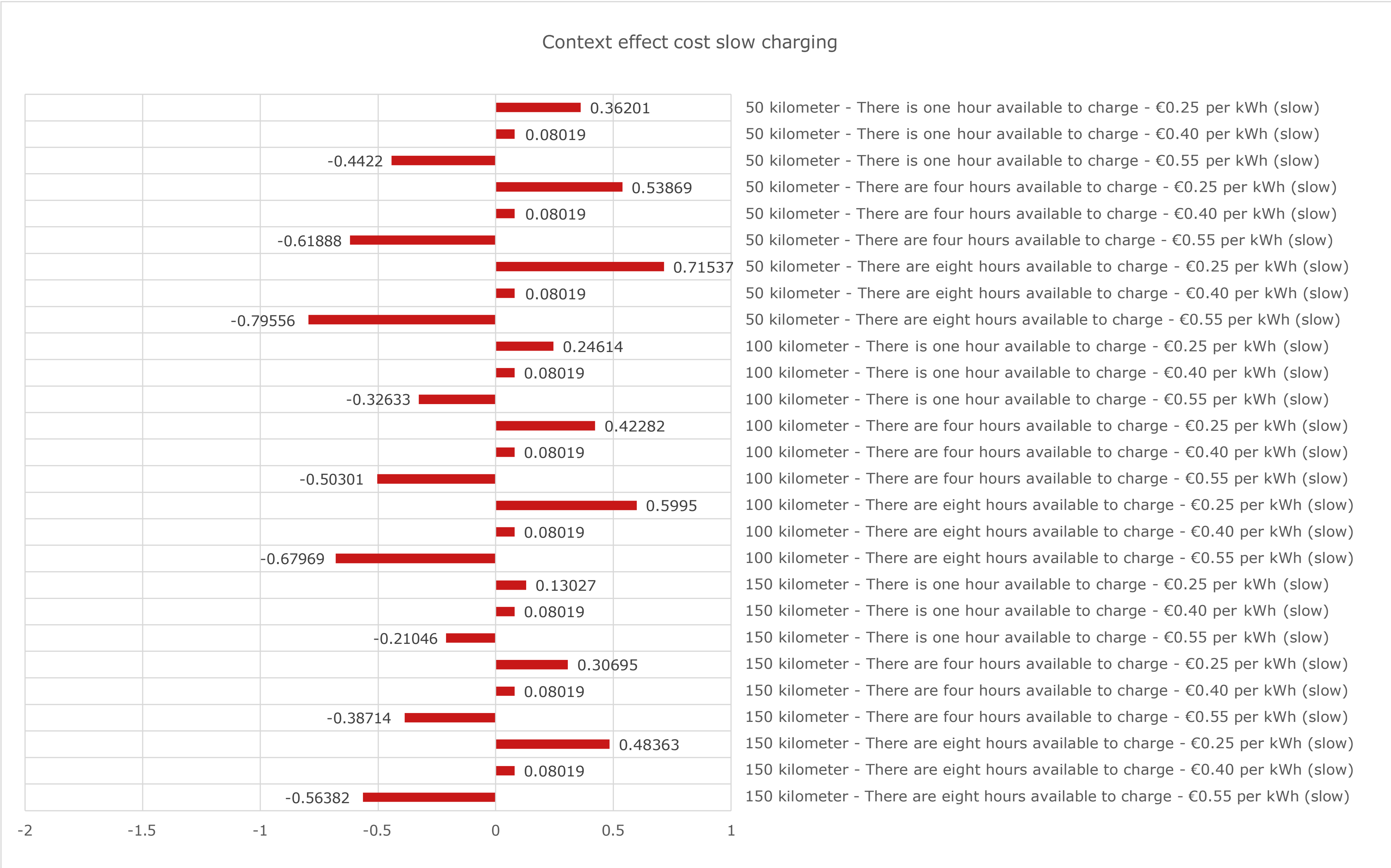

Figure 29. MNL path-worth utility of context effect for the cost of slow charging of the reduced MNL model before excluding several context effects

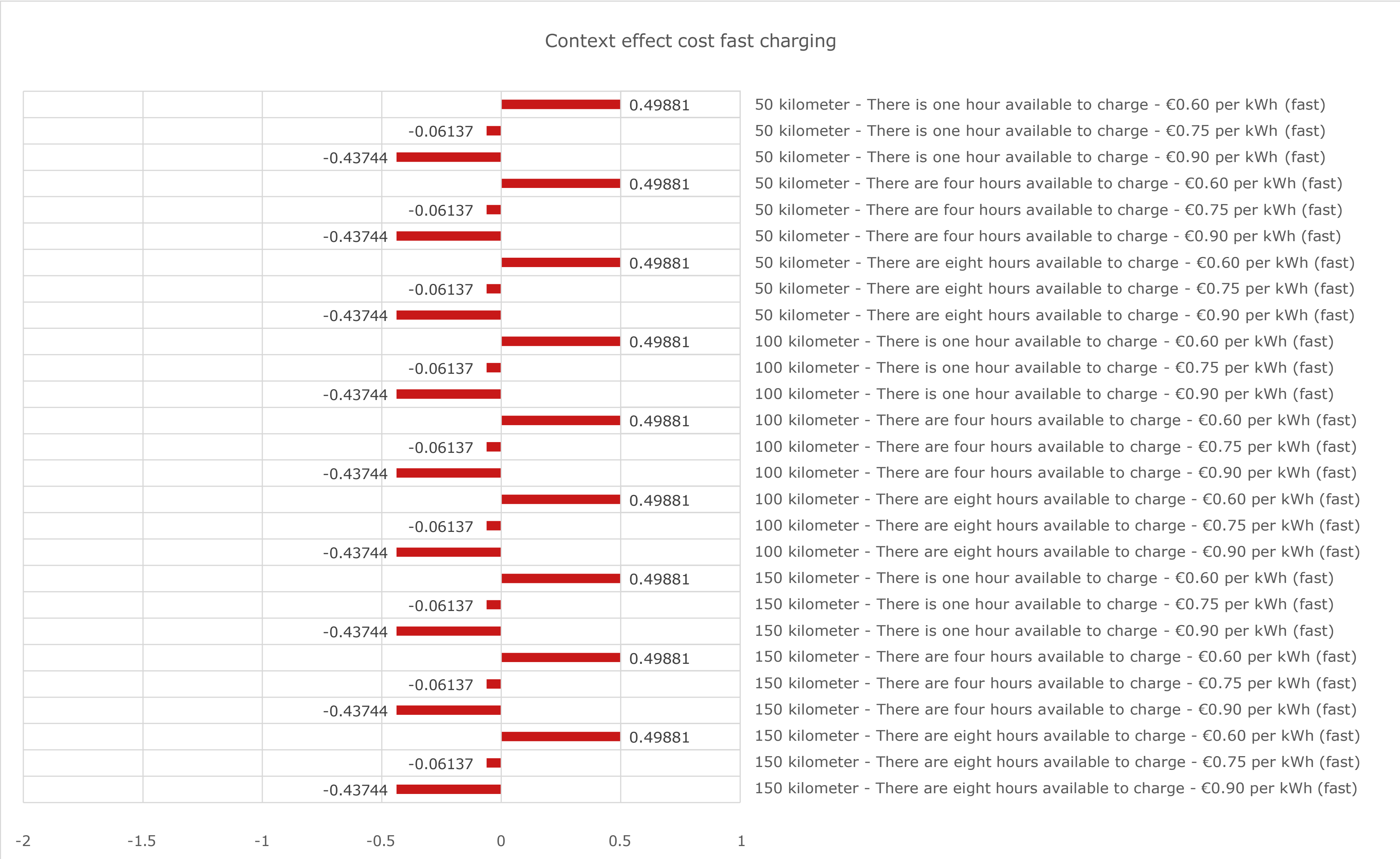

Figure 30. MNL path-worth utility of context effect for the cost of fast charging of the reduced MNL model before excluding several context effects

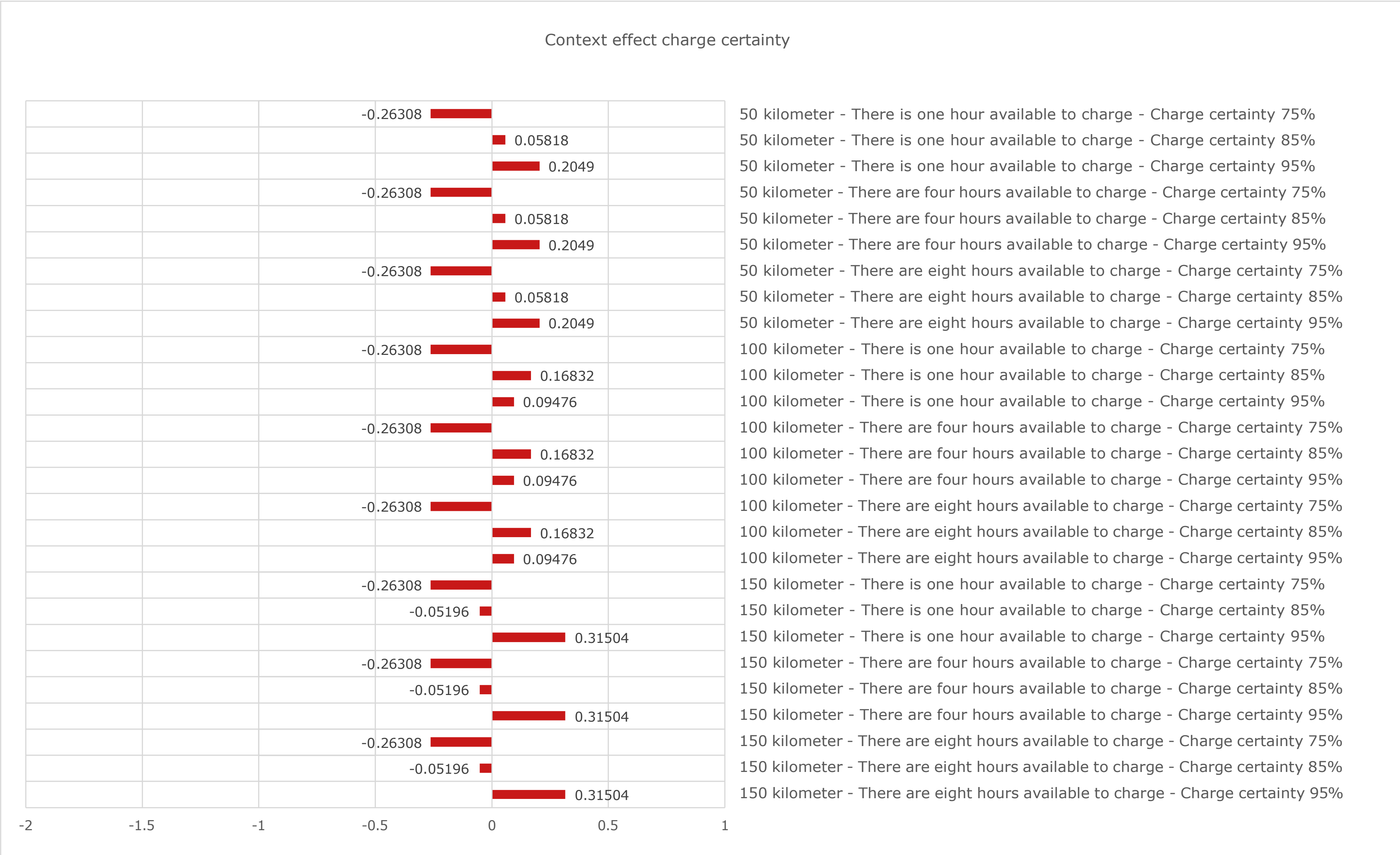

Figure 31. MNL path-worth utility of context effect for charge certainty of the reduced MNL model before excluding several context effects

Figure 32. MNL path-worth utility of context effect for the walking distance of the reduced MNL model before excluding several context effects

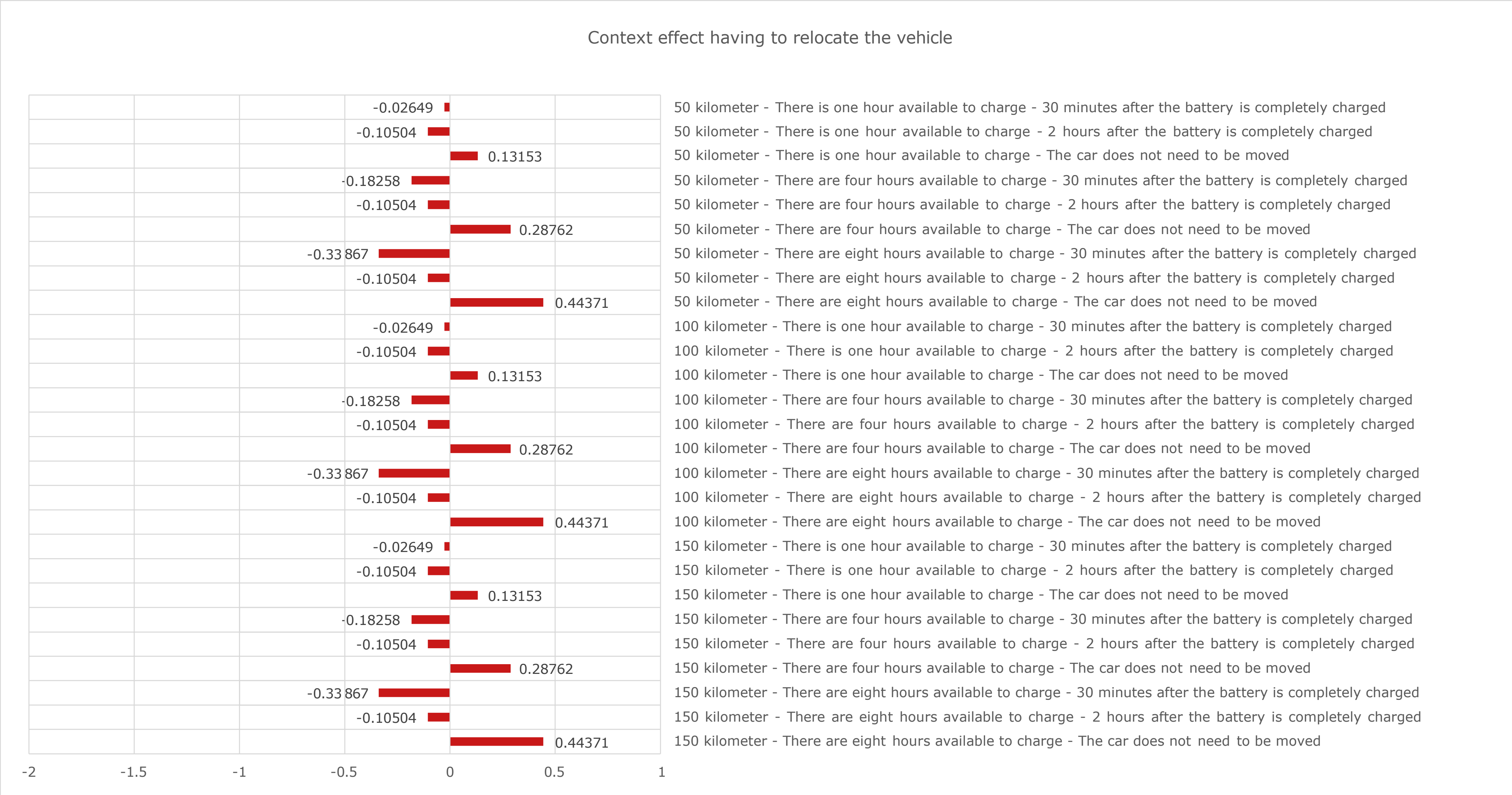

Figure 33. MNL path-worth utility of context effect for having to relocate the vehicle of the reduced MNL model before excluding several context effects

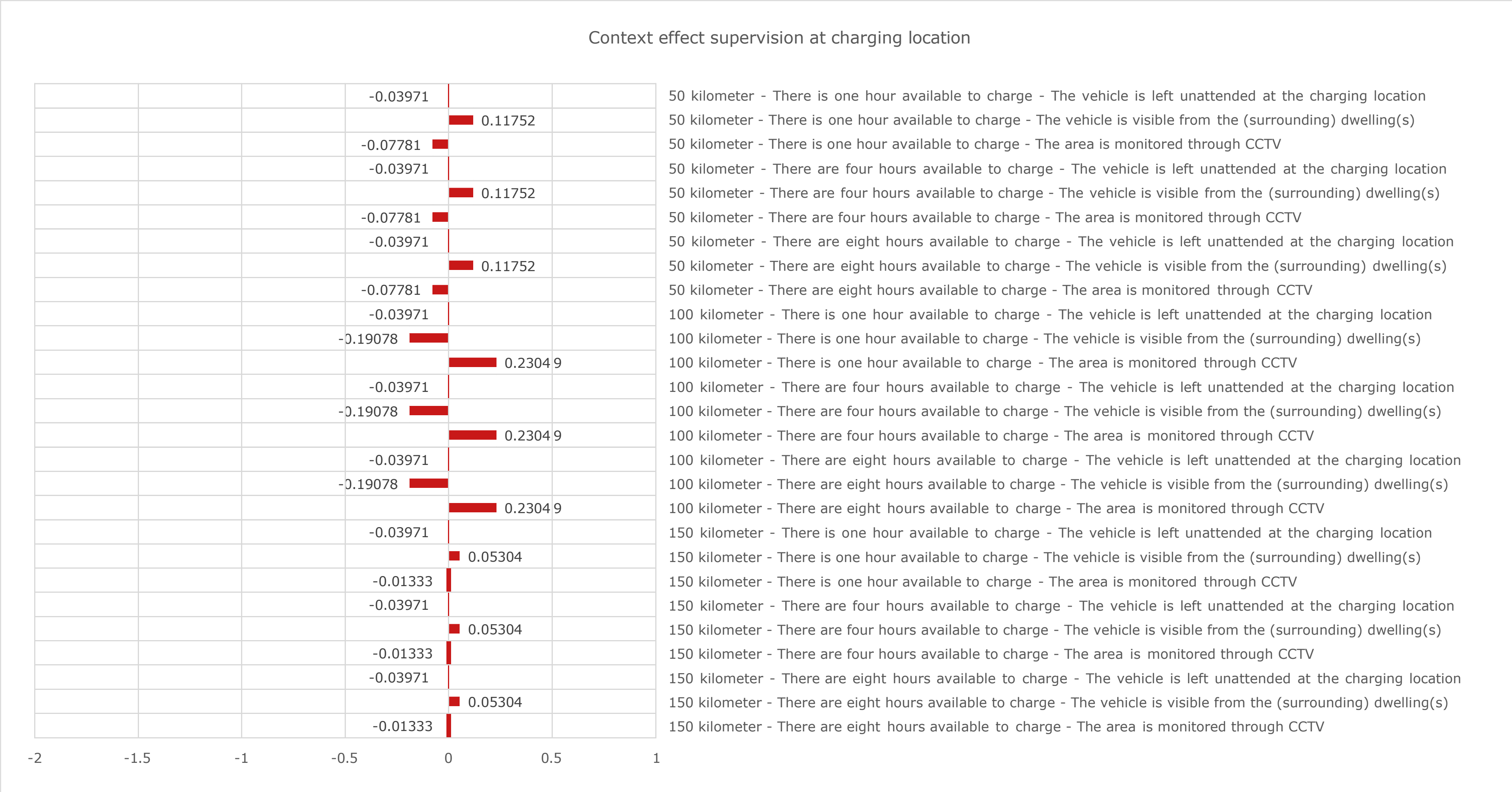

Figure 34. MNL path-worth utility of context effect for the supervision at a charging location of the reduced MNL model before excluding several context effects

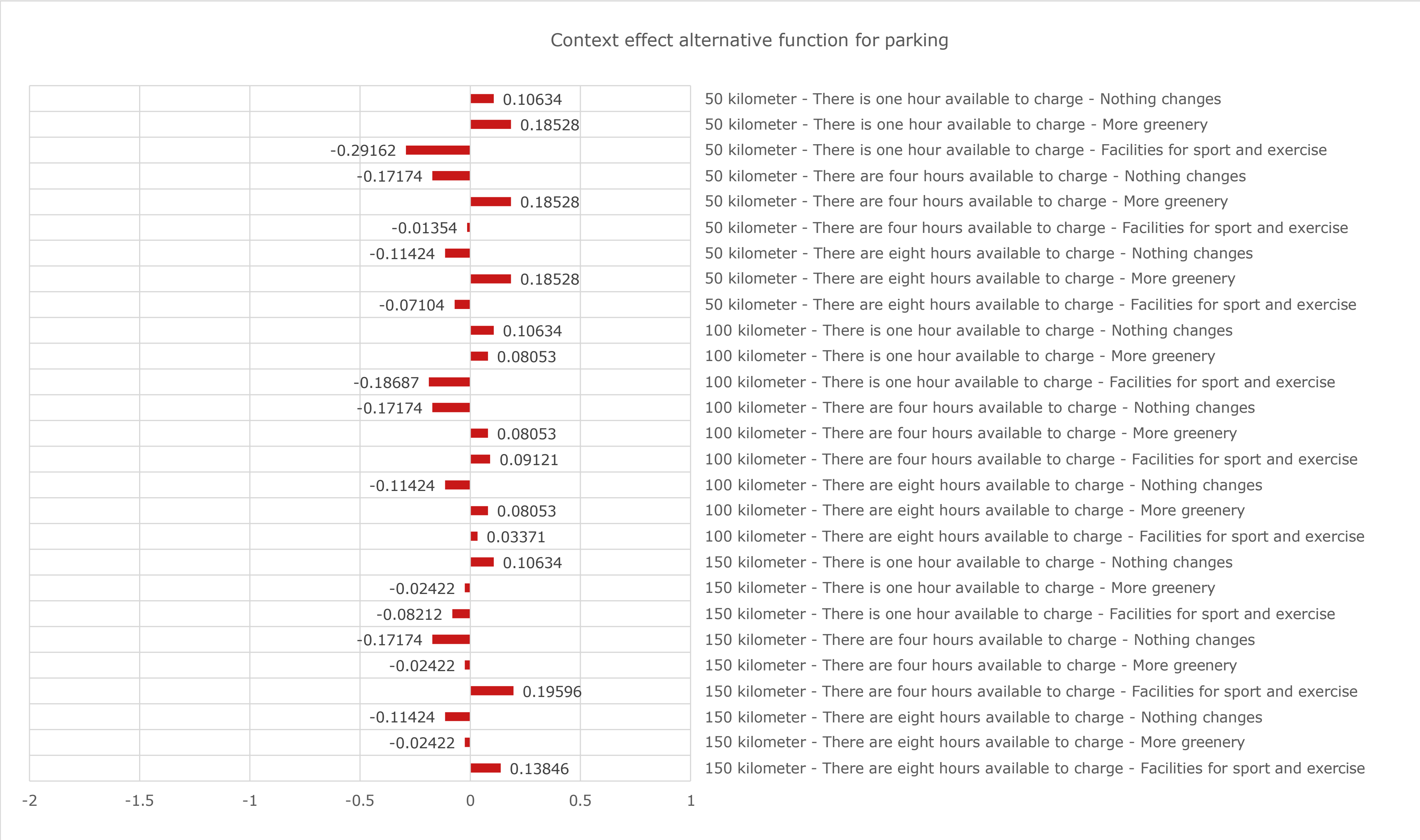

Figure 35. MNL path-worth utility of context effect for the alternative functions for parking of the reduced MNL model before excluding several context effects

Appendix I – Detailed graphs final MNL results

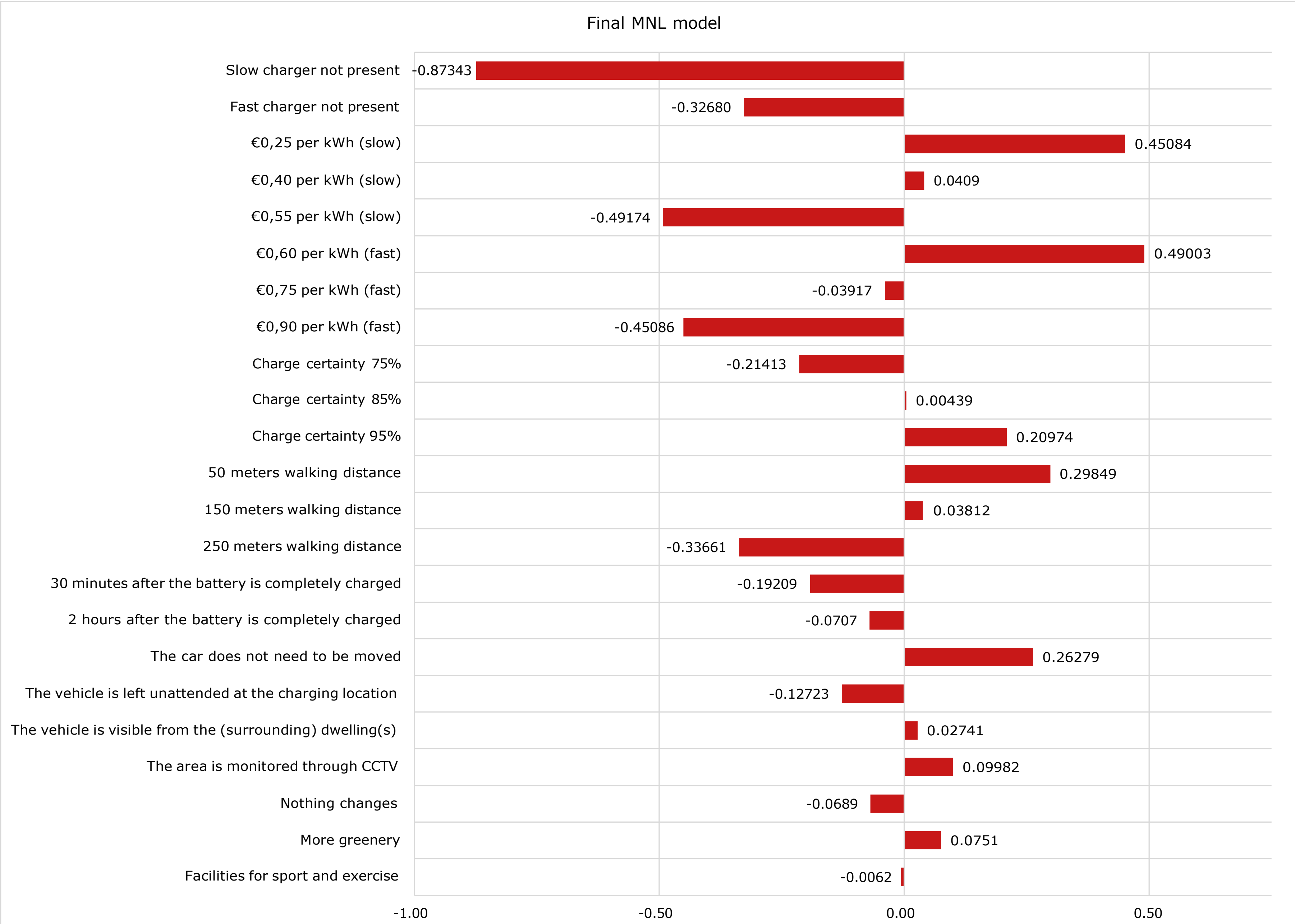

Figure 36. Detailed results final MNL model (main parameters)

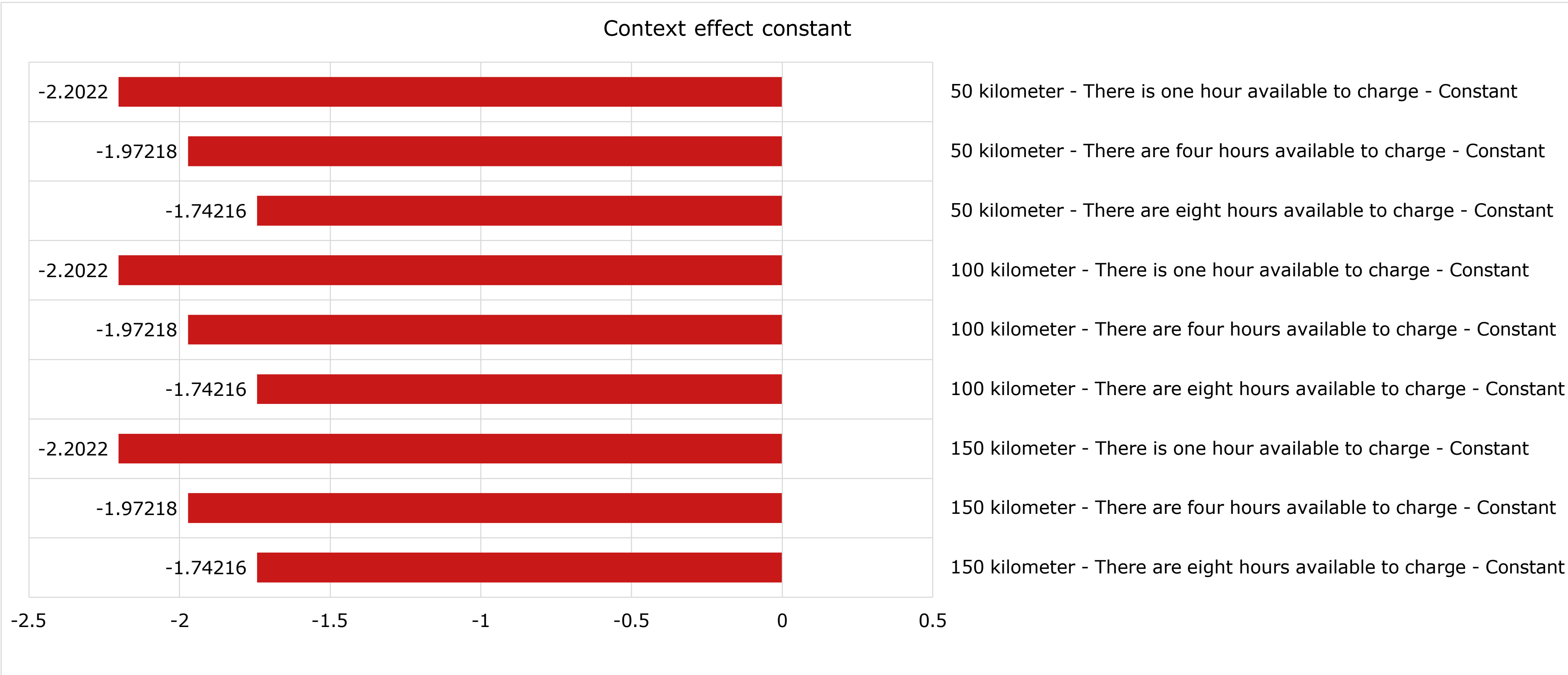

Figure 37. Detailed results final MNL model (context effect constant)

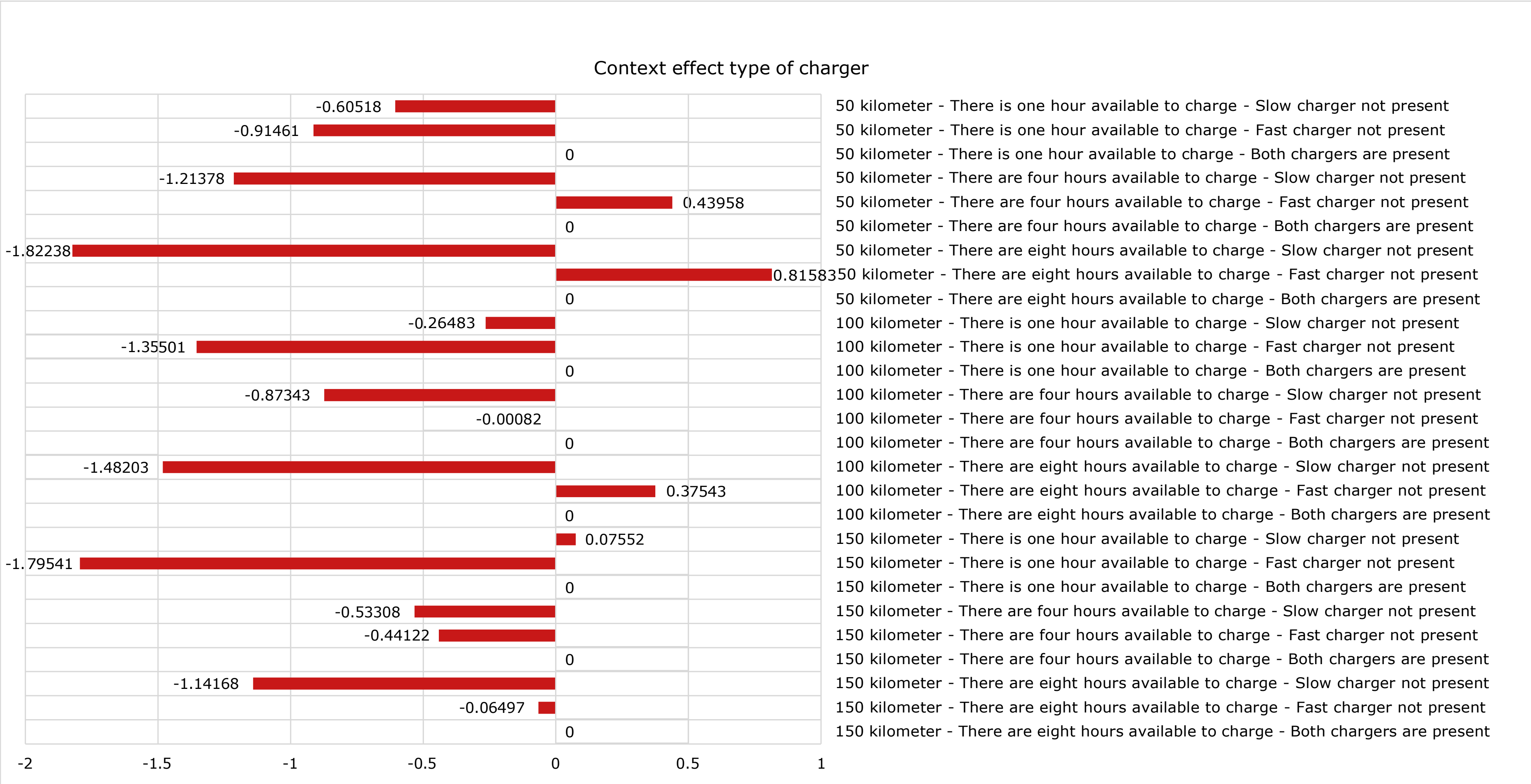

Figure 38. Detailed results final MNL model (context effect type of charger)

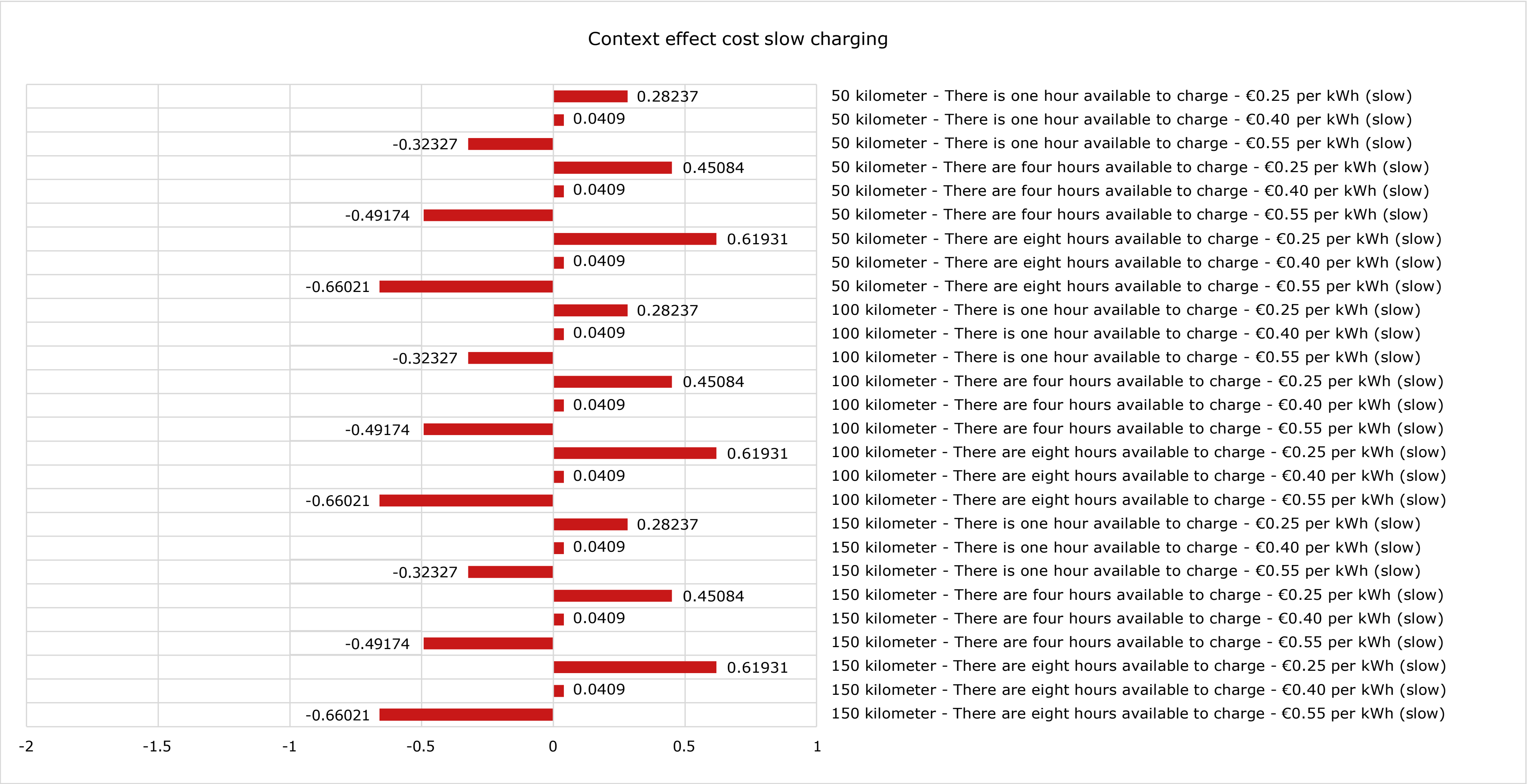

Figure 39. Detailed results final MNL model (context effect costs slow charging)

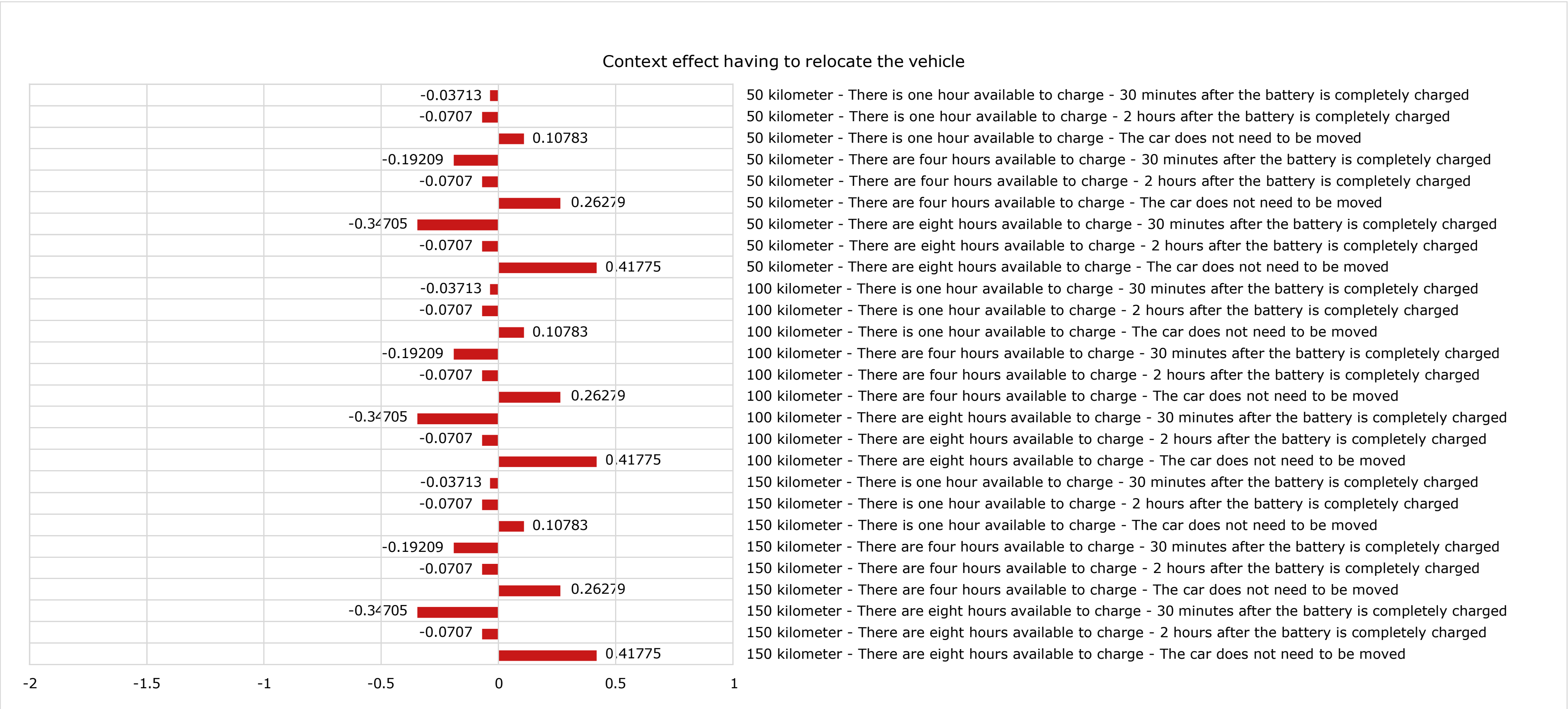

Figure 40. Detailed results final MNL model (context effect having to relocate the vehicle)

Appendix J – Effect coding scheme socio-demographics

Table 22. Effect coding scheme for the socio-demographics including the indication of the X-variable in Nlogit

Attribute	Level	e1	e2	
Gender	Male	1		A11
	Female	-1		
Age	Below 25 years old	1	0	A21
	25 - 65 years old	0	1	A22
	Above 65 years old	-1	-1	
Urbanity level	Urban environment	1	0	A31
	No urban/rural environment	0	1	A32
	Rural environment	-1	-1	
Highest completed education	Vocationally educated	1		A41
	Theoretically educated	-1		
Household composition	Single person household	1	0	A51
	Multi-person household without children	0	1	A52
	Multi-person household with children	-1	-1	
Income	<€20,000 euro	1	0	A61
	€20,001 - €40,000 euro	0	1	A62
	>€40,001 euro	-1	-1	

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Appendix K1 – LC output original model (2 classes)

Code:

```
Reset $
READ; file = "D: \(…)\LCA 5.csv" $

NLOGIT
; Lhs = Obsch
; Choices = 1, 2, 3
; rhs = con,X31,X32,X41,X42,X51,X52,X61,X62,X71,X72,
        X81,X82,X91,X92,X101,X102,X111,X112,X121,X122,X131,X132,X141,
        X142,X151,X152,X161,X162,X171,X172,X181,X182,X191,X192,X201,
        X202,X211,X212,X221,X222,X231,X232,X241,X242,X251,X252,X261,
        X262,X271,X272,X281,X282,X291,X292,X301,X302,X311,X312,X321,
        X322,X331,X332,X341,X342,X351,X352,X361,X362,X371,X372,X381,
        X382,X391,X392,X401,X402,X411,X412,X421,X422,X431,X432,X441,X442
; Lcm = A11,A21,A22,A31,A32,A41,A51,A52,A61,A62
; Pts = 2
; Pds = 12
; Maxit = 300
$
```

Output:

```
-----------------------------------------------------------------------------
Discrete choice (multinomial logit) model
Dependent variable               Choice
Log likelihood function     -4681.64064
Estimation based on N =    5820, K =  85
Inf.Cr.AIC  =    9533.3 AIC/N =    1.638
---------------------------------------
            Log likelihood R-sqrd R2Adj
Constants only  -5499.7000  .1487 .1353
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as ind. choices
Number of obs.=   5820, skipped    0 obs
--------+--------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
   OBSCH|  Coefficient       Error       z    |z|>Z*         Interval
--------+--------------------------------------------------------------------
   CON|1|   -1.97777***      .05863   -33.74  .0000    -2.09268  -1.86287
   X31|1|     .87929***      .05961    14.75  .0000      .76246    .99612
   X32|1|     .34046***      .05897     5.77  .0000      .22488    .45604
   X41|1|     .37255***      .04342     8.58  .0000      .28745    .45766
   X42|1|     .11164***      .04250     2.63  .0086      .02834    .19494
   X51|1|     .49657***      .04387    11.32  .0000      .41058    .58255
   X52|1|    -.04847         .04219    -1.15  .2507     -.13117    .03423
   X61|1|    -.21576***      .03939    -5.48  .0000     -.29296   -.13856
   X62|1|     .02425         .03877      .63  .5316     -.05174    .10025
   X71|1|     .30166***      .04896     6.16  .0000      .20571    .39762
   X72|1|     .02622         .04944      .53  .5958     -.07067    .12312
   X81|1|    -.18187***      .03879    -4.69  .0000     -.25789   -.10584
   X82|1|    -.10535***      .03842    -2.74  .0061     -.18064   -.03005
```

X91|1|	-.07532	.05317	-1.42	.1566	-.17953	.02889
X92|1|	.00444	.06853	.06	.9483	-.12987	.13875
X101|1|	-.06991*	.04147	-1.69	.0918	-.15118	.01136
X102|1|	.03737	.04020	.93	.3526	-.04142	.11616
X111|1|	.07310	.08206	.89	.3730	-.08773	.23393
X112|1|	-.04192	.08155	-.51	.6072	-.20175	.11791
X121|1|	.33637***	.08489	3.96	.0001	.16999	.50276
X122|1|	-.48666***	.08388	-5.80	.0000	-.65106	-.32227
X131|1|	-.04703	.08238	-.57	.5680	-.20850	.11443
X132|1|	.03156	.08122	.39	.6975	-.12762	.19075
X141|1|	.12233*	.06486	1.89	.0593	-.00478	.24945
X142|1|	.02704	.06272	.43	.6664	-.09589	.14997
X151|1|	-.10954*	.06230	-1.76	.0787	-.23165	.01256
X152|1|	.07176	.06282	1.14	.2533	-.05136	.19488
X161|1|	-.07789	.06124	-1.27	.2034	-.19792	.04213
X162|1|	.03936	.05865	.67	.5022	-.07560	.15431
X171|1|	.07634	.05968	1.28	.2008	-.04063	.19332
X172|1|	-.00993	.05759	-.17	.8631	-.12282	.10295
X181|1|	.01947	.08483	.23	.8185	-.14679	.18572
X182|1|	.03584	.08381	.43	.6689	-.12843	.20011
X191|1|	-.11979	.08078	-1.48	.1381	-.27812	.03855
X192|1|	.18766**	.07502	2.50	.0124	.04063	.33469
X201|1|	.12134	.07719	1.57	.1160	-.02996	.27263
X202|1|	-.05384	.09504	-.57	.5711	-.24011	.13244
X211|1|	.03797	.07784	.49	.6257	-.11460	.19055
X212|1|	-.08256	.07973	-1.04	.3004	-.23883	.07370
X221|1|	-.00073	.05825	-.01	.9900	-.11490	.11343
X222|1|	.07033	.05780	1.22	.2237	-.04295	.18361
X231|1|	-.02107	.05430	-.39	.6980	-.12750	.08536
X232|1|	-.07169	.05382	-1.33	.1829	-.17718	.03381
X241|1|	-.06866	.06142	-1.12	.2636	-.18903	.05171
X242|1|	.21170***	.06072	3.49	.0005	.09269	.33071
X251|1|	.06252	.05951	1.05	.2935	-.05413	.17917
X252|1|	-.31082***	.05965	-5.21	.0000	-.42774	-.19390
X261|1|	.02701	.06449	.42	.6754	-.09939	.15341
X262|1|	.08596	.05604	1.53	.1250	-.02387	.19580
X271|1|	.00290	.06187	.05	.9626	-.11836	.12417
X272|1|	.01373	.05326	.26	.7965	-.09065	.11811
X281|1|	-.23388***	.08438	-2.77	.0056	-.39926	-.06850
X282|1|	-.02213	.08227	-.27	.7880	-.18338	.13913
X291|1|	-.67560***	.08230	-8.21	.0000	-.83691	-.51429
X292|1|	1.00392***	.08560	11.73	.0000	.83615	1.17169
X301|1|	.14486*	.08277	1.75	.0801	-.01737	.30709
X302|1|	-.26671***	.08093	-3.30	.0010	-.42533	-.10808
X311|1|	-.19783***	.05682	-3.48	.0005	-.30919	-.08646
X312|1|	-.01641	.05568	-.29	.7682	-.12554	.09273
X321|1|	.04031	.05576	.72	.4697	-.06898	.14960
X322|1|	.01795	.05419	.33	.7404	-.08826	.12417
X331|1|	.09020	.05819	1.55	.1211	-.02384	.20425
X332|1|	.01169	.05612	.21	.8351	-.09832	.12169
X341|1|	-.07617	.05751	-1.32	.1854	-.18890	.03655
X342|1|	.06059	.05510	1.10	.2715	-.04741	.16858
X351|1|	-.08361	.06030	-1.39	.1656	-.20179	.03458
X352|1|	.02269	.05921	.38	.7016	-.09337	.13874
X361|1|	.12412**	.06049	2.05	.0402	.00557	.24267
X362|1|	-.06325	.05977	-1.06	.2899	-.18039	.05388
X371|1|	.18549***	.06010	3.09	.0020	.06769	.30329

```
  X372|1|    -.12241**       .05970    -2.05  .0403     -.23941   -.00540
  X381|1|    -.13951**       .06027    -2.31  .0206     -.25765   -.02138
  X382|1|     .05723         .06119      .94  .3496     -.06269    .17716
  X391|1|     .10213         .07425     1.38  .1690     -.04339    .24765
  X392|1|    -.05396         .07255     -.74  .4570     -.19617    .08824
  X401|1|    -.02743         .08887     -.31  .7576     -.20161    .14675
  X402|1|     .07910         .07249     1.09  .2752     -.06298    .22118
  X411|1|    -.02913         .05734     -.51  .6114     -.14152    .08326
  X412|1|     .08723         .05700     1.53  .1259     -.02449    .19896
  X421|1|     .07692         .05545     1.39  .1653     -.03175    .18559
  X422|1|    -.07633         .05680    -1.34  .1790     -.18766    .03501
  X431|1|     .10491         .06712     1.56  .1180     -.02663    .23646
  X432|1|     .01372         .06081      .23  .8215     -.10546    .13290
  X441|1|    -.11110*        .06664    -1.67  .0955     -.24171    .01952
  X442|1|     .07659         .05956     1.29  .1984     -.04014    .19332
--------+-----------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Feb 26, 2023 at 00:52:20 PM
--------------------------------------------------------------------------

Line search at iteration171 does not improve the function
Exiting optimization

--------------------------------------------------------------------------
Latent Class Logit Model
Dependent variable                OBSCH
Log likelihood function     -4206.04891
Restricted log likelihood   -6393.92352
Chi squared [181](P= .000)   4375.74923
Significance level               .00000
McFadden Pseudo R-squared      .3421803
Estimation based on N =   5820, K = 181
Inf.Cr.AIC  =   8774.1 AIC/N =    1.508
---------------------------------------
            Log likelihood R-sqrd R2Adj
No coefficients -6393.9235  .3422 .3318
Constants only  -5499.7000  .2352 .2231
At start values -4681.4281  .1015 .0874
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as ind. choices
Number of latent classes =            2
Average Class Probabilities
     .846  .154
LCM model with panel has     485 groups
Fixed number of obsrvs./group=       12
BHHH estimator used for asymp. variance
Number of obs.=  5820, skipped    0 obs
--------+-----------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
   OBSCH|  Coefficient       Error       z    |z|>Z*         Interval
--------+-----------------------------------------------------------------
        |Random utility parameters in latent class -->>  1...................
   CON|1|   -3.40770***      .12861   -26.50  .0000    -3.65977  -3.15563
```

X31|1|	1.06624***	.06987	15.26	.0000	.92931	1.20318
X32|1|	.41578***	.07338	5.67	.0000	.27195	.55960
X41|1|	.45369***	.06275	7.23	.0000	.33071	.57667
X42|1|	.13552**	.06347	2.14	.0327	.01112	.25992
X51|1|	.60381***	.06211	9.72	.0000	.48208	.72554
X52|1|	-.06073	.05992	-1.01	.3108	-.17818	.05672
X61|1|	-.25322***	.04932	-5.13	.0000	-.34988	-.15656
X62|1|	.05534	.04828	1.15	.2517	-.03929	.14997
X71|1|	.40224***	.09516	4.23	.0000	.21573	.58874
X72|1|	.02325	.09767	.24	.8119	-.16818	.21468
X81|1|	-.28687***	.06938	-4.13	.0000	-.42285	-.15089
X82|1|	-.14097**	.06659	-2.12	.0343	-.27149	-.01046
X91|1|	-.06920	.10717	-.65	.5185	-.27925	.14085
X92|1|	.09090	.16076	.57	.5718	-.22418	.40599
X101|1|	-.06000	.07549	-.79	.4267	-.20796	.08795
X102|1|	.11485	.07988	1.44	.1505	-.04172	.27141
X111|1|	-.27527	.19267	-1.43	.1531	-.65289	.10236
X112|1|	.02775	.19073	.15	.8843	-.34607	.40158
X121|1|	.47163***	.10859	4.34	.0000	.25879	.68446
X122|1|	-.45786***	.11389	-4.02	.0001	-.68108	-.23465
X131|1|	-.07340	.11434	-.64	.5209	-.29749	.15070
X132|1|	-.02910	.11690	-.25	.8034	-.25822	.20002
X141|1|	.19239*	.09857	1.95	.0509	-.00079	.38558
X142|1|	.00251	.09997	.03	.9799	-.19342	.19844
X151|1|	-.17933**	.08946	-2.00	.0450	-.35468	-.00399
X152|1|	.11097	.09212	1.20	.2283	-.06957	.29152
X161|1|	.03357	.08763	.38	.7016	-.13817	.20532
X162|1|	-.01160	.08225	-.14	.8878	-.17282	.14961
X171|1|	.04331	.09169	.47	.6367	-.13640	.22302
X172|1|	-.01817	.08621	-.21	.8331	-.18713	.15080
X181|1|	-.04384	.15077	-.29	.7712	-.33935	.25166
X182|1|	.09845	.14705	.67	.5031	-.18975	.38666
X191|1|	.02893	.13501	.21	.8303	-.23568	.29355
X192|1|	.11971	.11875	1.01	.3134	-.11303	.35245
X201|1|	.17027	.13484	1.26	.2067	-.09401	.43455
X202|1|	-.14005	.18294	-.77	.4440	-.49860	.21851
X211|1|	.10216	.13019	.78	.4326	-.15300	.35733
X212|1|	-.05322	.12983	-.41	.6819	-.30769	.20125
X221|1|	-.04004	.08587	-.47	.6410	-.20834	.12826
X222|1|	.10977	.08191	1.34	.1802	-.05077	.27032
X231|1|	-.01697	.07928	-.21	.8305	-.17236	.13842
X232|1|	-.10837	.07987	-1.36	.1748	-.26492	.04818
X241|1|	-.03195	.08692	-.37	.7132	-.20232	.13842
X242|1|	.28543***	.08842	3.23	.0012	.11212	.45874
X251|1|	.05676	.08992	.63	.5279	-.11949	.23300
X252|1|	-.31963***	.08524	-3.75	.0002	-.48671	-.15256
X261|1|	-.21924*	.12479	-1.76	.0789	-.46382	.02535
X262|1|	.26305***	.09842	2.67	.0075	.07014	.45596
X271|1|	.05997	.11691	.51	.6080	-.16917	.28912
X272|1|	-.01520	.09328	-.16	.8706	-.19802	.16762
X281|1|	.12797	.17885	.72	.4743	-.22257	.47851
X282|1|	-.28570	.19333	-1.48	.1395	-.66461	.09321
X291|1|	-.81563***	.10469	-7.79	.0000	-1.02082	-.61045
X292|1|	1.14946***	.10965	10.48	.0000	.93455	1.36437
X301|1|	.10528	.11208	.94	.3476	-.11440	.32495
X302|1|	-.29799***	.10658	-2.80	.0052	-.50688	-.08910
X311|1|	-.23135***	.07115	-3.25	.0011	-.37080	-.09190

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X312|1|    -.00726         .07443      -.10  .9223     -.15313    .13861
X321|1|     .03230         .07604       .42  .6710     -.11673    .18134
X322|1|     .03933         .07053       .56  .5771     -.09891    .17757
X331|1|     .11945         .07989      1.50  .1348     -.03712    .27603
X332|1|     .01875         .07232       .26  .7954     -.12299    .16049
X341|1|    -.07744         .07311     -1.06  .2895     -.22073    .06585
X342|1|     .05943         .07634       .78  .4363     -.09020    .20906
X351|1|    -.16404*        .09514     -1.72  .0847     -.35051    .02243
X352|1|     .07732         .10031       .77  .4408     -.11928    .27393
X361|1|     .13868         .09071      1.53  .1263     -.03911    .31646
X362|1|    -.17034         .10359     -1.64  .1001     -.37337    .03269
X371|1|     .22442**       .09478      2.37  .0179      .03865    .41018
X372|1|    -.07068         .09658      -.73  .4643     -.25997    .11862
X381|1|    -.31681***      .09683     -3.27  .0011     -.50660   -.12703
X382|1|     .13467         .10015      1.34  .1787     -.06162    .33097
X391|1|     .13229         .14437       .92  .3595     -.15068    .41525
X392|1|    -.08036         .12010      -.67  .5034     -.31575    .15502
X401|1|     .12487         .20647       .60  .5453     -.27981    .52954
X402|1|     .01946         .13865       .14  .8884     -.25229    .29120
X411|1|    -.03338         .09845      -.34  .7345     -.22634    .15957
X412|1|     .11975         .10134      1.18  .2374     -.07888    .31837
X421|1|    -.03967         .10062      -.39  .6934     -.23688    .15753
X422|1|    -.10764         .12064      -.89  .3722     -.34408    .12880
X431|1|     .09382         .12455       .75  .4513     -.15029    .33793
X432|1|    -.00650         .11832      -.05  .9562     -.23841    .22541
X441|1|     .07241         .14117       .51  .6080     -.20428    .34911
X442|1|    -.06657         .11261      -.59  .5544     -.28728    .15414
      |Random utility parameters in latent class -->>  2...................
 CON|2|     .44156         .56030       .79  .4307     -.65660   1.53971
 X31|2|     .71513        1.75848       .41  .6842    -2.73143   4.16170
 X32|2|     .01502        1.40455       .01  .9915    -2.73784   2.76788
 X41|2|     .44834         .68487       .65  .5127     -.89399   1.79067
 X42|2|    -.07515        1.24932      -.06  .9520    -2.52378   2.37347
 X51|2|     .33857        1.02865       .33  .7421    -1.67755   2.35468
 X52|2|    -.00506        1.59061       .00  .9975    -3.12260   3.11247
 X61|2|    -.04923         .55006      -.09  .9287    -1.12733   1.02887
 X62|2|    -.14516         .81495      -.18  .8586    -1.74243   1.45211
 X71|2|     .23546        1.20570       .20  .8452    -2.12766   2.59859
 X72|2|    -.00436        1.41011       .00  .9975    -2.76812   2.75941
 X81|2|    -.16047        1.01959      -.16  .8749    -2.15882   1.83789
 X82|2|    -.09510         .95024      -.10  .9203    -1.95753   1.76733
 X91|2|    -.07230        1.19708      -.06  .9518    -2.41853   2.27393
 X92|2|    -.07194        1.19709      -.06  .9521    -2.41820   2.27431
X101|2|    -.06989        1.17748      -.06  .9527    -2.37771   2.23792
X102|2|     .01328        1.12580       .01  .9906    -2.19326   2.21981
X111|2|     .40567        1.60158       .25  .8000    -2.73336   3.54470
X112|2|    -.09439        1.26596      -.07  .9406    -2.57564   2.38685
X121|2|     .27845        2.12250       .13  .8956    -3.88156   4.43847
X122|2|    -.64495        1.11425      -.58  .5627    -2.82885   1.53895
X131|2|    -.21065        1.58806      -.13  .8945    -3.32319   2.90189
X132|2|     .18450        1.60457       .11  .9085    -2.96039   3.32939
X141|2|     .19356        1.96252       .10  .9214    -3.65292   4.04003
X142|2|     .07373        1.22319       .06  .9519    -2.32368   2.47115
X151|2|     .03700        2.31931       .02  .9873    -4.50876   4.58276
X152|2|    -.06588        1.59946      -.04  .9671    -3.20076   3.06899
X161|2|    -.19641        1.09845      -.18  .8581    -2.34933   1.95651
X162|2|     .22882        1.50171       .15  .8789    -2.71448   3.17212
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X171|2|	.02898	.92664	.03	.9751	-1.78721	1.84516
X172|2|	-.08135	1.38933	-.06	.9533	-2.80438	2.64168
X181|2|	.24369	1.96451	.12	.9013	-3.60668	4.09405
X182|2|	.04700	1.88875	.02	.9801	-3.65488	3.74887
X191|2|	-.37150	2.77905	-.13	.8937	-5.81834	5.07533
X192|2|	.11702	2.12078	.06	.9560	-4.03964	4.27367
X201|2|	.24019	2.35952	.10	.9189	-4.38438	4.86477
X202|2|	-.04103	2.12965	-.02	.9846	-4.21507	4.13301
X211|2|	-.26723	2.42325	-.11	.9122	-5.01671	4.48225
X212|2|	.01037	2.33038	.00	.9964	-4.55710	4.57784
X221|2|	-.01896	1.78164	-.01	.9915	-3.51091	3.47299
X222|2|	-.03039	1.07757	-.03	.9775	-2.14238	2.08161
X231|2|	-.04325	1.14253	-.04	.9698	-2.28257	2.19607
X232|2|	.17422	.89215	.20	.8452	-1.57436	1.92280
X241|2|	-.01451	1.42318	-.01	.9919	-2.80388	2.77487
X242|2|	-.00317	1.99572	.00	.9987	-3.91472	3.90838
X251|2|	-.07498	1.96890	-.04	.9696	-3.93396	3.78400
X252|2|	-.14315	1.64242	-.09	.9305	-3.36223	3.07592
X261|2|	.27092	1.45647	.19	.8524	-2.58371	3.12555
X262|2|	-.17496	1.32044	-.13	.8946	-2.76297	2.41305
X271|2|	-.11455	1.46633	-.08	.9377	-2.98850	2.75940
X272|2|	.05065	1.12068	.05	.9639	-2.14583	2.24714
X281|2|	-.76094	1.12582	-.68	.4991	-2.96750	1.44562
X282|2|	.03501	1.36030	.03	.9795	-2.63113	2.70115
X291|2|	-.41166	1.70968	-.24	.8097	-3.76258	2.93926
X292|2|	1.06690	1.74825	.61	.5417	-2.35961	4.49341
X301|2|	.13928	2.12036	.07	.9476	-4.01656	4.29511
X302|2|	-.31859	2.09126	-.15	.8789	-4.41738	3.78019
X311|2|	-.16374	1.25264	-.13	.8960	-2.61887	2.29139
X312|2|	-.12503	1.01613	-.12	.9021	-2.11661	1.86654
X321|2|	-.08056	1.69234	-.05	.9620	-3.39748	3.23636
X322|2|	.07024	1.52187	.05	.9632	-2.91257	3.05304
X331|2|	-.01038	1.08416	-.01	.9924	-2.13531	2.11454
X332|2|	-.09582	1.86426	-.05	.9590	-3.74970	3.55806
X341|2|	-.25364	1.45566	-.17	.8617	-3.10668	2.59940
X342|2|	.19785	1.37734	.14	.8858	-2.50169	2.89740
X351|2|	-.11900	1.13575	-.10	.9166	-2.34503	2.10703
X352|2|	-.02596	1.30224	-.02	.9841	-2.57831	2.52639
X361|2|	.12698	1.19073	.11	.9151	-2.20680	2.46076
X362|2|	-.11521	1.36620	-.08	.9328	-2.79291	2.56249
X371|2|	-.13111	1.04455	-.13	.9001	-2.17839	1.91618
X372|2|	.01428	1.17082	.01	.9903	-2.28049	2.30904
X381|2|	.11809	1.61728	.07	.9418	-3.05173	3.28791
X382|2|	.02514	2.39179	.01	.9916	-4.66269	4.71297
X391|2|	-.01307	1.81679	-.01	.9943	-3.57391	3.54778
X392|2|	.07864	1.50633	.05	.9584	-2.87371	3.03098
X401|2|	-.36391	2.13431	-.17	.8646	-4.54708	3.81926
X402|2|	.09708	1.59241	.06	.9514	-3.02399	3.21815
X411|2|	-.26982	1.17670	-.23	.8186	-2.57612	2.03648
X412|2|	.18385	1.35186	.14	.8918	-2.46574	2.83344
X421|2|	.07265	1.05064	.07	.9449	-1.98657	2.13188
X422|2|	.03565	1.16007	.03	.9755	-2.23804	2.30934
X431|2|	.01231	1.65357	.01	.9941	-3.22862	3.25324
X432|2|	-.05986	1.42830	-.04	.9666	-2.85927	2.73956
X441|2|	-.30321	1.92680	-.16	.8750	-4.07968	3.47326
X442|2|	.07920	1.63938	.05	.9615	-3.13392	3.29233

|This is THETA(01) in class probability model........................

```
  _ONE|1|    2.90130       6.02354       .48  .6300    -8.90462  14.70721
  _A11|1|    -.21163        .55526      -.38  .7031    -1.29993    .87666
  _A21|1|    2.24374      12.11313       .19  .8530   -21.49756  25.98503
  _A22|1|    -.60803       6.08497      -.10  .9204   -12.53435  11.31829
  _A31|1|    -.32608        .47514      -.69  .4925    -1.25733    .60518
  _A32|1|     .25306        .62494       .40  .6855     -.97179   1.47792
  _A41|1|    -.14945        .41121      -.36  .7163     -.95541    .65651
  _A51|1|     .03822        .82275       .05  .9630    -1.57434   1.65078
  _A52|1|     .05149        .60556       .09  .9322    -1.13538   1.23836
  _A61|1|     .12910       1.81048       .07  .9432    -3.41938   3.67757
  _A62|1|     .18284       1.23805       .15  .8826    -2.24370   2.60938
        |This is THETA(02) in class probability model.......................
  _ONE|2|        0.0    .....(Fixed Parameter).....
  _A11|2|        0.0    .....(Fixed Parameter).....
  _A21|2|        0.0    .....(Fixed Parameter).....
  _A22|2|        0.0    .....(Fixed Parameter).....
  _A31|2|        0.0    .....(Fixed Parameter).....
  _A32|2|        0.0    .....(Fixed Parameter).....
  _A41|2|        0.0    .....(Fixed Parameter).....
  _A51|2|        0.0    .....(Fixed Parameter).....
  _A52|2|        0.0    .....(Fixed Parameter).....
  _A61|2|        0.0    .....(Fixed Parameter).....
  _A62|2|        0.0    .....(Fixed Parameter).....
--------+--------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Fixed parameter ... is constrained to equal the value or
had a nonpositive st.error because of an earlier problem.
Model was estimated on Feb 26, 2023 at 00:53:19 PM
-----------------------------------------------------------------------------
```

Appendix K2 – LC output original model (3 classes)

Code:

```
Reset $
READ; file = "D: \(…)\LCA 5.csv" $

NLOGIT
; Lhs = Obsch
; Choices = 1, 2, 3
; rhs = con,X31,X32,X41,X42,X51,X52,X61,X62,X71,X72,
        X81,X82,X91,X92,X101,X102,X111,X112,X121,X122,X131,X132,X141,
        X142,X151,X152,X161,X162,X171,X172,X181,X182,X191,X192,X201,
        X202,X211,X212,X221,X222,X231,X232,X241,X242,X251,X252,X261,
        X262,X271,X272,X281,X282,X291,X292,X301,X302,X311,X312,X321,
        X322,X331,X332,X341,X342,X351,X352,X361,X362,X371,X372,X381,
        X382,X391,X392,X401,X402,X411,X412,X421,X422,X431,X432,X441,X442
; Lcm = A11,A21,A22,A31,A32,A41,A51,A52,A61,A62
; Pts = 3
; Pds = 12
; Maxit = 300
$
```

Output:

```
-----------------------------------------------------------------------------
Discrete choice (multinomial logit) model
Dependent variable                   Choice
Log likelihood function         -4681.64064
Estimation based on N =    5820, K =   85
Inf.Cr.AIC   =    9533.3 AIC/N =    1.638
---------------------------------------
            Log likelihood R-sqrd R2Adj
Constants only  -5499.7000  .1487 .1280
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as ind. choices
Number of obs.=   5820, skipped    0 obs
--------+--------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
   OBSCH|  Coefficient       Error       z     |z|>Z*         Interval
--------+--------------------------------------------------------------------
   CON|1|   -1.97777***      .05863   -33.74  .0000    -2.09268  -1.86287
   X31|1|     .87929***      .05961    14.75  .0000      .76246    .99612
   X32|1|     .34046***      .05897     5.77  .0000      .22488    .45604
   X41|1|     .37255***      .04342     8.58  .0000      .28745    .45766
   X42|1|     .11164***      .04250     2.63  .0086      .02834    .19494
   X51|1|     .49657***      .04387    11.32  .0000      .41058    .58255
   X52|1|    -.04847         .04219    -1.15  .2507     -.13117    .03423
   X61|1|    -.21576***      .03939    -5.48  .0000     -.29296   -.13856
   X62|1|     .02425         .03877      .63  .5316     -.05174    .10025
   X71|1|     .30166***      .04896     6.16  .0000      .20571    .39762
   X72|1|     .02622         .04944      .53  .5958     -.07067    .12312
   X81|1|    -.18187***      .03879    -4.69  .0000     -.25789   -.10584
   X82|1|    -.10535***      .03842    -2.74  .0061     -.18064   -.03005
```

X91|1|	-.07532	.05317	-1.42	.1566	-.17953	.02889
X92|1|	.00444	.06853	.06	.9483	-.12987	.13875
X101|1|	-.06991*	.04147	-1.69	.0918	-.15118	.01136
X102|1|	.03737	.04020	.93	.3526	-.04142	.11616
X111|1|	.07310	.08206	.89	.3730	-.08773	.23393
X112|1|	-.04192	.08155	-.51	.6072	-.20175	.11791
X121|1|	.33637***	.08489	3.96	.0001	.16999	.50276
X122|1|	-.48666***	.08388	-5.80	.0000	-.65106	-.32227
X131|1|	-.04703	.08238	-.57	.5680	-.20850	.11443
X132|1|	.03156	.08122	.39	.6975	-.12762	.19075
X141|1|	.12233*	.06486	1.89	.0593	-.00478	.24945
X142|1|	.02704	.06272	.43	.6664	-.09589	.14997
X151|1|	-.10954*	.06230	-1.76	.0787	-.23165	.01256
X152|1|	.07176	.06282	1.14	.2533	-.05136	.19488
X161|1|	-.07789	.06124	-1.27	.2034	-.19792	.04213
X162|1|	.03936	.05865	.67	.5022	-.07560	.15431
X171|1|	.07634	.05968	1.28	.2008	-.04063	.19332
X172|1|	-.00993	.05759	-.17	.8631	-.12282	.10295
X181|1|	.01947	.08483	.23	.8185	-.14679	.18572
X182|1|	.03584	.08381	.43	.6689	-.12843	.20011
X191|1|	-.11979	.08078	-1.48	.1381	-.27812	.03855
X192|1|	.18766**	.07502	2.50	.0124	.04063	.33469
X201|1|	.12134	.07719	1.57	.1160	-.02996	.27263
X202|1|	-.05384	.09504	-.57	.5711	-.24011	.13244
X211|1|	.03797	.07784	.49	.6257	-.11460	.19055
X212|1|	-.08256	.07973	-1.04	.3004	-.23883	.07370
X221|1|	-.00073	.05825	-.01	.9900	-.11490	.11343
X222|1|	.07033	.05780	1.22	.2237	-.04295	.18361
X231|1|	-.02107	.05430	-.39	.6980	-.12750	.08536
X232|1|	-.07169	.05382	-1.33	.1829	-.17718	.03381
X241|1|	-.06866	.06142	-1.12	.2636	-.18903	.05171
X242|1|	.21170***	.06072	3.49	.0005	.09269	.33071
X251|1|	.06252	.05951	1.05	.2935	-.05413	.17917
X252|1|	-.31082***	.05965	-5.21	.0000	-.42774	-.19390
X261|1|	.02701	.06449	.42	.6754	-.09939	.15341
X262|1|	.08596	.05604	1.53	.1250	-.02387	.19580
X271|1|	.00290	.06187	.05	.9626	-.11836	.12417
X272|1|	.01373	.05326	.26	.7965	-.09065	.11811
X281|1|	-.23388***	.08438	-2.77	.0056	-.39926	-.06850
X282|1|	-.02213	.08227	-.27	.7880	-.18338	.13913
X291|1|	-.67560***	.08230	-8.21	.0000	-.83691	-.51429
X292|1|	1.00392***	.08560	11.73	.0000	.83615	1.17169
X301|1|	.14486*	.08277	1.75	.0801	-.01737	.30709
X302|1|	-.26671***	.08093	-3.30	.0010	-.42533	-.10808
X311|1|	-.19783***	.05682	-3.48	.0005	-.30919	-.08646
X312|1|	-.01641	.05568	-.29	.7682	-.12554	.09273
X321|1|	.04031	.05576	.72	.4697	-.06898	.14960
X322|1|	.01795	.05419	.33	.7404	-.08826	.12417
X331|1|	.09020	.05819	1.55	.1211	-.02384	.20425
X332|1|	.01169	.05612	.21	.8351	-.09832	.12169
X341|1|	-.07617	.05751	-1.32	.1854	-.18890	.03655
X342|1|	.06059	.05510	1.10	.2715	-.04741	.16858
X351|1|	-.08361	.06030	-1.39	.1656	-.20179	.03458
X352|1|	.02269	.05921	.38	.7016	-.09337	.13874
X361|1|	.12412**	.06049	2.05	.0402	.00557	.24267
X362|1|	-.06325	.05977	-1.06	.2899	-.18039	.05388
X371|1|	.18549***	.06010	3.09	.0020	.06769	.30329

```
  X372|1|    -.12241**       .05970    -2.05  .0403     -.23941   -.00540
  X381|1|    -.13951**       .06027    -2.31  .0206     -.25765   -.02138
  X382|1|     .05723         .06119      .94  .3496     -.06269    .17716
  X391|1|     .10213         .07425     1.38  .1690     -.04339    .24765
  X392|1|    -.05396         .07255     -.74  .4570     -.19617    .08824
  X401|1|    -.02743         .08887     -.31  .7576     -.20161    .14675
  X402|1|     .07910         .07249     1.09  .2752     -.06298    .22118
  X411|1|    -.02913         .05734     -.51  .6114     -.14152    .08326
  X412|1|     .08723         .05700     1.53  .1259     -.02449    .19896
  X421|1|     .07692         .05545     1.39  .1653     -.03175    .18559
  X422|1|    -.07633         .05680    -1.34  .1790     -.18766    .03501
  X431|1|     .10491         .06712     1.56  .1180     -.02663    .23646
  X432|1|     .01372         .06081      .23  .8215     -.10546    .13290
  X441|1|    -.11110*        .06664    -1.67  .0955     -.24171    .01952
  X442|1|     .07659         .05956     1.29  .1984     -.04014    .19332
--------+-------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Feb 26, 2023 at 00:55:16 PM
----------------------------------------------------------------------------

Iterative procedure has converged
Normal exit: 296 iterations. Status=0, F=    .4067157D+04

----------------------------------------------------------------------------
Latent Class Logit Model
Dependent variable                OBSCH
Log likelihood function    -48500.00000
Estimation based on N =   5820, K = 277
Inf.Cr.AIC  =  97554.0 AIC/N =   16.762
---------------------------------------
            Log likelihood R-sqrd R2Adj
No coefficients -6393.9235 ************
Constants only  -5499.7000 ************
At start values -4681.5601 ************
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as ind. choices
Number of latent classes =            3
Average Class Probabilities
     .716  .049  .234
LCM model with panel has     485 groups
Fixed number of obsrvs./group=       12
BHHH estimator used for asymp. variance
Number of obs.=  5820, skipped    0 obs
--------+-------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
   OBSCH|  Coefficient       Error       z     |z|>Z*         Interval
--------+-------------------------------------------------------------------
        |Random utility parameters in latent class -->> 1..................
   CON|1|   -4.45513***      .11495    -38.76  .0000    -4.68043  -4.22983
   X31|1|    1.04962***      .13610      7.71  .0000      .78287   1.31637
   X32|1|     .34978***      .12662      2.76  .0057      .10161    .59795
   X41|1|     .49917***      .11707      4.26  .0000      .26972    .72861
   X42|1|     .16681         .13519      1.23  .2173     -.09816    .43178
```

X51|1|	.63177***	.12412	5.09	.0000	.38849	.87505
X52|1|	-.06828	.11388	-.60	.5488	-.29149	.15493
X61|1|	-.26448*	.13712	-1.93	.0537	-.53322	.00426
X62|1|	.06826	.13774	.50	.6202	-.20171	.33822
X71|1|	.54391***	.13244	4.11	.0000	.28433	.80348
X72|1|	-.05382	.13837	-.39	.6973	-.32501	.21737
X81|1|	-.31422***	.10936	-2.87	.0041	-.52857	-.09987
X82|1|	-.27549***	.10147	-2.71	.0066	-.47438	-.07661
X91|1|	-.12915	.14009	-.92	.3566	-.40373	.14542
X92|1|	.12960	.14206	.91	.3616	-.14883	.40804
X101|1|	-.02626	.11160	-.24	.8140	-.24498	.19247
X102|1|	.19832*	.11045	1.80	.0725	-.01815	.41479
X111|1|	-.23394	.32584	-.72	.4728	-.87258	.40469
X112|1|	-.29792	.33484	-.89	.3736	-.95419	.35835
X121|1|	.39906*	.20948	1.90	.0568	-.01152	.80963
X122|1|	-.48183***	.16075	-3.00	.0027	-.79688	-.16677
X131|1|	-.02025	.19691	-.10	.9181	-.40619	.36569
X132|1|	-.04881	.16554	-.29	.7681	-.37327	.27564
X141|1|	.18340	.18491	.99	.3213	-.17902	.54581
X142|1|	.01198	.18845	.06	.9493	-.35738	.38133
X151|1|	-.19506	.20320	-.96	.3371	-.59332	.20320
X152|1|	.18136	.19502	.93	.3524	-.20087	.56360
X161|1|	.08393	.17721	.47	.6358	-.26339	.43124
X162|1|	-.01991	.16953	-.12	.9065	-.35219	.31236
X171|1|	.13137	.18373	.72	.4746	-.22874	.49148
X172|1|	-.10804	.18040	-.60	.5492	-.46162	.24554
X181|1|	-.02397	.23290	-.10	.9180	-.48045	.43251
X182|1|	.05890	.24449	.24	.8096	-.42030	.53809
X191|1|	.14206	.18948	.75	.4534	-.22931	.51344
X192|1|	.00278	.20953	.01	.9894	-.40788	.41344
X201|1|	.19641	.21857	.90	.3688	-.23197	.62480
X202|1|	-.12988	.23911	-.54	.5870	-.59853	.33878
X211|1|	.16774	.23209	.72	.4698	-.28715	.62262
X212|1|	-.12493	.27041	-.46	.6441	-.65492	.40507
X221|1|	-.02943	.19717	-.15	.8813	-.41587	.35701
X222|1|	.13384	.19836	.67	.4999	-.25495	.52262
X231|1|	-.05237	.18122	-.29	.7726	-.40756	.30283
X232|1|	-.11468	.18040	-.64	.5250	-.46825	.23889
X241|1|	.07651	.21900	.35	.7268	-.35273	.50574
X242|1|	.28577*	.16395	1.74	.0813	-.03556	.60710
X251|1|	-.00776	.20230	-.04	.9694	-.40425	.38874
X252|1|	-.30041*	.18041	-1.67	.0959	-.65401	.05320
X261|1|	-.47207***	.15098	-3.13	.0018	-.76798	-.17617
X262|1|	.43946***	.16645	2.64	.0083	.11322	.76570
X271|1|	.09578	.15290	.63	.5311	-.20390	.39545
X272|1|	-.00543	.14964	-.04	.9711	-.29872	.28786
X281|1|	.18403	.28342	.65	.5161	-.37147	.73953
X282|1|	-.52964*	.29726	-1.78	.0748	-1.11226	.05297
X291|1|	-.78219***	.19326	-4.05	.0001	-1.16097	-.40340
X292|1|	1.05239***	.20986	5.01	.0000	.64108	1.46370
X301|1|	.02942	.19847	.15	.8821	-.35957	.41842
X302|1|	-.22198	.18296	-1.21	.2250	-.58058	.13661
X311|1|	-.28308	.18370	-1.54	.1233	-.64314	.07697
X312|1|	-.02274	.18712	-.12	.9033	-.38950	.34401
X321|1|	.01805	.17540	.10	.9180	-.32572	.36183
X322|1|	.05461	.17816	.31	.7592	-.29458	.40380
X331|1|	.08913	.16207	.55	.5823	-.22852	.40678

X332|1|	.05686	.18786	.30	.7621	-.31135	.42506
X341|1|	-.07260	.17097	-.42	.6711	-.40770	.26250
X342|1|	.07018	.19533	.36	.7194	-.31266	.45303
X351|1|	-.27398	.16866	-1.62	.1043	-.60454	.05658
X352|1|	.13373	.16697	.80	.4232	-.19352	.46097
X361|1|	.18392	.17058	1.08	.2809	-.15041	.51826
X362|1|	-.25906	.18533	-1.40	.1622	-.62229	.10417
X371|1|	.28508	.20576	1.39	.1659	-.11821	.68837
X372|1|	-.03040	.17119	-.18	.8590	-.36592	.30512
X381|1|	-.57169***	.17119	-3.34	.0008	-.90723	-.23616
X382|1|	.25680	.17589	1.46	.1443	-.08793	.60154
X391|1|	.20716	.20642	1.00	.3156	-.19741	.61174
X392|1|	-.04476	.18376	-.24	.8075	-.40493	.31540
X401|1|	.17486	.21249	.82	.4106	-.24161	.59134
X402|1|	-.05527	.20531	-.27	.7878	-.45767	.34712
X411|1|	.05688	.14789	.38	.7005	-.23297	.34673
X412|1|	.15302	.14288	1.07	.2842	-.12702	.43306
X421|1|	-.27414*	.15824	-1.73	.0832	-.58428	.03599
X422|1|	-.05004	.15490	-.32	.7467	-.35364	.25356
X431|1|	.25632*	.15126	1.69	.0902	-.04016	.55279
X432|1|	-.22108	.16165	-1.37	.1714	-.53791	.09574
X441|1|	.13676	.18410	.74	.4576	-.22407	.49759
X442|1|	-.06198	.15220	-.41	.6839	-.36029	.23633

|Random utility parameters in latent class -->> 2...................

CON|2|	8.91252***	.71301	12.50	.0000	7.51504	10.31000
X31|2|	-5.50455***	1.22770	-4.48	.0000	-7.91081	-3.09830
X32|2|	-.56160	.96962	-.58	.5625	-2.46202	1.33882
X41|2|	5.77183***	1.08307	5.33	.0000	3.64905	7.89461
X42|2|	-10.6766***	1.14504	-9.32	.0000	-12.9208	-8.4324
X51|2|	.41184	1.18002	.35	.7271	-1.90095	2.72464
X52|2|	.19229	1.13495	.17	.8655	-2.03218	2.41676
X61|2|	.62748	1.28575	.49	.6255	-1.89255	3.14752
X62|2|	-.55718	1.19583	-.47	.6413	-2.90098	1.78661
X71|2|	-.34170	1.14547	-.30	.7655	-2.58679	1.90339
X72|2|	-.41565	1.49033	-.28	.7803	-3.33665	2.50534
X81|2|	.00754	1.12748	.01	.9947	-2.20229	2.21737
X82|2|	.44349	.94772	.47	.6398	-1.41402	2.30099
X91|2|	-1.37522	1.35747	-1.01	.3110	-4.03580	1.28536
X92|2|	.60942	1.28080	.48	.6342	-1.90091	3.11975
X101|2|	-1.62772	1.20750	-1.35	.1777	-3.99438	.73894
X102|2|	.72871	1.19473	.61	.5419	-1.61292	3.07033
X111|2|	-5.36151**	2.69769	-1.99	.0469	-10.64889	-.07413
X112|2|	10.9521***	2.79689	3.92	.0001	5.4703	16.4339
X121|2|	6.28054***	2.03630	3.08	.0020	2.28946	10.27162
X122|2|	-.53279	1.57698	-.34	.7355	-3.62362	2.55804
X131|2|	-12.1684***	1.81925	-6.69	.0000	-15.7341	-8.6028
X132|2|	-1.39260	1.55887	-.89	.3717	-4.44794	1.66273
X141|2|	-4.76266***	1.52348	-3.13	.0018	-7.74863	-1.77669
X142|2|	9.88333***	1.61540	6.12	.0000	6.71720	13.04946
X151|2|	10.4438***	1.85256	5.64	.0000	6.8128	14.0747
X152|2|	-21.0382***	1.62158	-12.97	.0000	-24.2164	-17.8600
X161|2|	-2.65348	1.80061	-1.47	.1406	-6.18260	.87564
X162|2|	.97323	1.80946	.54	.5907	-2.57324	4.51970
X171|2|	.91020	1.86089	.49	.6248	-2.73708	4.55748
X172|2|	-.28140	1.85286	-.15	.8793	-3.91294	3.35013
X181|2|	.53497	2.53429	.21	.8328	-4.43214	5.50208
X182|2|	.02555	2.54858	.01	.9920	-4.96958	5.02068

X191|2|	-.97992	2.38053	-.41	.6806	-5.64568	3.68583
X192|2|	.37316	2.22628	.17	.8669	-3.99027	4.73658
X201|2|	-.55414	2.12288	-.26	.7941	-4.71490	3.60663
X202|2|	.30366	2.21171	.14	.8908	-4.03121	4.63853
X211|2|	-.69494	2.04700	-.34	.7342	-4.70697	3.31710
X212|2|	.31225	2.62112	.12	.9052	-4.82506	5.44956
X221|2|	-.69244	1.88522	-.37	.7134	-4.38741	3.00253
X222|2|	.30876	1.87777	.16	.8694	-3.37160	3.98912
X231|2|	1.05624	1.88166	.56	.5746	-2.63174	4.74422
X232|2|	-.77728	1.84494	-.42	.6735	-4.39330	2.83874
X241|2|	-1.29998	2.00318	-.65	.5164	-5.22614	2.62619
X242|2|	.54581	1.68251	.32	.7456	-2.75185	3.84346
X251|2|	.38813	1.87086	.21	.8356	-3.27869	4.05496
X252|2|	-.55754	1.79896	-.31	.7566	-4.08344	2.96835
X261|2|	1.62939	1.71829	.95	.3430	-1.73840	4.99718
X262|2|	-.40586	1.48487	-.27	.7846	-3.31615	2.50443
X271|2|	.12265	1.58528	.08	.9383	-2.98444	3.22973
X272|2|	-1.06202	1.48927	-.71	.4758	-3.98093	1.85689
X281|2|	-1.81411	1.93085	-.94	.3475	-5.59850	1.97029
X282|2|	-.49445D-04	1.69303	.00	1.0000	-.33183D+01	.33182D+01
X291|2|	-.00208	1.73063	.00	.9990	-3.39405	3.38990
X292|2|	1.77642	1.77815	1.00	.3178	-1.70870	5.26154
X301|2|	.25126	1.91595	.13	.8957	-3.50394	4.00646
X302|2|	.16805	1.66896	.10	.9198	-3.10305	3.43916
X311|2|	-.12531	1.74538	-.07	.9428	-3.54620	3.29558
X312|2|	-.20578	1.81821	-.11	.9099	-3.76942	3.35785
X321|2|	-.55417	1.93129	-.29	.7742	-4.33943	3.23110
X322|2|	1.40772	1.75966	.80	.4237	-2.04116	4.85660
X331|2|	1.98816	1.65894	1.20	.2307	-1.26329	5.23962
X332|2|	-.50412	1.88845	-.27	.7895	-4.20541	3.19718
X341|2|	-1.78584	1.66863	-1.07	.2845	-5.05630	1.48463
X342|2|	-.18666	1.74119	-.11	.9146	-3.59932	3.22600
X351|2|	-.06842	1.73370	-.04	.9685	-3.46640	3.32956
X352|2|	-1.21771	1.59294	-.76	.4446	-4.33981	1.90439
X361|2|	-.32084	2.01174	-.16	.8733	-4.26377	3.62209
X362|2|	.18730	2.15065	.09	.9306	-4.02789	4.40249
X371|2|	1.35071	1.92844	.70	.4837	-2.42897	5.13039
X372|2|	-.83184	1.89164	-.44	.6601	-4.53938	2.87570
X381|2|	-.52243	1.65331	-.32	.7520	-3.76285	2.71799
X382|2|	.93441	2.28117	.41	.6821	-3.53660	5.40541
X391|2|	-1.41019	1.89577	-.74	.4570	-5.12584	2.30545
X392|2|	.67076	1.75308	.38	.7020	-2.76522	4.10674
X401|2|	-.47627	2.02340	-.24	.8139	-4.44207	3.48953
X402|2|	.48435	2.14271	.23	.8212	-3.71530	4.68399
X411|2|	-.75632	1.52050	-.50	.6189	-3.73644	2.22380
X412|2|	-.07598	1.54103	-.05	.9607	-3.09633	2.94438
X421|2|	.52585	1.50101	.35	.7261	-2.41607	3.46777
X422|2|	.70195	1.47388	.48	.6339	-2.18679	3.59070
X431|2|	.06944	1.45722	.05	.9620	-2.78666	2.92553
X432|2|	.00480	1.49763	.00	.9974	-2.93050	2.94011
X441|2|	-.26300	1.75445	-.15	.8808	-3.70167	3.17567
X442|2|	-.98000	1.55255	-.63	.5279	-4.02294	2.06294
|Random utility parameters in latent class -->> 3...................						
CON|3|	-1.09775***	.29228	-3.76	.0002	-1.67061	-.52488
X31|3|	1.14070***	.38003	3.00	.0027	.39586	1.88555
X32|3|	.48622	.31118	1.56	.1182	-.12367	1.09611
X41|3|	.41926	.30625	1.37	.1710	-.18098	1.01950

X42|3|	-.05170	.33147	-.16	.8761	-.70137	.59797
X51|3|	.35028	.36181	.97	.3330	-.35885	1.05942
X52|3|	.01277	.31185	.04	.9673	-.59846	.62399
X61|3|	-.18605	.33125	-.56	.5743	-.83528	.46318
X62|3|	-.08031	.31449	-.26	.7984	-.69671	.53609
X71|3|	.18072	.34872	.52	.6043	-.50276	.86421
X72|3|	.11734	.36740	.32	.7494	-.60275	.83743
X81|3|	-.16723	.27518	-.61	.5434	-.70657	.37211
X82|3|	-.06984	.26095	-.27	.7890	-.58129	.44160
X91|3|	.08223	.38099	.22	.8291	-.66450	.82897
X92|3|	-.02938	.38407	-.08	.9390	-.78215	.72339
X101|3|	-.00273	.29213	-.01	.9925	-.57528	.56983
X102|3|	-.03094	.26276	-.12	.9063	-.54594	.48406
X111|3|	.17702	.83474	.21	.8321	-1.45903	1.81307
X112|3|	-.05899	.88707	-.07	.9470	-1.79761	1.67964
X121|3|	.51058	.59931	.85	.3942	-.66405	1.68521
X122|3|	-.61694	.40070	-1.54	.1236	-1.40230	.16842
X131|3|	-.11239	.51432	-.22	.8270	-1.12045	.89566
X132|3|	.33088	.41408	.80	.4243	-.48070	1.14246
X141|3|	.11243	.48078	.23	.8151	-.82988	1.05474
X142|3|	.14024	.48162	.29	.7709	-.80372	1.08419
X151|3|	-.06406	.50818	-.13	.8997	-1.06007	.93195
X152|3|	-.02807	.49894	-.06	.9551	-1.00597	.94984
X161|3|	-.12988	.45075	-.29	.7732	-1.01333	.75358
X162|3|	.12531	.45244	.28	.7818	-.76145	1.01207
X171|3|	-.20953	.49821	-.42	.6741	-1.18600	.76693
X172|3|	.03319	.48913	.07	.9459	-.92550	.99187
X181|3|	.05179	.62448	.08	.9339	-1.17216	1.27575
X182|3|	.12427	.69633	.18	.8584	-1.24052	1.48906
X191|3|	-.14066	.54581	-.26	.7966	-1.21042	.92910
X192|3|	.17865	.57851	.31	.7575	-.95521	1.31251
X201|3|	.06563	.59242	.11	.9118	-1.09549	1.22675
X202|3|	-.12136	.65559	-.19	.8531	-1.40630	1.16358
X211|3|	-.19852	.57793	-.34	.7312	-1.33125	.93421
X212|3|	.11031	.63993	.17	.8631	-1.14394	1.36455
X221|3|	-.16274	.52859	-.31	.7582	-1.19875	.87327
X222|3|	-.06606	.49034	-.13	.8928	-1.02711	.89499
X231|3|	.06345	.48200	.13	.8953	-.88126	1.00816
X232|3|	.17558	.44239	.40	.6915	-.69150	1.04265
X241|3|	-.15622	.56599	-.28	.7825	-1.26555	.95311
X242|3|	.12115	.44712	.27	.7864	-.75520	.99749
X251|3|	.09281	.53128	.17	.8613	-.94847	1.13410
X252|3|	-.24309	.48750	-.50	.6180	-1.19858	.71240
X261|3|	.30098	.36893	.82	.4146	-.42212	1.02407
X262|3|	-.00935	.44469	-.02	.9832	-.88093	.86223
X271|3|	-.20153	.36573	-.55	.5816	-.91835	.51530
X272|3|	.14208	.39505	.36	.7191	-.63220	.91636
X281|3|	-.41297	.68240	-.61	.5451	-1.75044	.92450
X282|3|	.02711	.73761	.04	.9707	-1.41858	1.47279
X291|3|	-.88902*	.48364	-1.84	.0660	-1.83693	.05889
X292|3|	1.49382***	.51907	2.88	.0040	.47645	2.51118
X301|3|	.31153	.50594	.62	.5381	-.68009	1.30315
X302|3|	-.66375	.45422	-1.46	.1439	-1.55400	.22651
X311|3|	.03043	.49449	.06	.9509	-.93874	.99961
X312|3|	-.03388	.49047	-.07	.9449	-.99518	.92742
X321|3|	.03342	.45813	.07	.9418	-.86450	.93135
X322|3|	.02715	.50245	.05	.9569	-.95764	1.01194

```
X331|3|     .09191         .42878       .21  .8303     -.74848     .93229
X332|3|    -.12794         .48036      -.27  .7900   -1.06943     .81355
X341|3|    -.15201         .44494      -.34  .7326   -1.02408     .72006
X342|3|     .07235         .48772       .15  .8821     -.88357   1.02827
X351|3|    -.04190         .45570      -.09  .9267     -.93506     .85126
X352|3|     .15397         .43479       .35  .7233     -.69821   1.00614
X361|3|     .07661         .47820       .16  .8727     -.86064   1.01386
X362|3|    -.10434         .47445      -.22  .8259   -1.03424     .82556
X371|3|    -.01192         .51528      -.02  .9815   -1.02184     .99800
X372|3|    -.11535         .46918      -.25  .8058   -1.03493     .80422
X381|3|     .18482         .45661       .40  .6856     -.71011   1.07976
X382|3|    -.01359         .48489      -.03  .9776     -.96395     .93677
X391|3|     .08529         .53965       .16  .8744     -.97241   1.14299
X392|3|    -.03350         .50409      -.07  .9470   -1.02151     .95450
X401|3|    -.05092         .56455      -.09  .9281   -1.15742   1.05558
X402|3|     .00134         .52942       .00  .9980   -1.03630   1.03898
X411|3|    -.09073         .40139      -.23  .8212     -.87744     .69597
X412|3|     .07010         .39741       .18  .8600     -.70880     .84901
X421|3|    -.01276         .42798      -.03  .9762     -.85158     .82606
X422|3|    -.05749         .40872      -.14  .8881     -.85858     .74359
X431|3|     .00324         .39870       .01  .9935     -.77820     .78467
X432|3|     .07840         .42614       .18  .8540     -.75682     .91362
X441|3|    -.09720         .46466      -.21  .8343   -1.00791     .81351
X442|3|     .09034         .41408       .22  .8273     -.72125     .90192
      |This is THETA(01) in class probability model.......................
_ONE|1|    28.3705      .3108D+16       .00 1.0000 ***********  ***********
_A11|1|    -.27789      .1596D+16       .00 1.0000 ***********  ***********
_A21|1|    54.1035      .4584D+16       .00 1.0000 ***********  ***********
_A22|1|   -26.9700      .3021D+16       .00 1.0000 ***********  ***********
_A31|1|    -.45076      .2128D+16       .00 1.0000 ***********  ***********
_A32|1|     .26731      .2351D+16       .00 1.0000 ***********  ***********
_A41|1|     .11451      .2078D+16       .00 1.0000 ***********  ***********
_A51|1|     .18639      .2794D+16       .00 1.0000 ***********  ***********
_A52|1|    -.15614      .2484D+16       .00 1.0000 ***********  ***********
_A61|1|     .26437      .5526D+16       .00 1.0000 ***********  ***********
_A62|1|    -.38639      .4234D+16       .00 1.0000 ***********  ***********
      |This is THETA(02) in class probability model.......................
_ONE|2|    24.6218      .1106D+18       .00 1.0000 ***********  ***********
_A11|2|    -.00222      .3261D+17       .00 1.0000 ***********  ***********
_A21|2|    52.9031      .2150D+18       .00 1.0000 ***********  ***********
_A22|2|   -26.9542      .1088D+18       .00 1.0000 ***********  ***********
_A31|2|    -.85545      .3114D+17       .00 1.0000 ***********  ***********
_A32|2|     .59394      .2398D+17       .00 1.0000 ***********  ***********
_A41|2|     .48967      .1893D+17       .00 1.0000 ***********  ***********
_A51|2|    -.20048      .5464D+17       .00 1.0000 ***********  ***********
_A52|2|     .14185      .3070D+17       .00 1.0000 ***********  ***********
_A61|2|    -.46472      .9318D+17       .00 1.0000 ***********  ***********
_A62|2|    -.35304      .6854D+17       .00 1.0000 ***********  ***********
      |This is THETA(03) in class probability model.......................
_ONE|3|        0.0    .....(Fixed Parameter).....
_A11|3|        0.0    .....(Fixed Parameter).....
_A21|3|        0.0    .....(Fixed Parameter).....
_A22|3|        0.0    .....(Fixed Parameter).....
_A31|3|        0.0    .....(Fixed Parameter).....
_A32|3|        0.0    .....(Fixed Parameter).....
_A41|3|        0.0    .....(Fixed Parameter).....
_A51|3|        0.0    .....(Fixed Parameter).....
```

```
  _A52|3|        0.0    .....(Fixed Parameter).....
  _A61|3|        0.0    .....(Fixed Parameter).....
  _A62|3|        0.0    .....(Fixed Parameter).....
--------+--------------------------------------------------------------------
nnnnn.D-xx or D+xx => multiply by 10 to -xx or +xx.
***, **, * ==>  Significance at 1%, 5%, 10% level.
Fixed parameter ... is constrained to equal the value or
had a nonpositive st.error because of an earlier problem.
Model was estimated on Feb 26, 2023 at 00:56:52 PM
-----------------------------------------------------------------------------
```

Appendix K3 – LC output stepwise reduced model (2 classes)

Code:

```
Reset $
READ; file = "D: \(…)\LCA 5.csv" $

NLOGIT
; Lhs = Obsch
; Choices = 1, 2, 3
; rhs = con,X31,X32,X41,X42,X51,X52,X61,X62,X71,X72,X81,X82,X91,X92,X101,X102,
        X121,X122,X281,X291,X292,X302,X311,X391
; Lcm = A11,A21,A22,A31,A32,A41,A51,A52,A61,A62
; Pts = 2
; Pds = 12
; Maxit = 300
$
```

Output:

```
-----------------------------------------------------------------------------
Discrete choice (multinomial logit) model
Dependent variable               Choice
Log likelihood function     -4736.03875
Estimation based on N =   5820, K =  25
Inf.Cr.AIC  =   9522.1 AIC/N =    1.636
---------------------------------------
            Log likelihood R-sqrd R2Adj
Constants only  -5499.7000  .1389 .1343
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as ind. choices
Number of obs.=  5820, skipped    0 obs
--------+--------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
   OBSCH|  Coefficient       Error       z    |z|>Z*         Interval
--------+--------------------------------------------------------------------
   CON|1|  -1.97218***      .05778   -34.13  .0000    -2.08543  -1.85893
   X31|1|    .87343***      .05870    14.88  .0000      .75837    .98848
   X32|1|    .32680***      .05800     5.63  .0000      .21313    .44046
   X41|1|    .45084***      .03640    12.38  .0000      .37949    .52219
   X42|1|    .04090         .03516     1.16  .2448    -.02802    .10982
   X51|1|    .49003***      .03692    13.27  .0000      .41768    .56239
   X52|1|   -.03917         .03573    -1.10  .2728    -.10919    .03085
   X61|1|   -.21413***      .02989    -7.16  .0000    -.27271   -.15554
   X62|1|    .00439         .02947      .15  .8815    -.05336    .06214
   X71|1|    .29849***      .02963    10.07  .0000      .24041    .35657
   X72|1|    .03812         .02980     1.28  .2009    -.02030    .09653
   X81|1|   -.19209***      .02926    -6.57  .0000    -.24943   -.13474
   X82|1|   -.07070**       .02991    -2.36  .0181    -.12932   -.01208
   X91|1|   -.12723***      .03058    -4.16  .0000    -.18715   -.06730
   X92|1|    .02741         .02933      .93  .3500    -.03008    .08489
  X101|1|   -.06890**       .02975    -2.32  .0205    -.12720   -.01060
```

```
  X102|1|     .07510**       .02929     2.56  .0103      .01769    .13250
  X121|1|     .34035***      .06096     5.58  .0000      .22088    .45983
  X122|1|    -.44040***      .06250    -7.05  .0000     -.56289   -.31790
  X281|1|    -.23002***      .07041    -3.27  .0011     -.36802   -.09201
  X291|1|    -.60860***      .07294    -8.34  .0000     -.75155   -.46564
  X292|1|    1.02821***      .08053    12.77  .0000      .87038   1.18605
  X302|1|    -.32598***      .06604    -4.94  .0000     -.45542   -.19654
  X311|1|    -.16847***      .04000    -4.21  .0000     -.24688   -.09007
  X391|1|     .15496***      .03211     4.83  .0000      .09202    .21790
--------+--------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 28, 2023 at 05:36:23 PM
-----------------------------------------------------------------------------

Iterative procedure has converged
Normal exit:  69 iterations. Status=0, F=    .4293942D+04

-----------------------------------------------------------------------------
Latent Class Logit Model
Dependent variable                OBSCH
Log likelihood function     -4293.94157
Restricted log likelihood   -6393.92352
Chi squared [ 61](P= .000)   4199.96389
Significance level               .00000
McFadden Pseudo R-squared      .3284340
Estimation based on N =   5820, K =  61
Inf.Cr.AIC  =   8709.9 AIC/N =    1.497
---------------------------------------
            Log likelihood R-sqrd R2Adj
No coefficients -6393.9235  .3284 .3249
Constants only  -5499.7000  .2192 .2151
At start values -4735.8191  .0933 .0885
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as ind. choices
Number of latent classes =            2
Average Class Probabilities
     .852  .148
LCM model with panel has     485 groups
Fixed number of obsrvs./group=       12
BHHH estimator used for asymp. variance
Number of obs.=  5820, skipped    0 obs
--------+--------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
   OBSCH|  Coefficient       Error       z    |z|>Z*         Interval
--------+--------------------------------------------------------------------
        |Random utility parameters in latent class -->> 1...................
   CON|1|    -3.26284***      .09161   -35.61  .0000    -3.44240  -3.08328
   X31|1|    1.04753***      .06015    17.42  .0000      .92964   1.16542
   X32|1|     .38767***      .06273     6.18  .0000      .26472    .51061
   X41|1|     .50610***      .04027    12.57  .0000      .42717    .58504
   X42|1|     .05296         .04117     1.29  .1983     -.02773    .13365
   X51|1|     .57810***      .04263    13.56  .0000      .49454    .66166
   X52|1|    -.06695*        .04019    -1.67  .0957     -.14572    .01181
```

```
  X61|1|    -.25880***      .03202    -8.08  .0000     -.32157   -.19604
  X62|1|     .01436         .03375      .43  .6706     -.05179    .08051
  X71|1|     .32236***      .03244     9.94  .0000      .25877    .38594
  X72|1|     .05310         .03515     1.51  .1308     -.01578    .12198
  X81|1|    -.23037***      .03210    -7.18  .0000     -.29327   -.16746
  X82|1|    -.06467*        .03693    -1.75  .0799     -.13705    .00771
  X91|1|    -.13065***      .03515    -3.72  .0002     -.19955   -.06176
  X92|1|     .03181         .03475      .92  .3600     -.03630    .09991
 X101|1|    -.08447**       .03520    -2.40  .0164     -.15346   -.01549
 X102|1|     .10719***      .03410     3.14  .0017      .04035    .17402
 X121|1|     .36052***      .07932     4.55  .0000      .20506    .51599
 X122|1|    -.52247***      .06922    -7.55  .0000     -.65813   -.38681
 X281|1|     .01023         .11440      .09  .9287     -.21398    .23445
 X291|1|    -.78553***      .08029    -9.78  .0000     -.94290   -.62816
 X292|1|    1.17578***      .08942    13.15  .0000     1.00053   1.35104
 X302|1|    -.36994***      .06945    -5.33  .0000     -.50606   -.23382
 X311|1|    -.19133***      .04576    -4.18  .0000     -.28102   -.10164
 X391|1|     .20700***      .03863     5.36  .0000      .13129    .28272
      |Random utility parameters in latent class -->>  2..................
  CON|2|     .38881***      .12430     3.13  .0018      .14518    .63243
  X31|2|     .67424***      .22456     3.00  .0027      .23412   1.11437
  X32|2|     .12187         .17203      .71  .4787     -.21531    .45905
  X41|2|     .45708***      .10552     4.33  .0000      .25027    .66388
  X42|2|    -.13089         .14499     -.90  .3667     -.41506    .15329
  X51|2|     .26509*        .14107     1.88  .0602     -.01139    .54158
  X52|2|     .00874         .15786      .06  .9558     -.30065    .31814
  X61|2|    -.03058         .13591     -.22  .8220     -.29696    .23580
  X62|2|    -.09510         .12863     -.74  .4597     -.34722    .15702
  X71|2|     .27920***      .10476     2.67  .0077      .07388    .48451
  X72|2|    -.07745         .11179     -.69  .4884     -.29655    .14165
  X81|2|    -.11617         .13523     -.86  .3903     -.38123    .14888
  X82|2|    -.10158         .14781     -.69  .4919     -.39128    .18812
  X91|2|    -.11692         .10423    -1.12  .2620     -.32121    .08737
  X92|2|     .00157         .13360      .01  .9906     -.26028    .26341
 X101|2|    -.07471         .11481     -.65  .5152     -.29974    .15032
 X102|2|    -.03006         .10804     -.28  .7808     -.24182    .18170
 X121|2|     .42573*        .21794     1.95  .0508     -.00143    .85289
 X122|2|    -.26808         .18389    -1.46  .1449     -.62849    .09234
 X281|2|    -.69145***      .16579    -4.17  .0000    -1.01640   -.36651
 X291|2|    -.34948         .25441    -1.37  .1695     -.84811    .14915
 X292|2|     .99358***      .31632     3.14  .0017      .37359   1.61356
 X302|2|    -.26456         .20390    -1.30  .1945     -.66420    .13508
 X311|2|    -.21434         .15998    -1.34  .1803     -.52789    .09920
 X391|2|     .01334         .11664      .11  .9089     -.21527    .24195
      |This is THETA(01) in class probability model.......................
 _ONE|1|    2.93274**      1.44557     2.03  .0425      .09948   5.76600
 _A11|1|    -.20967         .24861     -.84  .3990     -.69694    .27760
 _A21|1|    2.20096        3.02687      .73  .4671    -3.73159   8.13352
 _A22|1|    -.54664        1.51426     -.36  .7181    -3.51452   2.42125
 _A31|1|    -.30049         .25742    -1.17  .2431     -.80501    .20404
 _A32|1|     .24175         .30044      .80  .4210     -.34710    .83060
 _A41|1|    -.14833         .20710     -.72  .4739     -.55425    .25758
 _A51|1|     .04763         .38442      .12  .9014     -.70583    .80109
 _A52|1|     .02989         .30398      .10  .9217     -.56591    .62568
 _A61|1|     .15671         .77784      .20  .8403    -1.36783   1.68124
 _A62|1|     .17476         .51150      .34  .7326     -.82775   1.17728
      |This is THETA(02) in class probability model.......................
```

```
  _ONE|2|        0.0    .....(Fixed Parameter).....
  _A11|2|        0.0    .....(Fixed Parameter).....
  _A21|2|        0.0    .....(Fixed Parameter).....
  _A22|2|        0.0    .....(Fixed Parameter).....
  _A31|2|        0.0    .....(Fixed Parameter).....
  _A32|2|        0.0    .....(Fixed Parameter).....
  _A41|2|        0.0    .....(Fixed Parameter).....
  _A51|2|        0.0    .....(Fixed Parameter).....
  _A52|2|        0.0    .....(Fixed Parameter).....
  _A61|2|        0.0    .....(Fixed Parameter).....
  _A62|2|        0.0    .....(Fixed Parameter).....
--------+--------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Fixed parameter ... is constrained to equal the value or
had a nonpositive st.error because of an earlier problem.
Model was estimated on Mar 28, 2023 at 05:36:51 PM
-----------------------------------------------------------------------------
```

Appendix K4 – LC output stepwise reduced model (3 classes)

Code:

```
Reset $
READ; file = "D: \(...)\LCA 5.csv" $

NLOGIT
; Lhs = Obsch
; Choices = 1, 2, 3
; rhs = con,X31,X32,X41,X42,X51,X52,X61,X62,X71,X72,X81,X82,X91,X92,X101,X102,
        X121,X122,X281,X291,X292,X302,X311,X391
; Lcm = A11,A21,A22,A31,A32,A41,A51,A52,A61,A62
; Pts = 3
; Pds = 12
; Maxit = 300
$
```

Output:

```
-----------------------------------------------------------------------------
Discrete choice (multinomial logit) model
Dependent variable                Choice
Log likelihood function      -4736.03875
Estimation based on N =    5820, K =  25
Inf.Cr.AIC  =    9522.1 AIC/N =    1.636
---------------------------------------
            Log likelihood R-sqrd R2Adj
Constants only  -5499.7000  .1389 .1316
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as ind. choices
Number of obs.=   5820, skipped    0 obs
--------+--------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
   OBSCH|  Coefficient       Error       z     |z|>Z*        Interval
--------+--------------------------------------------------------------------
   CON|1|   -1.97218***      .05778   -34.13  .0000    -2.08543  -1.85893
   X31|1|     .87343***      .05870    14.88  .0000      .75837    .98848
   X32|1|     .32680***      .05800     5.63  .0000      .21313    .44046
   X41|1|     .45084***      .03640    12.38  .0000      .37949    .52219
   X42|1|     .04090         .03516     1.16  .2448     -.02802    .10982
   X51|1|     .49003***      .03692    13.27  .0000      .41768    .56239
   X52|1|    -.03917         .03573    -1.10  .2728     -.10919    .03085
   X61|1|    -.21413***      .02989    -7.16  .0000     -.27271   -.15554
   X62|1|     .00439         .02947      .15  .8815     -.05336    .06214
   X71|1|     .29849***      .02963    10.07  .0000      .24041    .35657
   X72|1|     .03812         .02980     1.28  .2009     -.02030    .09653
   X81|1|    -.19209***      .02926    -6.57  .0000     -.24943   -.13474
   X82|1|    -.07070**       .02991    -2.36  .0181     -.12932   -.01208
   X91|1|    -.12723***      .03058    -4.16  .0000     -.18715   -.06730
   X92|1|     .02741         .02933      .93  .3500     -.03008    .08489
  X101|1|    -.06890**       .02975    -2.32  .0205     -.12720   -.01060
```

```
  X102|1|     .07510**       .02929     2.56  .0103      .01769    .13250
  X121|1|     .34035***      .06096     5.58  .0000      .22088    .45983
  X122|1|    -.44040***      .06250    -7.05  .0000     -.56289   -.31790
  X281|1|    -.23002***      .07041    -3.27  .0011     -.36802   -.09201
  X291|1|    -.60860***      .07294    -8.34  .0000     -.75155   -.46564
  X292|1|    1.02821***      .08053    12.77  .0000      .87038   1.18605
  X302|1|    -.32598***      .06604    -4.94  .0000     -.45542   -.19654
  X311|1|    -.16847***      .04000    -4.21  .0000     -.24688   -.09007
  X391|1|     .15496***      .03211     4.83  .0000      .09202    .21790
--------+-------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 28, 2023 at 05:38:53 PM
----------------------------------------------------------------------------

Line search at iteration121 does not improve the function
Exiting optimization

----------------------------------------------------------------------------
Latent Class Logit Model
Dependent variable                OBSCH
Log likelihood function     -4195.48850
Restricted log likelihood   -6393.92352
Chi squared [ 97](P= .000)   4396.87004
Significance level               .00000
McFadden Pseudo R-squared      .3438319
Estimation based on N =   5820, K =  97
Inf.Cr.AIC  =   8585.0 AIC/N =    1.475
---------------------------------------
            Log likelihood R-sqrd R2Adj
No coefficients -6393.9235  .3438 .3383
Constants only  -5499.7000  .2371 .2307
At start values -4735.9492  .1141 .1067
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as ind. choices
Number of latent classes =            3
Average Class Probabilities
     .671  .083  .247
LCM model with panel has     485 groups
Fixed number of obsrvs./group=       12
BHHH estimator used for asymp. variance
Number of obs.=  5820, skipped    0 obs
--------+-------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
   OBSCH|  Coefficient       Error       z    |z|>Z*         Interval
--------+-------------------------------------------------------------------
        |Random utility parameters in latent class -->> 1...................
   CON|1|   -4.42390***      .25808   -17.14  .0000    -4.92973  -3.91807
   X31|1|    1.06517***      .07295    14.60  .0000      .92220   1.20815
   X32|1|     .31478***      .07513     4.19  .0000      .16752    .46204
   X41|1|     .52129***      .04736    11.01  .0000      .42847    .61411
   X42|1|     .06781         .05004     1.35  .1754     -.03028    .16590
   X51|1|     .61445***      .05224    11.76  .0000      .51207    .71683
   X52|1|    -.11411**       .04896    -2.33  .0198     -.21008   -.01814
```

X61|1|	-.27160***	.03823	-7.11	.0000	-.34652	-.19668
X62|1|	.04166	.03999	1.04	.2975	-.03672	.12004
X71|1|	.34788***	.03820	9.11	.0000	.27302	.42274
X72|1|	.02492	.04142	.60	.5475	-.05627	.10611
X81|1|	-.25068***	.03965	-6.32	.0000	-.32839	-.17297
X82|1|	-.07973*	.04489	-1.78	.0757	-.16772	.00826
X91|1|	-.19841***	.04197	-4.73	.0000	-.28066	-.11615
X92|1|	.06267	.04107	1.53	.1270	-.01782	.14316
X101|1|	-.12154***	.04241	-2.87	.0042	-.20466	-.03842
X102|1|	.15914***	.04082	3.90	.0001	.07912	.23915
X121|1|	.27788***	.10133	2.74	.0061	.07929	.47648
X122|1|	-.37973***	.09679	-3.92	.0001	-.56944	-.19003
X281|1|	-.52765*	.28394	-1.86	.0631	-1.08416	.02887
X291|1|	-.74761***	.09710	-7.70	.0000	-.93792	-.55729
X292|1|	.81039***	.11028	7.35	.0000	.59424	1.02654
X302|1|	-.24565***	.08761	-2.80	.0050	-.41736	-.07395
X311|1|	-.19885***	.05425	-3.67	.0002	-.30517	-.09252
X391|1|	.24309***	.04886	4.98	.0000	.14734	.33885
|Random utility parameters in latent class -->> 2...................						
CON|2|	1.37363***	.50223	2.74	.0062	.38927	2.35799
X31|2|	.27153	.74606	.36	.7159	-1.19072	1.73379
X32|2|	-.52746	.51852	-1.02	.3090	-1.54374	.48883
X41|2|	.47363*	.26797	1.77	.0771	-.05158	.99884
X42|2|	-.15972	.40802	-.39	.6955	-.95943	.63999
X51|2|	.42499	.28520	1.49	.1362	-.13399	.98397
X52|2|	-.05836	.36888	-.16	.8743	-.78135	.66464
X61|2|	-.01428	.41045	-.03	.9722	-.81875	.79018
X62|2|	-.15159	.34259	-.44	.6581	-.82305	.51987
X71|2|	.18395	.34334	.54	.5921	-.48899	.85689
X72|2|	-.26691	.29423	-.91	.3643	-.84360	.30978
X81|2|	-.18488	.33379	-.55	.5797	-.83909	.46934
X82|2|	.03716	.31751	.12	.9068	-.58514	.65947
X91|2|	-.31501	.35133	-.90	.3699	-1.00359	.37358
X92|2|	.07269	.33509	.22	.8283	-.58407	.72945
X101|2|	-.30710	.28498	-1.08	.2812	-.86566	.25146
X102|2|	.15316	.20784	.74	.4612	-.25419	.56052
X121|2|	.16048	.92299	.17	.8620	-1.64854	1.96950
X122|2|	-.16419	.32952	-.50	.6183	-.81003	.48165
X281|2|	-1.17378**	.46290	-2.54	.0112	-2.08105	-.26651
X291|2|	.18492	.79320	.23	.8157	-1.36973	1.73957
X292|2|	.76362	.68946	1.11	.2681	-.58770	2.11494
X302|2|	-.14971	.32947	-.45	.6495	-.79547	.49604
X311|2|	-.15566	.27173	-.57	.5668	-.68825	.37693
X391|2|	-.09154	.34814	-.26	.7926	-.77388	.59080
|Random utility parameters in latent class -->> 3...................						
CON|3|	-1.58471***	.15397	-10.29	.0000	-1.88649	-1.28293
X31|3|	.99730***	.13181	7.57	.0000	.73896	1.25563
X32|3|	.71621***	.15366	4.66	.0000	.41504	1.01738
X41|3|	.46835***	.10377	4.51	.0000	.26497	.67173
X42|3|	-.07440	.09551	-.78	.4359	-.26159	.11278
X51|3|	.35639***	.09977	3.57	.0004	.16084	.55194
X52|3|	.11153	.10523	1.06	.2892	-.09472	.31778
X61|3|	-.12995	.08719	-1.49	.1361	-.30083	.04093
X62|3|	-.10902	.09219	-1.18	.2370	-.28971	.07167
X71|3|	.29187***	.07563	3.86	.0001	.14364	.44011
X72|3|	.13878	.09822	1.41	.1577	-.05372	.33128
X81|3|	-.13679*	.08296	-1.65	.0992	-.29939	.02581

```
    X82|3|    -.09283         .09561      -.97  .3316     -.28022     .09457
    X91|3|     .08001         .08584       .93  .3513     -.08824     .24826
    X92|3|    -.06457         .09252      -.70  .4852     -.24590     .11676
   X101|3|     .05871         .08964       .66  .5125     -.11697     .23440
   X102|3|    -.10807         .07552     -1.43  .1524     -.25609     .03994
   X121|3|     .69756***      .14130      4.94  .0000      .42062     .97451
   X122|3|    -.68003***      .17347     -3.92  .0001    -1.02002    -.34004
   X281|3|    -.18224         .16594     -1.10  .2721     -.50749     .14301
   X291|3|    -.94446***      .18366     -5.14  .0000    -1.30443    -.58450
   X292|3|    2.15552***      .25083      8.59  .0000     1.66390    2.64714
   X302|3|    -.74198***      .18730     -3.96  .0001    -1.10908    -.37488
   X311|3|    -.21752*        .13168     -1.65  .0985     -.47560     .04056
   X391|3|     .08009         .08634       .93  .3536     -.08913     .24931
         |This is THETA(01) in class probability model.......................
   _ONE|1|    2.15157***      .63489      3.39  .0007      .90721    3.39592
   _A11|1|    -.35135         .22405     -1.57  .1168     -.79048     .08779
   _A21|1|    1.68583**       .81328      2.07  .0382      .09183    3.27984
   _A22|1|    -.94649**       .43785     -2.16  .0306    -1.80466    -.08832
   _A31|1|    -.25976         .20698     -1.25  .2095     -.66543     .14591
   _A32|1|     .13037         .26001       .50  .6161     -.37925     .63999
   _A41|1|    -.04211         .18808      -.22  .8228     -.41075     .32652
   _A51|1|     .21985         .32778       .67  .5024     -.42259     .86230
   _A52|1|    -.19635         .23660      -.83  .4066     -.66008     .26738
   _A61|1|     .55101         .95201       .58  .5627    -1.31490    2.41691
   _A62|1|    -.57225         .64795      -.88  .3771    -1.84221     .69770
         |This is THETA(02) in class probability model.......................
   _ONE|2|    -.81090        2.07906      -.39  .6965    -4.88579    3.26399
   _A11|2|     .06899         .74353       .09  .9261    -1.38830    1.52627
   _A21|2|    -.32746        4.60758      -.07  .9433    -9.35815    8.70322
   _A22|2|    -.66785        2.30462      -.29  .7720    -5.18481    3.84912
   _A31|2|    -.19218         .50844      -.38  .7054    -1.18871     .80434
   _A32|2|     .14432         .52566       .27  .7837     -.88595    1.17458
   _A41|2|     .20812         .36487       .57  .5684     -.50702     .92325
   _A51|2|     .26674         .85337       .31  .7546    -1.40585    1.93932
   _A52|2|    -.28156         .65694      -.43  .6682    -1.56913    1.00602
   _A61|2|     .73431        1.52566       .48  .6303    -2.25592    3.72455
   _A62|2|    -.78134        1.04217      -.75  .4534    -2.82396    1.26128
         |This is THETA(03) in class probability model.......................
   _ONE|3|        0.0    .....(Fixed Parameter).....
   _A11|3|        0.0    .....(Fixed Parameter).....
   _A21|3|        0.0    .....(Fixed Parameter).....
   _A22|3|        0.0    .....(Fixed Parameter).....
   _A31|3|        0.0    .....(Fixed Parameter).....
   _A32|3|        0.0    .....(Fixed Parameter).....
   _A41|3|        0.0    .....(Fixed Parameter).....
   _A51|3|        0.0    .....(Fixed Parameter).....
   _A52|3|        0.0    .....(Fixed Parameter).....
   _A61|3|        0.0    .....(Fixed Parameter).....
   _A62|3|        0.0    .....(Fixed Parameter).....
--------+--------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Fixed parameter ... is constrained to equal the value or
had a nonpositive st.error because of an earlier problem.
Model was estimated on Mar 28, 2023 at 05:40:10 PM
-----------------------------------------------------------------------------
```

Appendix K5 – LC output stepwise reduced model excluding class membership parameters (2 classes)

Code:

```
Reset $
READ; file = "D: \(…)\LCA 5.csv" $

NLOGIT
; Lhs = Obsch
; Choices = 1, 2, 3
; rhs = con,X31,X32,X41,X42,X51,X52,X61,X62,X71,X72,X81,X82,X91,X92,X101,X102,
        X121,X122,X281,X291,X292,X302,X311,X391
; Lcm
; Pts = 2
; Pds = 12
; Maxit = 300
$
```

Output:

```
-----------------------------------------------------------------------------
Discrete choice (multinomial logit) model
Dependent variable               Choice
Log likelihood function     -4736.03875
Estimation based on N =    5820, K =  25
Inf.Cr.AIC  =   9522.1 AIC/N =    1.636
---------------------------------------
            Log likelihood R-sqrd R2Adj
Constants only  -5499.7000  .1389 .1351
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as ind. choices
Number of obs.=  5820, skipped    0 obs
--------+--------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
   OBSCH|  Coefficient       Error       z    |z|>Z*         Interval
--------+--------------------------------------------------------------------
   CON|1|   -1.97218***      .05778   -34.13  .0000   -2.08543  -1.85893
   X31|1|     .87343***      .05870    14.88  .0000     .75837    .98848
   X32|1|     .32680***      .05800     5.63  .0000     .21313    .44046
   X41|1|     .45084***      .03640    12.38  .0000     .37949    .52219
   X42|1|     .04090         .03516     1.16  .2448    -.02802    .10982
   X51|1|     .49003***      .03692    13.27  .0000     .41768    .56239
   X52|1|    -.03917         .03573    -1.10  .2728    -.10919    .03085
   X61|1|    -.21413***      .02989    -7.16  .0000    -.27271   -.15554
   X62|1|     .00439         .02947      .15  .8815    -.05336    .06214
   X71|1|     .29849***      .02963    10.07  .0000     .24041    .35657
   X72|1|     .03812         .02980     1.28  .2009    -.02030    .09653
   X81|1|    -.19209***      .02926    -6.57  .0000    -.24943   -.13474
   X82|1|    -.07070**       .02991    -2.36  .0181    -.12932   -.01208
   X91|1|    -.12723***      .03058    -4.16  .0000    -.18715   -.06730
   X92|1|     .02741         .02933      .93  .3500    -.03008    .08489
  X101|1|    -.06890**       .02975    -2.32  .0205    -.12720   -.01060
```

```
  X102|1|     .07510**       .02929     2.56  .0103       .01769    .13250
  X121|1|     .34035***      .06096     5.58  .0000       .22088    .45983
  X122|1|    -.44040***      .06250    -7.05  .0000     -.56289   -.31790
  X281|1|    -.23002***      .07041    -3.27  .0011     -.36802   -.09201
  X291|1|    -.60860***      .07294    -8.34  .0000     -.75155   -.46564
  X292|1|    1.02821***      .08053    12.77  .0000      .87038   1.18605
  X302|1|    -.32598***      .06604    -4.94  .0000     -.45542   -.19654
  X311|1|    -.16847***      .04000    -4.21  .0000     -.24688   -.09007
  X391|1|     .15496***      .03211     4.83  .0000      .09202    .21790
--------+-------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 29, 2023 at 06:46:17 PM
----------------------------------------------------------------------------

Iterative procedure has converged
Normal exit:  58 iterations. Status=0, F=    .4307116D+04

----------------------------------------------------------------------------
Latent Class Logit Model
Dependent variable                OBSCH
Log likelihood function     -4307.11564
Restricted log likelihood   -6393.92352
Chi squared [ 51](P= .000)   4173.61576
Significance level               .00000
McFadden Pseudo R-squared      .3263736
Estimation based on N =   5820, K =  51
Inf.Cr.AIC  =   8716.2 AIC/N =    1.498
---------------------------------------
            Log likelihood R-sqrd R2Adj
No coefficients -6393.9235  .3264 .3234
Constants only  -5499.7000  .2168 .2134
At start values -4735.8191  .0905 .0865
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as ind. choices
Number of latent classes =            2
Average Class Probabilities
     .858  .142
LCM model with panel has     485 groups
Fixed number of obsrvs./group=       12
Number of obs.=  5820, skipped    0 obs
--------+-------------------------------------------------------------------
        |                Standard            Prob.      95% Confidence
   OBSCH|  Coefficient     Error       z    |z|>Z*         Interval
--------+-------------------------------------------------------------------
        |Random utility parameters in latent class -->> 1..................
   CON|1|   -3.21585***      .11176   -28.78  .0000    -3.43489  -2.99681
   X31|1|    1.04303***      .07051    14.79  .0000      .90485   1.18122
   X32|1|     .39218***      .06860     5.72  .0000      .25773    .52662
   X41|1|     .50064***      .04214    11.88  .0000      .41804    .58324
   X42|1|     .05377         .03989     1.35  .1776     -.02441    .13195
   X51|1|     .57217***      .04282    13.36  .0000      .48824    .65611
   X52|1|    -.06189         .04042    -1.53  .1257     -.14110    .01733
   X61|1|    -.25710***      .03383    -7.60  .0000     -.32340   -.19080
```

```
    X62|1|     .01161         .03336      .35  .7278      -.05377    .07699
    X71|1|     .32178***      .03377     9.53  .0000       .25559    .38797
    X72|1|     .05150         .03387     1.52  .1284      -.01488    .11787
    X81|1|    -.22834***      .03305    -6.91  .0000      -.29312   -.16356
    X82|1|    -.06358*        .03360    -1.89  .0584      -.12943    .00226
    X91|1|    -.12850***      .03540    -3.63  .0003      -.19789   -.05911
    X92|1|     .03182         .03324      .96  .3383      -.03332    .09697
   X101|1|    -.08476**       .03366    -2.52  .0118      -.15074   -.01878
   X102|1|     .10520***      .03337     3.15  .0016       .03980    .17059
   X121|1|     .35743***      .07753     4.61  .0000       .20547    .50939
   X122|1|    -.52690***      .07911    -6.66  .0000      -.68195   -.37185
   X281|1|     .01099         .11530      .10  .9240      -.21498    .23697
   X291|1|    -.79962***      .08852    -9.03  .0000      -.97313   -.62612
   X292|1|    1.17940***      .09657    12.21  .0000       .99014   1.36867
   X302|1|    -.37883***      .08047    -4.71  .0000      -.53655   -.22111
   X311|1|    -.18925***      .04614    -4.10  .0000      -.27967   -.09882
   X391|1|     .20352***      .03721     5.47  .0000       .13058    .27645
        |Random utility parameters in latent class -->>  2..................
    CON|2|     .46348***      .16025     2.89  .0038       .14939    .77756
    X31|2|     .65966***      .19190     3.44  .0006       .28354   1.03577
    X32|2|     .07224         .17426      .41  .6785      -.26930    .41378
    X41|2|     .48356***      .10429     4.64  .0000       .27916    .68796
    X42|2|    -.14938         .11162    -1.34  .1808      -.36816    .06939
    X51|2|     .28754***      .10914     2.63  .0084       .07363    .50144
    X52|2|    -.02715         .11791     -.23  .8179      -.25826    .20395
    X61|2|    -.03296         .09182     -.36  .7196      -.21291    .14700
    X62|2|    -.08746         .09551     -.92  .3598      -.27466    .09974
    X71|2|     .28138***      .09514     2.96  .0031       .09492    .46785
    X72|2|    -.08074         .08882     -.91  .3633      -.25483    .09334
    X81|2|    -.12174         .09389    -1.30  .1948      -.30577    .06228
    X82|2|    -.11518         .09419    -1.22  .2214      -.29979    .06943
    X91|2|    -.13970         .10132    -1.38  .1680      -.33828    .05889
    X92|2|    -.00041         .09144      .00  .9965      -.17962    .17881
   X101|2|    -.07149         .09143     -.78  .4343      -.25069    .10772
   X102|2|    -.02718         .08856     -.31  .7589      -.20075    .14640
   X121|2|     .45787***      .16444     2.78  .0054       .13558    .78017
   X122|2|    -.24837         .15124    -1.64  .1005      -.54479    .04805
   X281|2|    -.77170***      .16747    -4.61  .0000     -1.09994   -.44346
   X291|2|    -.24188         .23537    -1.03  .3041      -.70321    .21944
   X292|2|     .99832***      .22251     4.49  .0000       .56221   1.43442
   X302|2|    -.22849         .17058    -1.34  .1804      -.56282    .10585
   X311|2|    -.24024**       .11477    -2.09  .0363      -.46520   -.01529
   X391|2|     .01893         .09614      .20  .8439      -.16950    .20736
        |Estimated latent class probabilities..............................
  PrbCls1|     .85827***     .01856    46.23  .0000       .82189    .89466
  PrbCls2|     .14173***     .01856     7.63  .0000       .10534    .17811
--------+--------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 29, 2023 at 06:46:39 PM
-----------------------------------------------------------------------------
```

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Appendix L – Detailed graphs final LC results

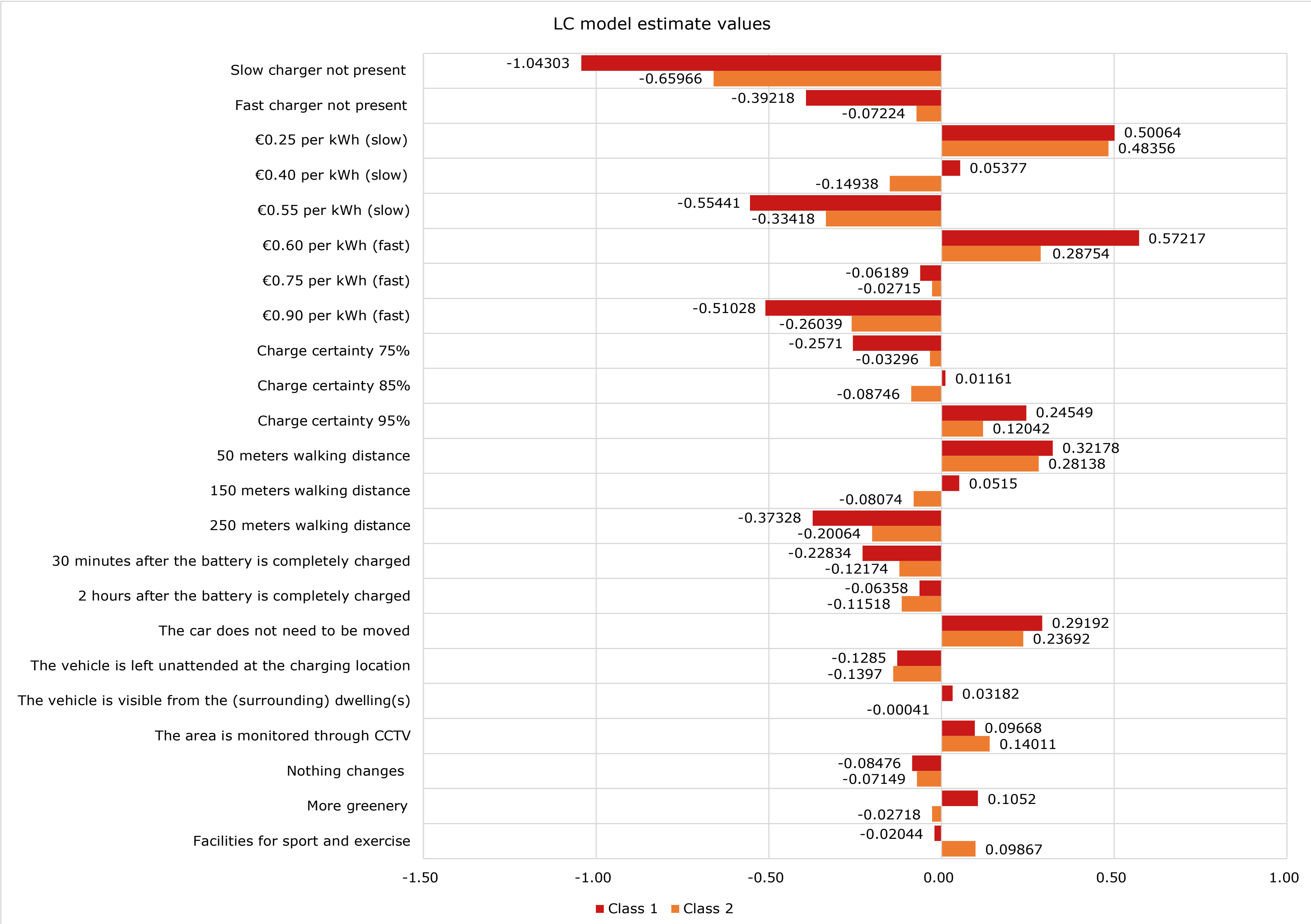

Figure 41. Detailed results final LC model (main parameters)

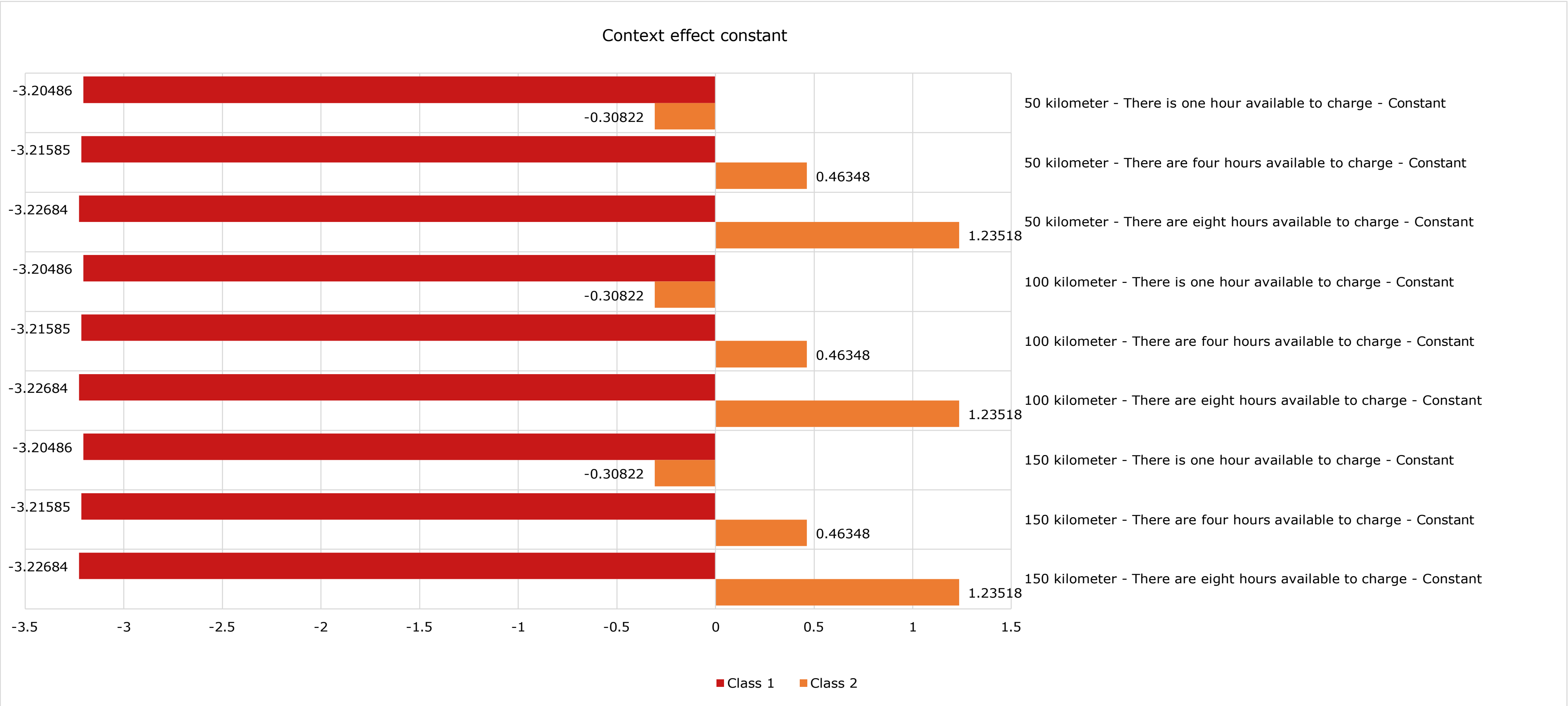

Figure 42. Detailed results final LC model (context effect constant)

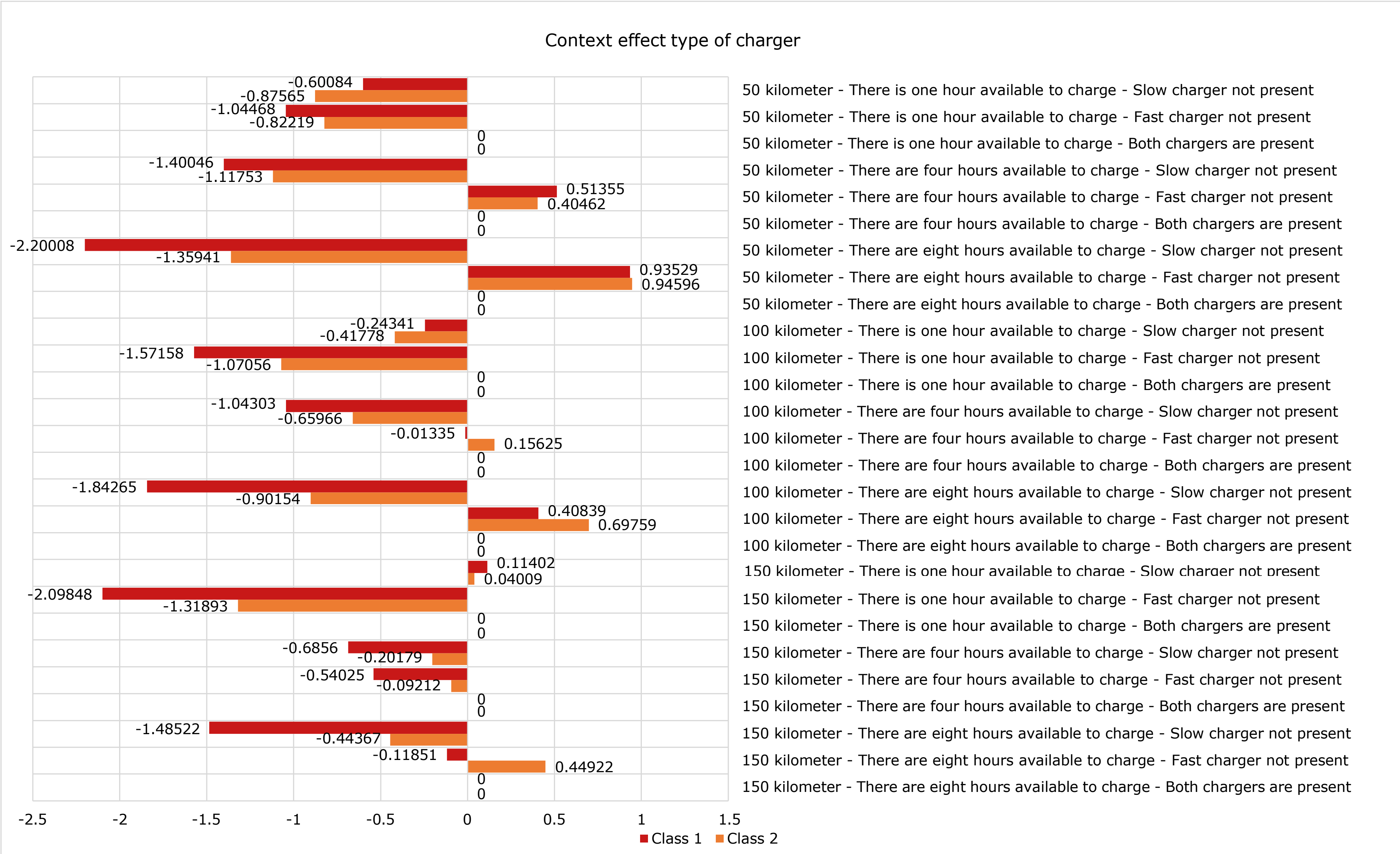

Figure 43. Detailed results final LC model (context effect type of charger)

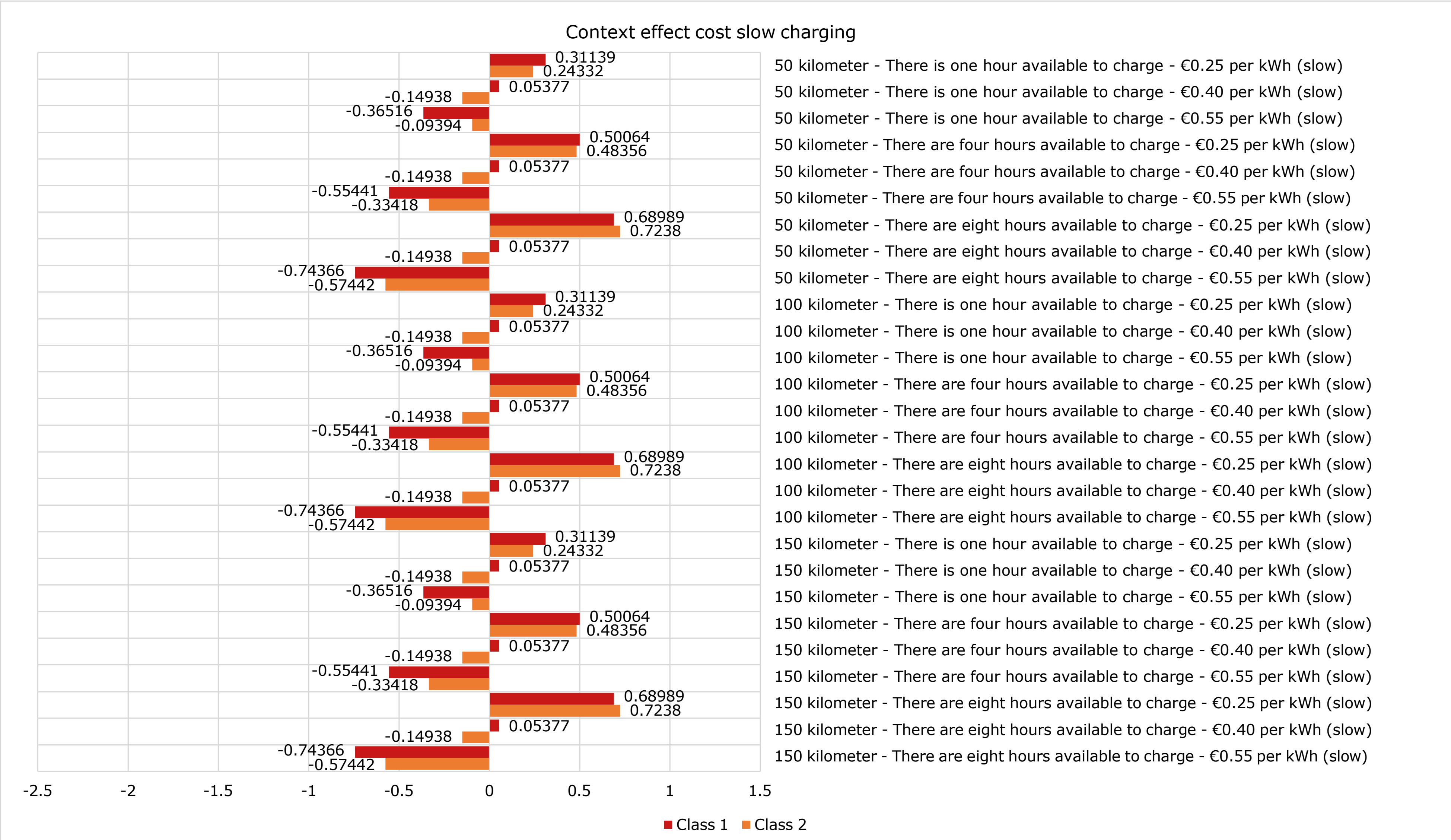

Figure 44. Detailed results final LC model (context effect cost slow charging)

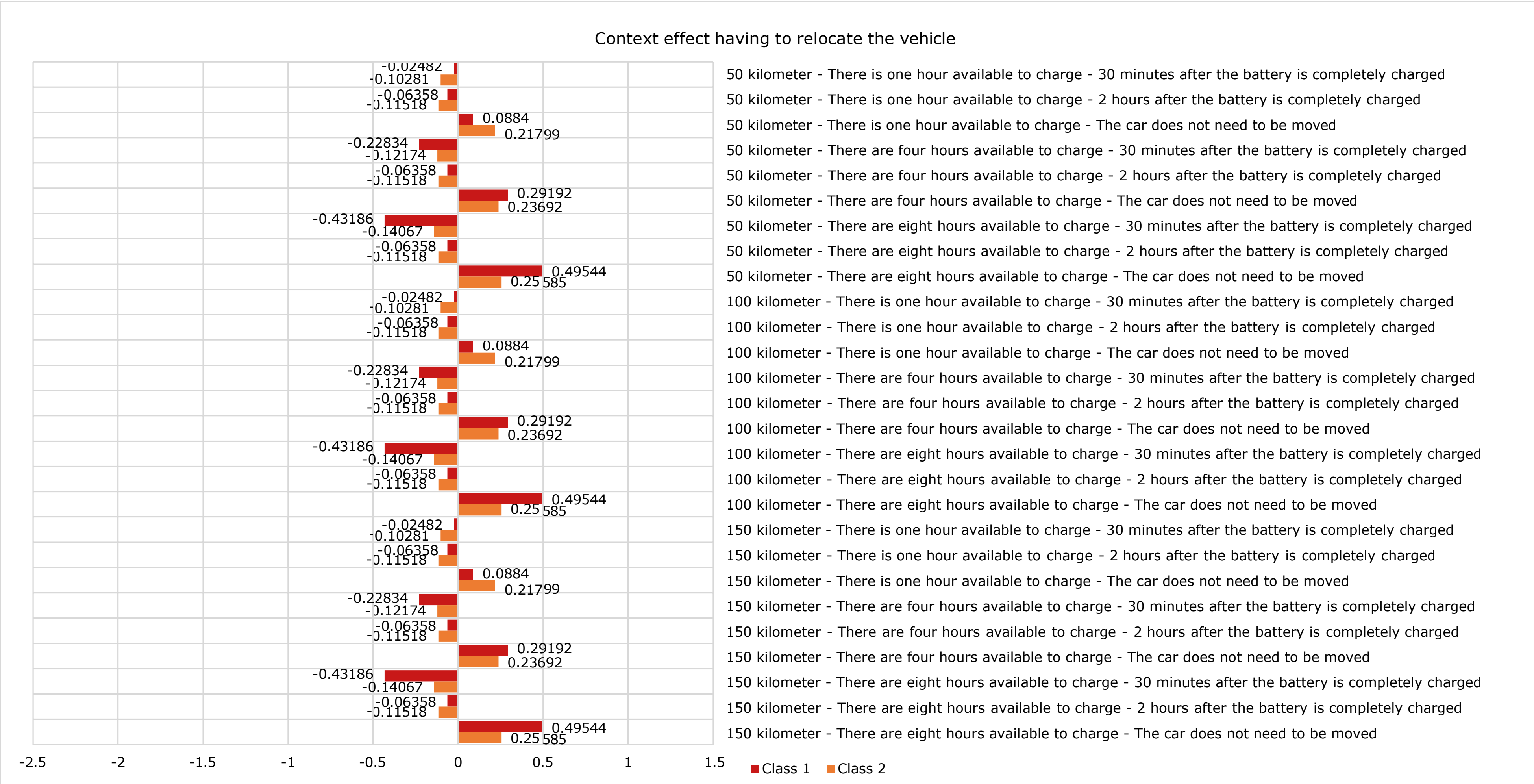

Figure 45. Detailed results final LC model (context effect having to relocate the vehicle)

Appendix M – Case study results

Table 23. Intermediate results utility calculation case study

Block A

Since the procedure for block B – I is the same, only the intermediate results of block A are shown in detail.

	Constant	50 kilometer	100 kilometer	150 kilometer	There is one hour available to charge	There are four hours available to charge	There are eight hours available to charge	Slow charger not present	Fast charger not present	€0.25 per kWh (slow)	€0.40 per kWh (slow)	€0.55 per kWh (slow)	€0.60 per kWh (fast)	€0.75 per kWh (fast)	€0.90 per kWh (fast)	Charge certainty 75%	Charge certainty 85%	Charge certainty 95%	50 meters walking distance	150 meters walking distance	250 meters walking distance	30 minutes after the battery is completely charged	2 hours after the battery is completely charged	The car does not need to be moved	The vehicle is left unattended at the charging location	The vehicle is visible from the (surrounding) dwelling(s)	The area is monitored through CCTV	Nothing changes	More greenery	Facilities for sport and exercise	50 kilometers - Slow charger not present	50 kilometer - Fast charger not present	Constant - There is one hour available to charge	There is one hour available to charge - Slow charger not present	There is one hour available to charge - Fast charger not present	There are four hours available to charge - Fast charger not present	There is one hour available to charge - €0.25 per kWh (slow)	There is one hour available to charge - 30 minutes after the battery is completely charged			
Coefficient	-1.97218	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.87343	0.32680	0.45084	0.04090	-0.49174	0.49003	-0.03917	-0.45086	-0.21413	0.00439	0.20974	0.29849	0.03812	-0.33661	-0.19209	-0.07070	0.26279	-0.12723	0.02741	0.09982	-0.06890	0.07510	-0.00620	0.34035	-0.44040	-0.23002	-0.60860	1.02821	-0.32598	-0.16847	0.15496			
50 kilometers in one hour																																							*Viq*	EXP(*Viq*)	*Piq*
Site 8	0	1	0	0	1	0	0	0	-1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	1	0	0	0	-1	0	0	-1	0	0	0	-0.34953	0.71	55%
Site 11	0	1	0	0	1	0	0	0	-1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	0	0	0	-1	0	0	-1	0	0	0	-0.77928	0.46	36%
None	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	-2.2022	0.11	9%
50 kilomters in four hours																																							*Viq*	EXP(*Viq*)	*Piq*
Site 8	0	1	0	0	0	1	0	0	-1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	1	0	0	0	-1	0	0	0	-1	0	0	1.00466	2.73	59%
Site 11	0	1	0	0	0	1	0	0	-1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	0	0	0	-1	0	0	0	-1	0	0	0.57491	1.78	38%
None	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1.97218	0.14	3%
50 kilomters in eight hours																																							*Viq*	EXP(*Viq*)	*Piq*
Site 8	0	1	0	0	0	0	1	0	-1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	1	0	0	0	-1	0	0	0	0	0	0	0.67868	1.97	58%
Site 11	0	1	0	0	0	0	1	0	-1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	0	0	0	-1	0	0	0	0	0	0	0.24893	1.28	38%
None	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1.97218	0.14	4%
100 kilometers in one hour																																							*Viq*	EXP(*Viq*)	*Piq*
Site 8	0	0	1	0	1	0	0	0	-1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	-1	0	0	0	-0.78993	0.45	53%
Site 11	0	0	1	0	1	0	0	0	-1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	0	0	0	0	0	0	-1	0	0	0	-1.21968	0.30	34%
None	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	-2.2022	0.11	13%
100 kilomters in four hours																																							*Viq*	EXP(*Viq*)	*Piq*
Site 8	0	0	1	0	0	1	0	0	-1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	-1	0	0	0.56426	1.76	58%
Site 11	0	0	1	0	0	1	0	0	-1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	-1	0	0	0.13451	1.14	38%
None	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1.97218	0.14	5%
100 kilomters in eight hours																																							*Viq*	EXP(*Viq*)	*Piq*
Site 8	0	0	1	0	0	0	1	0	-1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0.23828	1.27	57%
Site 11	0	0	1	0	0	0	1	0	-1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	-0.19147	0.83	37%
None	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1.97218	0.14	6%
150 kilometers in one hour																																							*Viq*	EXP(*Viq*)	*Piq*
Site 8	0	0	0	1	1	0	0	0	-1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	-1	0	0	0	-0.78993	0.45	53%
Site 11	0	0	0	1	1	0	0	0	-1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	0	0	0	0	0	0	-1	0	0	0	-1.21968	0.30	34%
None	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	-2.2022	0.11	13%
150 kilomters in four hours																																							*Viq*	EXP(*Viq*)	*Piq*
Site 8	0	0	0	1	0	1	0	0	-1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	-1	0	0	0.56426	1.76	58%
Site 11	0	0	0	1	0	1	0	0	-1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	-1	0	0	0.13451	1.14	38%
None	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1.97218	0.14	5%
150 kilomters in eight hours																																							*Viq*	EXP(*Viq*)	*Piq*
Site 8	0	0	0	1	0	0	1	0	-1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0.23828	1.27	57%
Site 11	0	0	0	1	0	0	1	0	-1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	-0.19147	0.83	37%
None	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1.97218	0.14	6%

Table 24. Intermediate case study results when having to charge 50 kilometers in one hour

50 kilometers in **one hour**							
	Estimated EV possession	Probability			Demand for public chargers		
		Site 8	Site 11	None	Site 8	Site 11	None
Block A	2.25	55%	36%	9%	1.24	0.81	0.20
Block B	2.7	48%	45%	7%	1.28	1.21	0.20
Block C	0.08	48%	45%	7%	0.04	0.04	0.01
Block D	3.6	48%	45%	7%	1.71	1.62	0.27
Block E	4.2	48%	45%	7%	2.00	1.89	0.31
Block F	2.7	36%	57%	7%	0.97	1.54	0.20
Block G	1.8	36%	57%	7%	0.64	1.03	0.13
Block H	2.25	36%	57%	7%	0.80	1.28	0.16
Block I	2.25	41%	51%	8%	0.93	1.14	0.19
Total					**10**	**11**	**2**

Table 25. Intermediate case study results when having to charge 50 kilometers in four hours

50 kilometers in **four hours**							
	Estimated EV possession	Probability			Demand for public chargers		
		Site 8	Site 11	None	Site 8	Site 11	None
Block A	2.25	59%	38%	3%	1.32	0.86	0.07
Block B	2.7	50%	47%	3%	1.35	1.28	0.07
Block C	0.08	50%	47%	3%	0.04	0.04	0.00
Block D	3.6	50%	47%	3%	1.80	1.71	0.09
Block E	4.2	50%	47%	3%	2.10	1.99	0.11
Block F	2.7	38%	60%	2%	1.02	1.62	0.07
Block G	1.8	38%	60%	2%	0.68	1.08	0.04
Block H	2.25	38%	60%	2%	0.85	1.35	0.06
Block I	2.25	44%	54%	3%	0.98	1.20	0.06
Total					**10**	**11**	**1**

Table 26. Intermediate case study results when having to charge 50 kilometers in eight hours

50 kilometers in **eight hours**							
	Estimated EV possession	Probability			Demand for public chargers		
		Site 8	Site 11	None	Site 8	Site 11	None
Block A	2.25	58%	38%	4%	1.31	0.85	0.09
Block B	2.7	50%	47%	3%	1.34	1.27	0.09
Block C	0.08	50%	47%	3%	0.04	0.04	0.00
Block D	3.6	50%	47%	3%	1.78	1.69	0.13
Block E	4.2	50%	47%	3%	2.08	1.97	0.15
Block F	2.7	37%	59%	3%	1.01	1.60	0.09
Block G	1.8	37%	59%	3%	0.67	1.07	0.06
Block H	2.25	37%	59%	3%	0.84	1.34	0.08
Block I	2.25	43%	53%	4%	0.97	1.19	0.09
Total					**10**	**11**	**1**

Table 27. Intermediate case study results when having to charge 100 kilometers in one hour

100 kilometers in **one hour**	Estimated EV possession		Probability				Demand for public chargers		
			Site 8	Site 11	None		Site 8	Site 11	None
Block A	2.25		53%	34%	13%		1.19	0.77	0.29
Block B	2.7		46%	43%	11%		1.23	1.17	0.30
Block C	0.08		46%	43%	11%		0.04	0.03	0.01
Block D	3.6		46%	43%	11%		1.64	1.56	0.40
Block E	4.2		46%	43%	11%		1.92	1.82	0.47
Block F	2.7		34%	55%	11%		0.93	1.48	0.29
Block G	1.8		34%	55%	11%		0.62	0.99	0.20
Block H	2.25		34%	55%	11%		0.77	1.23	0.24
Block I	2.25		39%	48%	12%		0.88	1.09	0.28
Total							**9**	**10**	**2**

Table 28. Intermediate case study results when having to charge 100 kilometers in four hours

100 kilometers in **four hours**	Estimated EV possession		Probability				Demand for public chargers		
			Site 8	Site 11	None		Site 8	Site 11	None
Block A	2.25		58%	38%	5%		1.30	0.85	0.10
Block B	2.7		49%	47%	4%		1.33	1.26	0.11
Block C	0.08		49%	47%	4%		0.04	0.04	0.00
Block D	3.6		49%	47%	4%		1.78	1.68	0.14
Block E	4.2		49%	47%	4%		2.07	1.96	0.16
Block F	2.7		37%	59%	4%		1.00	1.60	0.10
Block G	1.8		37%	59%	4%		0.67	1.06	0.07
Block H	2.25		37%	59%	4%		0.83	1.33	0.09
Block I	2.25		43%	53%	4%		0.97	1.19	0.10
Total							**10**	**11**	**1**

Table 29. Intermediate case study results when having to charge 100 kilometers in eight hours

100 kilometers in **eight hours**	Estimated EV possession		Probability				Demand for public chargers		
			Site 8	Site 11	None		Site 8	Site 11	None
Block A	2.25		57%	37%	6%		1.28	0.83	0.14
Block B	2.7		49%	46%	5%		1.31	1.24	0.14
Block C	0.08		49%	46%	5%		0.04	0.04	0.00
Block D	3.6		49%	46%	5%		1.75	1.66	0.19
Block E	4.2		49%	46%	5%		2.04	1.93	0.22
Block F	2.7		37%	58%	5%		0.99	1.57	0.14
Block G	1.8		37%	58%	5%		0.66	1.05	0.09
Block H	2.25		37%	58%	5%		0.82	1.31	0.12
Block I	2.25		42%	52%	6%		0.95	1.17	0.14
Total							**10**	**11**	**1**

Table 30. Intermediate case study results when having to charge 150 kilometers in one hour

150 kilometers in **one hour**									
	Estimated EV possession		Probability				Demand for public chargers		
			Site 8	Site 11	None		Site 8	Site 11	None
Block A	2.25		53%	34%	13%		1.19	0.77	0.29
Block B	2.7		46%	43%	11%		1.23	1.17	0.30
Block C	0.08		46%	43%	11%		0.04	0.03	0.01
Block D	3.6		46%	43%	11%		1.64	1.56	0.40
Block E	4.2		46%	43%	11%		1.92	1.82	0.47
Block F	2.7		34%	55%	11%		0.93	1.48	0.29
Block G	1.8		34%	55%	11%		0.62	0.99	0.20
Block H	2.25		34%	55%	11%		0.77	1.23	0.24
Block I	2.25		39%	48%	12%		0.88	1.09	0.28
Total							**9**	**10**	**2**

Table 31. Intermediate case study results when having to charge 150 kilometers in four hours

150 kilometers in **four hours**									
	Estimated EV possession		Probability				Demand for public chargers		
			Site 8	Site 11	None		Site 8	Site 11	None
Block A	2.25		58%	38%	5%		1.30	0.85	0.10
Block B	2.7		49%	47%	4%		1.33	1.26	0.11
Block C	0.08		49%	47%	4%		0.04	0.04	0.00
Block D	3.6		49%	47%	4%		1.78	1.68	0.14
Block E	4.2		49%	47%	4%		2.07	1.96	0.16
Block F	2.7		37%	59%	4%		1.00	1.60	0.10
Block G	1.8		37%	59%	4%		0.67	1.06	0.07
Block H	2.25		37%	59%	4%		0.83	1.33	0.09
Block I	2.25		43%	53%	4%		0.97	1.19	0.10
Total							**10**	**11**	**1**

Table 32. Intermediate case study results when having to charge 150 kilometers in eight hours

150 kilometers in **eight hours**									
	Estimated EV possession		Probability				Demand for public chargers		
			Site 8	Site 11	None		Site 8	Site 11	None
Block A	2.25		57%	37%	6%		1.28	0.83	0.14
Block B	2.7		49%	46%	5%		1.31	1.24	0.14
Block C	0.08		49%	46%	5%		0.04	0.04	0.00
Block D	3.6		49%	46%	5%		1.75	1.66	0.19
Block E	4.2		49%	46%	5%		2.04	1.93	0.22
Block F	2.7		37%	58%	5%		0.99	1.57	0.14
Block G	1.8		37%	58%	5%		0.66	1.05	0.09
Block H	2.25		37%	58%	5%		0.82	1.31	0.12
Block I	2.25		42%	52%	6%		0.95	1.17	0.14
Total							**10**	**11**	**1**