TRAVELERS' PREFERENCES TOWARDS EINDHOVEN CITY CENTER

IMPLICATIONS OF MOBILITY AS A SERVICE IN THE BUILT ENVIRONMENT

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Master Construction Management & Engineering

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Master Thesis
Travelers' preferences towards Eindhoven city center
Implications of Mobility as a Service in the built environment

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PREFACE

Having started my student career at Eindhoven University of Technology with the idea of becoming an architect, the subject of my master thesis may be rather surprising. However, it has been due to the trips towards the university that my interest for mobility grew. Coming from a small village in Brabant, I traveled by bus towards university in the beginning of my student career. Watching the peak hours at the A50 from that bus, kept me wondering why all those people were traveling by themselves in their private cars creating the everyday traffic jams.

My interest in architecture changed towards how human beings behave in this built environment. This interest grew by doing a master project on pedestrian behavior during the Dutch Design Week. Studying people's behavior is in my opinion essential in designing the built environment. Therefore, with the introduction of smart city and smart mobility concepts, the user of these concepts should not be left unnoticed.

This thesis reflects these interests and for this I would like to thank my supervisors from TU/e, Aloys, Gamze and Tao. Thank you for providing me with the support, guidance and critical feedback throughout the process of obtaining the subject of, and writing this thesis. I am very happy that the main subject of this thesis is the city of Eindhoven, in collaboration with the municipality of Eindhoven. Jan-Willem and Astrid, thank you for your support, useful insights and involvement during these past months. Moreover, team Smart Mobility in its entirety, thank you for being so welcoming, providing me with different points of view and opportunities to learn.

Writing this preface means that the rest of this thesis is finished, and with that the end of my student career. A special thanks to my friends, family and boyfriend that supported me along the way, without you the journey would have been way less fun!

All that rest, is that I hope you enjoy reading this thesis, since I enjoyed writing it.

Kim Raijmakers
Eindhoven, April 2019

TABLE OF CONTENTS

SUMMARY

Eindhoven, as heart of the Brainport region, is gaining more interest of businesses settling in the region, resulting in a population growth of the city itself as well. The vision of the city is to densify, which means that new residential buildings will be constructed within the ring road, increasing the pressure on its traffic network even further. However, parallel to these developments, the EU norms obligate the city to reduce its greenhouse gasses, in order to limit global warming. Since the mobility sector is contributing significantly to these greenhouse gasses, this is an area of focus for the municipality of Eindhoven.

So, the challenges for Eindhoven are in twofold: on the one hand the city needs to stay accessible and attractive for its (future) residents, businesses and visitors, but on the other hand, the share of sustainable transportation needs to increase, reducing the greenhouse gasses. The ambition of the city is to create a multimodal traffic network in order to keep the city and its economic high priority locations well-accessible. The focus is therefore on well-connecting the various modalities and making the switch from private car towards sustainable and shared-mobility as convenient as possible. Mobility as a Service (MaaS) seems promising in being part of the solution. This new mobility concept offers a tailormade and demand-responsive mobility package arranged via one application. The concept is user-centric and focuses on the service of providing its users with the most convenient (co-modal) travel alternatives according to their preferences. The users can plan, book and pay their trip within the MaaS application and the application also provides them with the necessary tickets and service. Being able to offer these modalities, MaaS has its implications in the built environment as well, in the form of mobility hubs where the shared-mobility is located. Insights in the preferences regarding these hubs in the MaaS context is limited and therefore this research focusses on these hubs in the context of Eindhoven.

The aim of this research is therefore to obtain more insights in the determinants influencing travelers' decisions to switch to more sustainable (shared-)mobility alternatives and the willingness to use the hubs. Resulting in the main research question: '*Which factors can influence visitors' inclination to switch to sustainable (shared) mobility for their visit of Eindhoven city center (in transition towards MaaS)?'* In order to answer this research question, a Stated Choice experiment has been conducted. Respondents were provided with their personalized travel alternatives towards Eindhoven city center. These varied from: i) car, ii) car to hub and transfer to bus iii) car to hub and transfer to shared-bike iv) public transportation and walk v) public transportation and transfer to shared-bike, and when applicable, vi) (e-)bike. These alternatives were presented in a complete overview including travel times, waiting times, parking tariffs, travel costs and facilities, similar to a MaaS platform. The 'push' factor of increased parking tariffs in the city center has been included in the study for encouraging more sustainable mode choice behavior.

The target group for the research were visitors of the Eindhoven city center, which have been recruited by means of a travelers panel in the South of the Netherlands, by the network of the municipality of Eindhoven and Eindhoven University of Technology, and personal network. All in all, the data of 375 respondents was used for the analyses of which 259 respondents lived further than 10 kilometers from Eindhoven city center. In order to obtain an extensive understanding of the data, several discrete choice models: Multinomial Logit models, Mixed

Logit models, and Latent Class models were estimated. Moreover, several scenarios have been sketched (both planned and hypothetical) based on these results, to obtain more insights in the combination of variables. The scenarios split the respondents up into two groups: one group of people living within 10 kilometers from the center and the other group living further away. The first group seems not to be the target group for the hubs as they do not prefer using them, which makes sense due to the distance. The other group does seem to have interest in using the hubs.

The results of the estimations provide an understanding of the determinants of mode choice behavior in the Eindhoven context. Overall can be concluded that respondents prefer alternatives without a transfer (public transportation + walk or private (e-)bike). In order to make the alternatives including a transfer more interesting, the waiting time for the bus should be short by operating the busses on a frequent schedule. Therefore it is important that the hubs are located near the HOV lines of Eindhoven, which already serve at a quite frequent schedule. Moreover, the travel times by bus and bike from the hub negatively affect these alternatives as well. However, in general the bus remains the most preferred 'last mile' transport mode from the hub. People having a working purpose; the group between 30 and 50 years old; and people living in villages seem especially sensitive to the increased travel times. People over 50 years old on the other hand seem less sensitive to the travel times.

Regarding the facilities at the hub, no indication has been found that these affect the hub usage in this sample. Which is also the case for the travel costs of the bus or bike from the hub. However, the costs for using a bike after public transportation seem to affect the choice for this alternative. Other financial incentives appeared to have an effect on people's willingness to use the hubs. The parking tariffs at the hub seem to influence its usage, and can even create unintended effects. A free hub also attracts people living within 10 kilometers of the city center that would otherwise possibly use the bike or public transportation, and are therefore not the target group for the hub. It is therefore not recommended to make the hub free of charge.

Since the aim for Eindhoven is to increase the share of sustainable transportation (public transportation and private (e-)bike) towards the city center, it is recommended to increase the parking costs in the city center. This 'push' measure results in the highest share of sustainable transportation. In order to have the most effective deployment of the hubs in combination with the use of public transportation and cycling this is recommended. The results of the scenarios show that the planned hub at Genneper Parken seems to be a good location in terms of travel time. The location closer to the city center, near the ring road seems only to have limited effect on its usage, and as these locations would also result in more traffic near the ring road, this is not desired. For the use of the bike from the hub, the location at the ring road would be better since this has a shorter cycling time, but possibly other measures, such as making the cycling routes convenient or providing shared e-bikes, would have the preferred effect as well. In general, also a strong preference has been found for using the private (e-)bike for trips towards Eindhoven city center as well. Therefore, the strategy of the municipality of focusing on making the infrastructure more friendly for slow traffic is positive. The municipality of Eindhoven can use the knowledge obtained in this study as underpinning for their strategy regarding hubs and increasing the share of sustainable transportation towards Eindhoven.

SAMENVATTING

Eindhoven wordt gezien als het hart van de Brainport regio en voor veel bedrijven is het interessant om zich hier te vestigen. Voor Eindhoven betekent dit ook een toenemend inwonersaantal en voor de huisvesting focust Eindhoven zich op verdichting van het centrumgebied. Dit betekent dat er binnen de ring meer woningen gebouwd zullen worden en dit zal de druk op de infrastructuur alleen maar groter maken. Naast deze ontwikkelingen, heeft de stad ook te maken met de EU regelgeving voor het reduceren van de uitstoot van broeikasgassen tegen het opwarmen van de aarde. Aangezien de mobiliteitssector een aanzienlijke bijdrager is aan deze broeikasgassen, is dit een aandachtspunt voor de gemeente.

Eindhoven heeft dus een tweezijdige uitdaging: aan de ene kant moet de stad bereikbaar en aantrekkelijk blijven voor zijn (toekomstige) bewoners, bezoekers en bedrijven, maar aan de andere kant moet ook het aandeel duurzame vervoersmiddelen omhoog om de uitstoot van broeikasgassen te reduceren. Eindhoven heeft de ambitie om een multimodaal vervoersnetwerk te creëren, om de stad en zijn economische toplocaties bereikbaar te houden. De focus ligt daarom op het goed verbinden van de verschillende modaliteiten en de overstap naar duurzame, gedeelde mobiliteit zo gemakkelijk mogelijk. Mobility as a Service (MaaS) lijkt veelbelovend op dit vlak en kan wellicht een deel van de oplossing zijn. Dit nieuwe mobiliteitsconcept biedt zijn gebruikers een persoonlijk en vraag gestuurd mobiliteitspakket via één applicatie. De gebruiker staat centraal en de service voorziet deze van de meest geschikte (co-modale) reisopties aan de hand van zijn/haar voorkeuren. De gebruikers kunnen hun reis plannen, boeken en betalen via de MaaS applicatie en hierin zullen dan ook de benodigde tickets en service beschikbaar zijn. MaaS heeft door zijn aanbod van modaliteiten, ook implicaties in de gebouwde omgeving; in de vorm van mobiliteit hubs waar de deelmobiliteit beschikbaar is. Er is weinig bekend over de voorkeuren voor deze hubs in relatie tot MaaS en daarom richt dit onderzoek zich op deze hubs in de Eindhoven context.

Het doel van dit onderzoek is om meer inzichten te verkrijgen in de factoren die van invloed zijn op de keuze van reizigers om over te stappen op duurzamere (gedeelde) mobiliteit en hun bereidheid om hubs te gebruiken. Dit resulteert in de volgende hoofdonderzoeksvraag: *'Welke factoren hebben invloed op de geneigdheid van reizigers om over te stappen op duurzame (gedeelde) mobiliteit voor hun bezoek aan het centrum van Eindhoven (in de overgangsfase naar MaaS)?'*. Om deze vraag te kunnen beantwoorden, is een Stated Choice experiment uitgevoerd. Respondenten kregen via een online enquête gepersonaliseerde vervoersalternatieven naar het centrum van Eindhoven. Deze varieerden van: i) auto, ii) auto naar hub en overstappen naar bus, iii) auto naar hub en overstappen naar deelfiets, iv) openbaar vervoer en lopen, v) openbaar vervoer en deelfiets, en wanneer van toepassing vi) (e-)bike. Deze alternatieven werden voorgelegd aan de respondenten in een compleet overzicht met reistijden, wachttijden, parkeertarieven, reiskosten en faciliteiten, vergelijkbaar met een MaaS platform. Verhoogde parkeertarieven zijn gebruikt in het experiment om te onderzoeken of dit effect heeft op het stimuleren van duurzamer keuzegedrag.

De doelgroep voor dit onderzoek waren bezoekers van het centrum van Eindhoven, en deze zijn geworven via een reizigerspanel van Zuid-Nederland, het netwerk van de gemeente Eindhoven en de Technische Universiteit Eindhoven, en persoonlijk netwerk. In totaal, is de data van 375 respondenten gebruikt voor de analyses, waarvan 259 respondenten verder dan 10 kilometer van het centrum van Eindhoven af wonen. Voor de analyses zijn verschillende

discrete choice modellen gebruikt: Multinomial Logit modellen, Mixed Logit modellen en Latent Class modellen. Daarnaast zijn er aan de hand van deze resultaten verschillende scenario's geschetst (zowel gepland als hypothetisch) om meer inzicht de krijgen in de combinatie van variabelen. De scenario's verdeelde de respondenten in twee groepen of ze wel of niet binnen 10 kilometer van het centrum van Eindhoven woonden. Over het algemeen is de groep die binnen 10 kilometer van het centrum woont minder geneigd om gebruik te maken van de hubs dan de andere groep.

De resultaten geven een beeld van de factoren die van invloed zijn op vervoersmiddelkeuze in de context van Eindhoven. Over het algemeen hebben de respondenten de voorkeur voor alternatieven die geen overstap vereisen (ov + lopen of privé (elektrische) fiets. Om de alternatieven die een overstap vereisen interessanter te maken, dient de wachttijd voor de bus zo laag mogelijk te zijn. Het is daarom van belang dat de hubs aan de HOV lijnen van Eindhoven worden gepositioneerd, omdat de bussen hier al op een hoge frequentie passeren. De reistijden van de bus en deelfiets vanaf een hub hebben ook een negatief effect op deze alternatieven. Wanneer er alleen naar deze twee alternatieven wordt gekeken, gaat in het algemeen de voorkeur uit naar de bus als vervoersmiddel vanaf de hub. Respondenten die werk als doel van hun reis hebben, in de leeftijdscategorie van 30 tot 50 jaar zitten, of in een dorp wonen zijn gevoeliger voor deze reistijden. Respondenten ouder dan 50 jaar zijn juist minder gevoelig voor deze reistijden.

Er is geen indicatie gevonden dat de faciliteiten bij de hub invloed hebben op het gebruik van de hub. Dit is ook het geval voor de kosten van de bus of deelfiets vanaf de hub. De kosten voor de fiets na openbaar vervoer aan de andere kant, lijken wel invloed te hebben op de keuze voor dit alternatief. De andere financiële factoren lijken ook van invloed te zijn op de geneigdheid om de hubs te gebruiken. De parkeertarieven bij de hubs lijken zelfs ongewenste effecten te hebben. Wanneer de hub gratis is, zullen ook mensen die binnen 10 kilometer van het centrum wonen hier ook gebruik van maken, welke anders misschien het openbaar vervoer of de fiets zouden gebruiken. Daarom is het niet aan te raden om de hub gratis te maken.

Om het aandeel duurzame mobiliteit naar Eindhoven te verhogen, wordt er aangeraden om de parkeertarieven in het centrumgebied te verhogen. Deze stimulerende maatregel zorgt voor het hoogste aandeel duurzame mobiliteit en goed gebruik van de hub. De scenario's lieten ook zien dat de geplande hub Genneper Parken een goede locatie is. Een locatie dichter bij het centrumgebied had beperkt effect op het gebruik, en omdat een dergelijke locatie waarschijnlijk zal resulteren in meer drukte bij de ring, levert dit niet genoeg voordelen op. Voor het gebruik van de deelfiets van de hub zou een locatie dichterbij wel beter zijn door de kortere fietstijd. Echter, wellicht zijn er andere maatregelen die hetzelfde effect kunnen hebben, zoals het verbeteren van de fietsroutes of het aanbieden van elektrische deelfietsen. Over het algemeen was er ook nog een sterke voorkeur voor het gebruik van de privé (elektrische) fiets voor een bezoek aan het centrum van Eindhoven. Daarom is de strategie van gemeente om de infrastructuur toegankelijker te maken voor langzaam vervoer sowieso van belang.

ABSTRACT

Eindhoven is facing the challenging task of keeping the city accessible with the increasing pressure on its infrastructure, and meanwhile reducing its emission levels. Mobility as a Service (MaaS) is deemed promising to be one of the solutions. This new mobility concept offers its users a tailormade and demand-responsive mobility package arranged via one platform. However, the supply of the transport modes offered by MaaS has its implications in the built environment as well: the mobility hubs. A knowledge gap exists on the preferences regarding these hubs in relation to other forms of (sustainable) mobility. The aim of this research is therefore to obtain more insights in the determinants influencing travelers' decisions to switch to more sustainable (shared-)mobility alternatives. Resulting in the main research question: '*Which factors can influence visitors' inclination to switch to sustainable (shared) mobility for their visit of Eindhoven city center (in transition towards MaaS)?'* This study provides insights in the determinants of mode choice with a focus on mobility hubs in the context of MaaS. An online survey including a Stated Choice experiment has been conducted, and the data of 375 respondents is used for the analyses. A number of discrete choice models have been estimated using NLogit to distinguish the determining factors for travelers' preferences towards Eindhoven city center.

Results indicate that overall alternatives without a transfer are preferred. Increased travel time and waiting time negatively influences the choice for the hub alternatives, and this effect seems stronger for people with a working purpose and people in the age category between 30 and 50 years. Moreover, taking the bus from the hub seems to be preferred over using the bike. The costs for the hub are also determinant in mode choice, and can even attract unintended users when the hub is free. Increased parking tariffs in the city center on the other hand seem to influence the share of sustainable transportation. For the municipality of Eindhoven the insights generated in this study can be used as underpinning in their considerations on the realization of hubs and increasing the share of sustainable transportation towards the city.

LIST OF ABBREVATIONS

AIC	Akaike Information Criterion
DRT	Demand Responsive Transit
EC	Error Component
GP	P+R Genneper Parken
GPS	Global Positioning System
HOV	Hoogwaardig Openbaar Vervoer (high quality public transportation)
KiM	Kennisinstituut voor Mobiliteitsbeleid (The Netherlands Institute for Transport Policy Analysis)
LC	Latent Class
MaaS	Mobility as a Service
MH	P+R Meerhoven
MNL	Multinomial Logit
PC	Parking costs
P+R	Park and Rides
RP	Random Parameter
SC	Stated Choice
SP	Stated Preference
SQ	Sub question
TC	Travel Costs
TT	Travel Time
WT	Waiting Time

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Eindhoven has grown to one of the Netherlands' most important economic locations with its focus on technological innovations. As heart of the Brainport region, the city had the strongest economic growth (4.9%) of the Netherlands in 2017. This results in an increased interest in businesses settling in the region (Gemeente Eindhoven, 2018a). This growth brings more employment opportunities and hence an increase in population of 20,000 inhabitants (Statistics Netherlands, 2016). Together with the increasing urbanization, this results in a densification of the city and an increased pressure on its traffic network. In addition to the growth and increasing pressure, the municipality needs to meet the EU norms regarding the reduction of greenhouse gas emissions. These should be almost halved by 2030 to limit global warming to 2°C on average (United Nations, 2015). The mobility sector contributes to a significant part of these emissions in Eindhoven, since 28% of total CO_2 emissions in 2014 (Municipality of Eindhoven, 2016).

The city is therefore facing a challenging task: on the one hand keeping the city attractive and accessible for its (future) residents and businesses, but on the other hand reducing the pressure on the traffic network and reducing the emission levels. The ambition of the mobility sector focuses on creating an emission free multimodal traffic network in order to keep the city and its economic high priority locations accessible (Gemeente Eindhoven, 2013; Metropool regio Eindhoven, 2016). Having the various sustainable modalities well-connected in the city, and making the switch towards sustainable and shared-mobility as convenient as possible, is therefore the focus of the municipality. Mobility as a Service (MaaS) is promised to be part of the solution, which is a new and user-centric mobility concept that provides its users with co-modal travel possibilities which include multiple transport modes seamlessly linked providing the most convenient trip (Giesecke, Surakka, & Hakonen, 2016; Jittrapirom, Caiati, et al., 2017). This new mobility service seems promising in reducing the use of private cars and the pressure on the traffic network. MaaS will bring implications for the built environment as well, as the service can only be launched successfully when travelers are ensured with convenient transfer possibilities at strategic locations, resulting in mobility hubs. In addition to newly constructed hub locations; current train stations are planned to be mobility hubs in the future, but also smaller transfer locations can be transformed into mobility hubs, serving multiple purposes. However, no quantitative research has been performed on the specification of these hubs in relation to the transition towards MaaS. Moreover, insights have to be obtained on what determinants influence travelers' decisions to switch to more sustainable (shared-mobility) alternatives in the context of Eindhoven. This results in the main research question:

Which factors can influence visitors' inclination to switch to sustainable (shared) mobility for their visit of Eindhoven city center (in transition towards to MaaS)?

The following sub questions (SQ) have been composed to answer the main research question:

- SQ 1 What are the current developments and vision of the municipality of Eindhoven regarding emission free mobility?
- SQ 2 What is the state-of-the-art concerning MaaS?
  - What features should the MaaS service include?
  - What transport modes should be included in the service?
  - What additional facilities should be realized to facilitate the transition towards the service?
- SQ 3 What could be the influence of travel costs and travel time on the inclination of visitors to switch from private car to sustainable (shared) mobility?
  - What type of sustainable (shared) mobility alternatives are preferred?
- SQ 4 What criteria should the mobility hubs meet? In terms of:
  - Location
  - Tariffs
  - Modalities
  - Facilities
- SQ 5 What is the effect of the investigated measures on the current travel behavior towards the city?
  - What is the current modal split?

1.1. Research design

The research design was explorative at first. By means of a literature review the subject has been specified to the implications of MaaS in the built environment. The literature review therefore answers the first two sub questions on the state-of-the-art concerning MaaS and how this relates to the current developments and vision of the municipality of Eindhoven regarding sustainable traffic. As the supply of applicable transport modes is the essential base of a good-working MaaS system, a Stated Choice (SC) experiment has been constructed in order to investigate the preferences of visitors regarding their mode choice towards Eindhoven. This SC experiment has been constructed including the potential determining factors identified from the literature. In line with a MaaS platform, respondents are provided with an overview of their potential travel alternatives towards the city center, which vary from private car or bike, to using a hub, or using public transportation. Some of which might have never crossed a respondents' mind or are not available at the moment. Each individual has its own intrinsic preferences, as well as factors that will be determinant in their choice. This is aimed on being identified in this research. The results of this Stated Choice experiment provide answers to the third and fourth sub question. In order to elaborate the fifth sub question, various scenarios are constructed that represent the current situation, planned situation and the situation of possible implementation of investigated measures.

1.2. Societal and scientific importance

The relevance of this thesis can be specified on societal and scientific level. The ambition of the municipality focuses on creating an emission free multimodal traffic network, keeping the city and its economic high priority locations well-accessible. On societal level, this research aims to provide the municipality of Eindhoven with useful insights in the effects of the implementation of mobility hubs. The municipality can therefore use the knowledge generated in this thesis as underpinning for their considerations in the realization of hubs. Since the data collected and analyzed is directly applicable to Eindhoven, the municipality obtains very specific information about its visitors. Moreover, the study includes all transport modes towards Eindhoven, and therefore it can provide the consequences of possible measures on the total share of sustainable transportation modes towards the city.

Regarding the scientific relevance, the research aims to contribute to the academic understanding of mode choice behavior, with a focus on the implementation of hubs in the context of MaaS. Previous Stated Preference experiments focused on the adoption of the service and the bundles. This study contributes to this knowledge as it focuses on the demand of transportation modes and the utilization of hubs, which are crucial in the deployment of MaaS. Differentiating parking tariffs have been identified in literature as a possible determinant in the use of hubs, this research aims to provide more knowledge on this topic as well. Using multiple discrete choice models there aimed to obtain a thorough understanding of the data collected.

1.3. Reading guide

This chapter provided a brief introduction on the subject and the main outlines of the thesis. Chapter 2 extensively discusses the relevant literature on the topic, specified onto the national climate goals and what this implies for the mobility sector, as well as, how MaaS relates to these goals and how this translates to Eindhoven. Chapter 3 discusses the methodology of the research; a stated choice study aimed at the travelers towards the Eindhoven city center. Chapter 4 describes the results of this study. Chapter 5 concludes this thesis by summarizing the main results and recommendations, and evaluates on the method used and its scientific and societal relevance.

CHAPTER 2

LITERATURE

This chapter reviews relevant literature regarding the goals set to reduce the emission levels of the transportation sector in the Netherlands in Section 2.1. One of the potential solutions which has been proposed to make the passenger transport more sustainable, is Mobility as a Service. This concept is elaborated upon in Section 2.2, together with its current applications. Section 2.3 introduces the city of Eindhoven, which currently faces challenges regarding its accessibility and emission levels. Here, the implementation of Mobility as a Service is proposed to keep the city accessible in the future. Section 2.4 concludes this literature review by integrating the various topics and elaborating the research question and the scope of this study.

2.1. Climate goals mobility sector the Netherlands

This section elaborates on the current developments on the reduction of the greenhouse gas emissions in the Netherlands and more specifically in the transportation sector. This sector significantly contributes to the current greenhouse gas emissions.

Increasing energy consumption by human activities causing the rise of greenhouse gas emissions, is the main cause for climate change (Huisingh, Zhang, Moore, Qiao, & Li, 2015). To limit these greenhouse gas emissions, the Paris Climate Agreement has been signed internationally by 195 countries in 2015 and these countries hereby approved the binding agreements of limiting the global warming to 2°C on average. This means the greenhouse gas emissions worldwide should be almost halved (49%) by 2030. In order to reach this goal, every country is obliged to take national measures, and the Netherlands has agreed on its own Energy Agreement for sustainable growth (Energieakkoord voor duurzame groei) (Klimaatakkoord, 2018). This agreement provides a long-term perspective on energy savings, more sustainable energy and extra employment opportunities. It has been signed by, amongst others, the government, employers, labor-unions and environmental organizations (Sociaal-Economische Raad, 2013).

Building on the Energy Agreement, the Cabinet of the Netherlands decided to define a Climate Agreement as elaboration of the Paris climate Agreement. Recently, the main strategy outlines for the Climate Agreement of the Netherlands are determined per sector; electricity, built environment, industry, agriculture and land use, and mobility (Nijpels, 2018). During the last ten years, the transport sector contributed for one third of the final energy demand of the European Union (Dominković, Bačeković, Pedersen, & Krajačić, 2018). Moreover, in the Netherlands the mobility sector also contributes for more than one third to the total environmental damage (Nijpels, 2018). In the strategy outlines of the Climate Agreement the ambition for the mobility sector is formulated as: "the transition towards carefree mobility, excellent accessibility, an optimal connection of modalities, high traffic safety and all this emission free" (Nijpels, 2018). This should be accomplished by means of the four main pillars on: sustainable physical infrastructure; sustainable commodity flow; sustainable energy carriers; and sustainable passenger traffic.

The pillar on sustainable physical infrastructure states that governmental tenders should have a focus on the reduction of the CO_2 footprint of vehicles and materials, and should aim for circularity of resources. Parallel to these intentions, an improvement of the accessibility should be realized, by means of an extension of the infrastructure in the metropolitan area to realize better connections nationally and regionally.

The second pillar on sustainable commodity flow focuses on the optimization of the flow of goods in terms of logistics by means of ICT-support and chain collaboration. Moreover, building logistics should be more efficient by means of a strong reduction of physical movements. This is stimulated by realizing emission free zones by 2025 in the thirty largest municipalities of the Netherlands concerning delivery vans and trucks. Moreover, the inland navigation should be made more sustainable.

Thirdly, the pillar on sustainable energy carriers concerns the replacement of fossil fuels by more sustainable energy carriers such as electricity, biofuels and hydrogen. The highest potential for the transition of the transport sector seems to be electrification, as it is beneficial in terms of reduction of CO_2 emissions, energy efficiency, air quality and the possibility of integrating different energy sectors e.g. vehicle-to-grid concepts (Dominković et al., 2018). The Netherlands is also focusing on this transition and there is aimed for an electrification of passenger vehicles, both business and private, as well as delivery vans, light traffic (scooters), cargo trains and trucks. The accompanying charging facilities should be developed accordingly, and possibly a financial incentive is necessary such as a reduction of energy taxes on charging facilities. Additionally, emission free public transport busses should be ready by 2030 and in 2025 already for target group traffic. Biofuels should be used as a transition fuel for heavy road traffic, the shipping industry and aviation. Green hydrogen fuel is expected to become available as resource for industry as energy carrier after 2030 (Nijpels, 2018).

The last pillar on sustainable passenger traffic states that an optimization of existing capacity is necessary in terms of better flow and transfer possibilities between modalities such as bicycle, public transport and cars. Attention should be paid to transfer possibilities by means of for example creating hubs in the rural areas to facilitate concepts such as Mobility as a Service. Mobility as a Service is a new mobility concept which offers tailor-made transport possibilities offered on-demand and seamlessly via one platform (this will be further elaborated in Section 2.2). Moreover, employers should stimulate their employees as well on the usage of sustainable modalities for business traffic by the 'Employers approach' ('Werkgeversaanpak'). A separate point of attention is the stimulation of bicycle usage and this will be parallelly done by employers, the Environmental Code, Mobility as a Service and stimulation of chain mobility, create fiscally favorability and by an improvement of the infrastructure. Lastly, behavioral measures are necessary to make people drive more sustainably with appropriate tires and stimulate car-sharing (Nijpels, 2018). Car-sharing is defined as the utilization of unused capacity of the car. By far the largest part of a day a car is parked, using up valuable space in cities. Shared-cars can be offered traditionally by business-to-consumer concepts or by a private provider via consumer-to-consumer concepts. In the Energy Agreement for sustainable growth the ambition is formulated to have 100,000 shared-cars with averagely low emission levels by 2020 (KiM, 2017).

2.1.1. Conclusion

As discussed, these mobility strategies focus on the sustainability of infrastructure, commodity traffic, energy carriers and passenger traffic. The tasks are often interconnected, which makes it a complex assignment. The sharing economy and concepts such as Mobility as a Service have potential in reducing the pressure on the infrastructure in cities as it should reduce the need for a private car. This might provide potential in keeping cities accessible by using the current capacity of the infrastructure more efficiently, considering the growing urbanization and potential emission free zones. The concept Mobility as a Service is still quite new (2014), and the potential of this mobility service is still being investigated. Section 2.2 elaborates further on the concept and Section 2.3 discusses the study area of this research: the city of Eindhoven.

2.2. Mobility as a Service (MaaS)

This section discusses the state-of-the-art of the concept of Mobility as a Service (MaaS), which was mentioned by the main strategy outlines of the Climate Agreement as one of the promises in making passenger traffic more sustainable. It has potential in keeping cities accessible in the future considering the growing urbanization. Both the supply and demand side of the service are discussed, respectively in Section 2.2.1 and Section 2.2.2. Section 2.2.3 discusses the developments of MaaS in the Netherlands.

MaaS is a new mobility concept, which offers a tailormade, demand-responsive and sustainable mobility package to its customers all arranged via one platform (Giesecke et al., 2016; Jittrapirom, Caiati, et al., 2017). The general idea is to consider mobility as a service product, which is available on-demand instead of having to buy the physical product (Ambrosino, Nelson, Boero, & Pettinelli, 2016). The concept is user-centric and the service provides users with the opportunity to plan (based on real-time information), book and pay a trip all in one application. Additionally, it provides them with co-modal transport options that are seamlessly linked across multiple transport modes. According to Chowdhury & Ceder (2016) the seamlessness of an integrated transport service such as MaaS is important to make it a feasible alternative for the users. Moreover, Giesecke et al. (2016) state that a sustainable MaaS system should focus on providing an environmentally friendly alternative that is economically attractive and socially acceptable to make it interesting.

The MaaS service provider should be the broker between the public and private transport providers and the users, so the user does not have to deal with paperwork, and is provided with a mobility option according to his/her preferences (Karlsson, Sochor, & Strömberg, 2016). This means that all mobility providers should have real-time data available and this information is combined and provided in one integrated MaaS application, empowering customers with the guarantee of a trip from location A to location B at a specific time (Jittrapirom, Marchau, & Meurs, 2017). Collaboration is key in making MaaS successful; mobility providers, service providers and (local) governments have to bundle their capabilities and work towards the best possible service (Matyas & Kamargianni, 2017). According to Jittrapirom, Marchau, van der Heijden, & Meurs (2018) a lack of collaboration is even considered the largest vulnerability in implementing a MaaS scheme. When the service is designed accurately, it can function as a demand management tool to contribute in realizing more sustainable trips (Matyas & Kamargianni, 2017).

However, this supply side is challenging as it integrates (on-demand) transport modes, a real-time planning system, payment options and support, all according to the preferences of the users; the demand side. The balance between this supply and demand side needs to be found to make the service beneficial. The attraction of this "critical mass of buyers and suppliers" is challenging. Network effects, both direct and indirect, are distinguished by Meurs & Timmermans (2017) regarding this balance seeking. Direct network effects create an increasing utility of the service caused by a growing number of users. Indirect network effects are the effects that the utility of joining the service increases when the size of the user group increases. These effects create positive feedback loops for the critical mass to evolve (Meurs & Timmermans, 2017). The features of this supply and demand side of MaaS are more extensively discussed in respectively Section 2.2.1 and Section 2.2.2.

2.2.1. Supply side

The supply side of the MaaS system is essentially one MaaS provider, providing all functionalities and services via one application; the MaaS platform. Figure 2.1 shows a simplistic overview of the MaaS ecosystem, and as can be seen, the MaaS provider functions as the broker between the users and the transportation providers. All travel needs are being offered in one package, eliminating all difficulty from the users (Karlsson et al., 2016). Real-time travel information is a critical aspect of the service to provide an accurate and reliable transportation option. Moreover, as can be seen, eventually the travel data can be shared with governmental bodies to optimize the infrastructure and policies (Dutch Mobility Innovations, 2018).

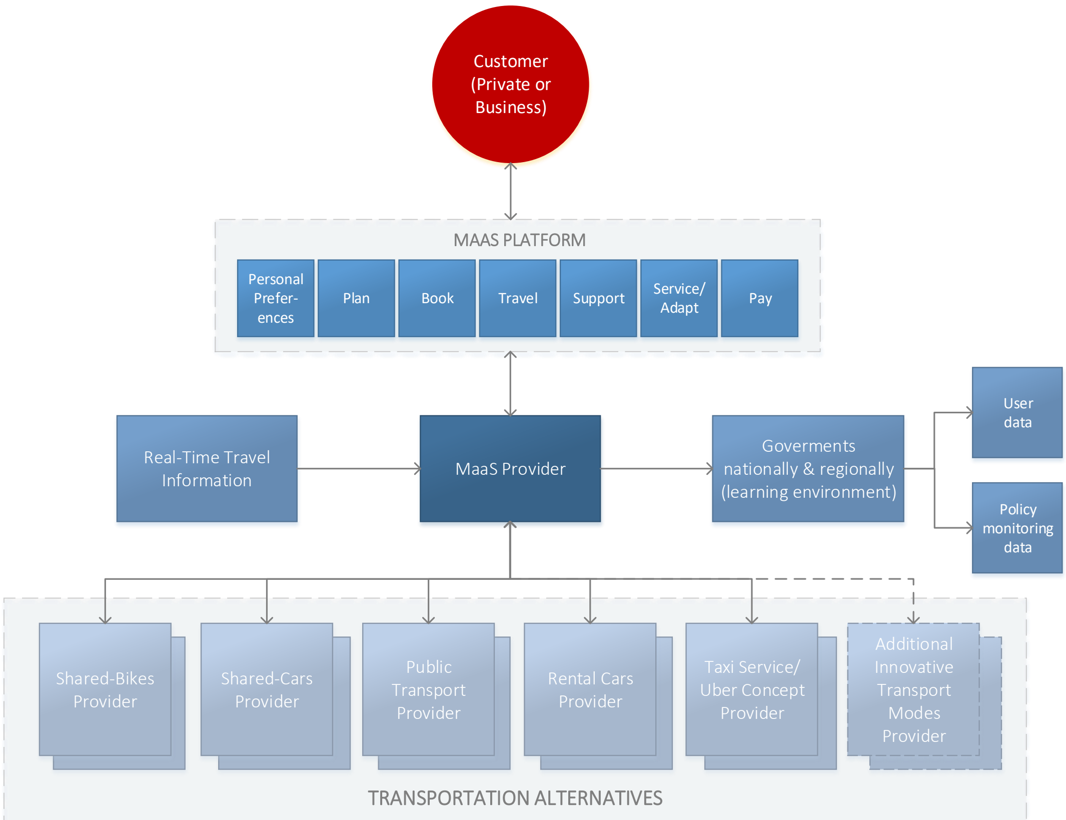

Fig. 2.1 Simplistic overview MaaS ecosystem, adapted from Dutch Mobility Innovations (2018)

The supply side of MaaS is characterized by the availability of various transport modes, as co-modality is a critical feature in the feasibility of MaaS. Various transportation facilitators must be available in all areas of the city and preferably also in other cities to have the customers well-connected (Sochor, Strömberg, & Karlsson, 2014b). The possible transport modes included in a MaaS scheme are discussed in Section 2.2.1.1, and Section 2.2.1.2 elaborates on the MaaS functionalities shown the ‘MaaS platform’ box in Figure 2.1. Section 2.2.1.3 briefly discusses challenges the suppliers face.

2.2.1.1. Transport modes

Already existing transport modes form the basis of the system, and therefore it is crucial that a city already has a proper public transportation system available when implementing MaaS (Li & Voege, 2017). According to Ambrosino, Nelson, Boero, & Pettinelli (2016) the public transport sector should still have an essential role. They state that the bus operators should reconsider their frequency, regularity and comfort to be as efficient as possible, having fixed route and flexible services. Flexible transport services can also be defined as demand-responsive (collective) transport, so no fixed schedule is followed, but the service is operated based on the demand. In the Netherlands BrengFlex and Bravoflex are examples of these demand responsive (collective) transport services (Sharmeen & Meurs, 2019).

Other existing transport modes such as bike(-sharing) can be integrated into a MaaS system as well. Bicycles provided by the Dutch railway company already link the two modalities train and bike (NS, 2018b). Other shared-bicycle services such as FlickBike and Hopperpoint mainly operate isolated from other transport modes in cities (FlickBike, n.d.; Hopperpoint, n.d.). Shared e-bikes even offer more potential as longer distances can be traveled more easily.

The car can also be one of the mode choices within MaaS, however, instead of using a private car, car-sharing and ridesharing are promoted within the service. Car-sharing schemes, such as Greenwheels, Car2Go and Amber, and ridesharing schemes, such as BlaBlaCar are already operational in the Netherlands (Amber, 2018; car2go Nederland B.V., 2018; Greenwheels, 2018). The shared-cars of Greenwheels are already located at approximately a hundred train stations in the Netherlands to facilitate, similar to the OV-bicycles, 'the last mile' of the passengers (NS, 2018a).

The Netherlands Institute for Transport Policy Analysis (KiM) has performed research regarding the use of these shared-cars and state that for Dutch people it does not seem to matter if the car needs to be booked in advance, only in the case of doing groceries it seems to matter (KiM, 2015b). However, the study of Ho, Hensher, Mulley, & Wong (2018) in Sydney concludes that it is perceived more attractive that car-sharing schemes are demand-responsively available, and do not have to be booked days in advance. This on-demand availability is challenging, as it entails that multiple hubs, that provide shared-vehicles, should be distributed across cities, and a balance should be found between supply and demand of shared-modalities. Giesecke, Surakka, & Hakonen (2016) justly mention a concern regarding these hubs, as these transport modes will be located at a different spot than the 'A-location' of the user's trip from A to B, so they have to travel to the hub first when making a trip. The location of this hub seems to be an important condition for usage of shared-cars; a walk of 5 minutes maximum is considered acceptable (KiM, 2015b), and for shared-cars also the variety of supply seems to be an important condition for usage (KiM, 2017).

Hubs or Park and Rides (P+R's) are therefore an important facet in the built environment for the feasibility of MaaS. P+R's were primarily introduced in cities to have more parking space available for visitors. Currently, the use of P+R's is stimulated to reduce the car traffic and congestion in the city center (Liao, Arentze, & Timmermans, 2012). An incentive for using these P+R's instead of driving by car to the city center, is the increased parking tariffs in the city center. Molin, Arentze, van der Pas, Guit, & Liao (2014) conclude this, using a super network model; increasing the parking tariffs at strategic locations seems to have a large impact and increases the use of P+R's. Hounsell, Shrestha, & Piao (2011) also conclude that to let people use a Park and Ride, car parking in the city center might need to be discouraged by removing the parking spots or increasing the parking tariffs. These 'push' policies are also found by Habibian & Kermanshah (2013) to have an effect on mode choice. In the future, these P+R's might become transfer locations between several MaaS modalities. Therefore the term 'hub' is used from now on, as these locations serve a broader purpose than only a Park and Ride. The transport modes offered within the MaaS system, and at these hubs, are essential as the supply of these transport modes should meet the demand of the users. MaaS is aiming to reduce the need for private car ownership, but this can only be achieved when the MaaS transport modes are easy to use and well-accessible. The hubs can integrate multiple functionalities, for example a pick up point for groceries or parcels, or include a daycare, so kids can be picked up immediately after work.

Taxi services (or Uber) do not have this "hub-problem", as they offer a service that is from A to B (Giesecke et al., 2016; Uber Technologies Inc., 2018a). In the future, autonomous vehicles can also serve a significant purpose in the taxi and car-sharing sector of MaaS, as no drivers are necessary and the car can pick up people at their origin by itself and drop them off at their destination (Litman, 2018). As Li & Voege (2017) state, MaaS might only be realized to its full potential when autonomous vehicles are introduced and integrated in the system. Related to this, Ho, Hensher, Mulley, & Wong (2018), Jittrapirom et al. (2017) and KiM (2015) conclude that it is currently preferred to have one-way car-share over round-trip car-share. This means the shared-cars can be left at the final destination, providing customers with more flexibility. More convenience-related factors are that it should not take too much effort to use them, such as an easy financial transaction procedure and the providers should be in charge of all paper-work and cleaning. Other important factors that influence the use of shared-cars are designated parking locations and parking permits for shared-cars as well as the increase of parking tariffs for private cars (KiM, 2017). Moreover, MaaS can also include possibilities in other transport related services or other new and innovative transport modes can be added to the system (Jittrapirom et al., 2017).

When introducing a MaaS scheme, these transport modes should be well-designed and operated to improve the integration of the new mobility concepts in the overall mobility scheme and hereby contributing to the mobility, accessibility and sustainability of the city (Ambrosino et al., 2016). This can only be achieved when ICT platforms are developed accordingly, and integrate these mobility options with real-time travel information and payment possibilities (Jittrapirom, Caiati, et al., 2017). Section 2.2.1.2 describes these necessary MaaS functionalities of the service in more detail.

2.2.1.2. MaaS functionalities

Preferably, the MaaS platform contains seven functionalities that have to be well-developed to serve the customers according their preferences and provide a seamless travel. These layers are defined by the Programme of Requirements of the Framework Agreement for the implementation of seven regional, nationally scalable MaaS Pilots, which will be elaborated in Section 2.2.3 (Dutch Mobility Innovations, 2018). Insights from literature review are included in these functionalities of the MaaS platform.

- **Personal aspects and preferences** – The customers can enter their travel preferences in the application; such as if they own a car or bike, or if they have certain disabilities that restrict them from traveling by public transportation or riding a bike (Dutch Mobility Innovations, 2018).
- **Plan** – The application should contain a real-time and multimodal travel planner. This provides customers with a transparent overview of their trip when entering origin, destination and time of a trip, so customers can easily compare their options. Price, travel time, CO_2 emissions, amount of transfers, transport mode, and availability of the transportation option are possible attributes in deciding what transport mode(s) are selected (Sochor, Strömberg, & Karlsson, 2014a) More factors are discussed in Section 2.2.2. Moreover, it is recommended that the customer receives feedback on their travel patterns, so they consider their travel behavior more consciously (Sochor et al., 2014a). Lastly, it is of value that the travel planner provides suitable possibilities for both short and long distance travels and this should not lead to problems, and ideally other cities and countries would also be covered (Karlsson et al., 2016).
- **Booking** – The possibility for the customer to book a complete trip (including multiple modalities) or part of the trip in the application according to his/her preferences (Dutch Mobility Innovations, 2018).
- **Travel –** The application should provide the customer with the necessary ticket or unlock-code for a vehicle or bike that they recently booked (Dutch Mobility Innovations, 2018). There should be taken into account that this service should also work when a network connection cannot be established (Sochor et al., 2014b). Additionally, for the seamlessness of the trip (Chowdhury & Ceder, 2016) it is important that the public transport ticket controllers are informed of the service, so the customers do not have to deal with the difficulty of explaining the service and defending themselves (Sochor et al., 2014b).
- **Support** – A 24/7 customer service should be available, centralized by the MaaS provider, so the customers do not have to contact the transportation providers separately (Dutch Mobility Innovations, 2018; Sochor et al., 2014a).
- **Adjustments** – Travel guarantee is important for the convenience of the MaaS service. When a trip cannot be completed with the specific transport mode booked in the MaaS application, an alternative transport mode should be provided to guarantee the trip (Sochor et al., 2014b).
- **Payment** – The application provides one central payment service, to pay for the trip that is booked across several transportation providers. This can be achieved by various contract forms:
    - Pay-as-you-go; the customer pays a small monthly subscription fee, and each trip is paid separately when utilized.

- Subscription:
  - Customer pays a fixed amount at the beginning of the month, and have a certain amount of travel credits (money, kilometers, points) available. Less sustainable modes can for example have a higher price.
  - Monthly invoice, customers will not feel restricted to a certain amount of credit determined at the beginning of the month (Sochor et al., 2014b).

  Transferability of the credits to the next month is considered to be important, as well as the possibility to increase the number of travel credits halfway the month (Sochor et al., 2014a). When it will not be possible to transfer the credits to the next month, customers might conduct unnecessary trips at the end of the month to empty their credit.

- *Additional features* – A bonus system can be installed to reward customers when they use a sustainable transport mode. It is recommended that these rewards are intrinsic and contain extra credit to travel, and not external incentives such a cinema ticket for example (Sochor et al., 2014b). Moreover, the application should also give insight in the up-to-date balance of a customer's travel credits when they have a subscription and their trip history regarding the subscription. Other possible features are the possibilities to have a distinction between personal and business traffic. Regarding this last one, direct declaration at the business should be possible.

2.2.1.3. Challenges suppliers

Many actors will be involved creating these functionalities, and the collaboration between them for realizing and operating the MaaS service is challenging but crucial for the successfulness of the service. First of all, the mobility providers might be competitors in the mobility market and therefore can be hesitant to work together and share their data (Meurs, Sharmeen, Marchau, & van der Heijden, 2018). Secondly, the reselling of tickets by the MaaS provider is challenging. Public transportation is often subsidized in cities and if MaaS providers would make profits on their tickets, the public transportation authority would get a smaller amount, which would mean more subsidies are necessary (Jittrapirom, Caiati, et al., 2017). This was also one of the restrictions the UbiGo pilot faced (this pilot is elaborated in Section 2.2.2), MaaS would have to be subsidized by taxes, as public transportation is also subsidized in Sweden. As UbiGo was a non-profit organization during the pilot, it was not possible to continue the service after the trial due to the restrictions regarding law and regulations when changing to a regular business model (Karlsson et al., 2016).

2.2.1.4. Conclusion

The supply side involves many actors, functionalities and services creating a challenging level of collaboration between them. This supply side has to be developed to an extent that the first users can be attracted to the service. In the built environment, MaaS can only be launched successfully when travelers are provided and ensured with convenient travel possibilities at strategic locations, such as hubs at the edge of the city. Insights should be gained in the deployment of these hubs, as these form the foundation for MaaS in the built environment. The positioning, facilities and offering of modalities is an important area of study for the usage and overall network of MaaS. Section 2.2.2 elaborates on the potential users and their attitudes towards MaaS.

2.2.2. Demand side

The implementation of MaaS requires insights in the attitudes and preferences of potential users regarding the adoption of MaaS. As the KiM states, current literature provides limited quantitative studies regarding the potential users of MaaS and the shift in travel behavior (KiM, 2018b). In order to better understand the motivations for people to perform certain mode choice behavior, Section 2.2.2.1 elaborates on previous research on this topic. Section 2.2.2.2 discusses relevant studies (mostly qualitative) on MaaS and a meaningful pilot regarding the adoption of the service.

2.2.2.1. Mode choice behavior

Mode choice behavior has been studied widely, and has been found to be influenced by many factors. A brief overview is provided in this section as these are as well applicable to the development and adoption of MaaS as a transportation service.

Yang, Wang, Liu, & Zhou (2018) divide the factors influencing mode choice behavior in Beijing, China into five categories. First the travel demand characteristics, which entail the purpose of the trip, the travel time and time of day. They found that for commuting or trips for education purposes, the utility for car is negatively influenced by travel time. Moreover they find the utility of traveling by car decreases for the purposes of shopping, social and leisure. When looking at travel time, Limtanakool et al. (2006), find that the propensity to travel by train increases when the absolute travel time by car increases. Strategy Development Partners (2019) on the other hand find, in their study on motives for the car market share, that travel time is not the determining factor in choosing either car or public transportation.

The second category is the travel mode characteristics that influence mode choice behavior, these have influence on the travel duration for a certain distance, waiting time, the costs, safety, comfort, flexibility and convenience. Looking at the relation between travel duration based on distance, slower transport modes such as walking and cycling are not used for longer distances in the Netherlands. However, for the choice between public transportation and car on distances between 20 and 200 kilometers, the travel time seems to be not the determining factor (Strategy Development Partners, 2019). When we take waiting (transfer) time and walking time, these seem to influence travelers' preferences for public transportation negatively. OECD/ITF (2014) also find this relation and waiting time especially is an important (negatively) influencer of the perceived convenience when traveling by public transportation. The parking costs, searching time for a parking spot and extreme congestion seem to have effect on the transition from car to public transportation according to KiM (2015a). According to Strategy Development Partners (2019) congestion does not seem to influence the mode choice between public transportation and car. The effect of strict parking policy on car use is quite strong for short and long distances in the Netherlands; stricter parking policies result in less car use. This effect is stronger for commuting travelers, and less strong for leisure trips (Strategy Development Partners, 2019). This last factor has already been further elaborated in Section 2.2.1.1 Transport modes.

The third category involves the socio-demographic characteristics, such as gender, age, income, education, occupation and car ownership. When looked at income for example, people with higher incomes seem to take the car more often (Hensher & Rose, 2007). Looking at education, Limtanakool et al. (2006) find that high-educated travelers for work purposes have a higher propensity to travel by train. Moreover, Yang et al. (2018) find that a higher level of education decreases the utility of traveling by car. However, for active transportation modes such as walking and cycling, socio-demographic characteristics seem to have little impact in stimulating active transport modes in the Netherlands (Ton, Duives, Cats, Hoogendoorn-Lanser, & Hoogendoorn, 2018).

The fourth category specified by Yang, Wang, Liu, & Zhou (2018) more subjective reasons are important, such as environmental consciousness, or intrinsic preference for a certain transport mode, or the evaluation of its comfort, and convenience.

The fifth category are the trip characteristics, for example weather conditions and urban characteristics. Ton, Duives, Cats, Hoogendoorn-Lanser, & Hoogendoorn (2018) conclude that when stimulating the use of active modes in the Netherlands, the trip characteristics and built environment are the most important categories. Regarding the land use or urban characteristics, Limtanakool, Dijst, & Schwanen (2006) also identify this as a determinant of mode choice behavior in the Netherlands.

Schneider (2013) adds some more factors to this, as proposed in his Theory of Routine Mode Choice Decisions. According to Schneider, the routine mode choice decisions have five stages, of which the first stage is the awareness and availability stage; people should have the transport mode available and see it is as a possible option for routine traveling. This also relates to the study of Limtanakool et al. (2006) as their results suggest that the absence of a train station at the origin of the trip, reduces the use of train as a transport mode substantially. This is coherent to the land-use and level of urbanization of the respondents' origin. Moreover, another related factor is the availability of a car, which if not available increases the probability of taking the train.

Stage two, three and four are considered happening simultaneously and influenced by socio-demographic characteristics of travelers. These stages include the basic safety and security; in which the transport modes are considered to provide a certain level of safety from accidents and security from crime. The stage of convenience and costs; which evaluates the travel time, effort and costs, which has already been discussed previously. And the stage of enjoyment; which discusses the benefits on personal, social and environmental level (Schneider, 2013).

Then there is stage five, which provides the habit stage; it is believed that this is a reinforcing loop. When people have used a certain transport mode on a regular basis before, they probably will choose it in the future (Schneider, 2013). Aarts, Verplanken, & Van Knippenberg (1997) also recognize the presence of habitual behavior in their study and find that people having strong modal habits do not take all relevant information into account for their transport mode choices.

When MaaS would be introduced, these factors will still play a role in user's mode choice when selecting their most appropriate trip, using the service. Therefore these factors should still be considered in the development of MaaS. Giesecke et al. (2016) mention quite some of these factors in their study on the key issues to be taken into account in the research, development and implementation of MaaS. Intrinsic factors which have already been mentioned, such as socio-demographic characteristics and perceived accessibility, but also social behavior, health, lifestyle and travel goals, and attitudes pay a role according to them.

They mention convenience as important as well for developing MaaS, when for example picking up kids on way home, or shopping after work can make people take the car more easily as public transportation is then seen as a hassle. The importance of convenience is also mentioned by the KiM, as well as costs benefits, choice freedom and customization (4 c's) (KiM, 2018a). Moreover, people often base their decisions on emotions, which is hard to study or change (Giesecke et al., 2016).

External factors are mentioned by Giesecke et al. (2016) as well, such as work trip purposes (private/professional or combination), trip distance, natural environment, borders and boundaries, transport policy (incentives and restrictions), ICT offers and mobility offers. Meurs & Timmermans (2017) also mention this complexity of social influence, trustfulness and word-of-mouth as important factors in the adoption process of MaaS.

In addition to the studies on mode choice behavior and what this implies for the development of MaaS, some real pilots have been performed. These are discussed in section 2.2.2.2, as well as insights from stated preference studies in Sydney and London, providing relevant insights in the adoption of the service.

2.2.2.2. MaaS studies

Important insights in the demand side of MaaS have been generated by studies on the first real MaaS pilot, which was performed in Gothenburg called UbiGo. The pilot had 195 people subscribed to a MaaS system during a six-month trial period. During this pilot, already existing mobility services were offered via a single subscription platform, including public transportation, car- and bicycle sharing, taxi services, and car rental. The participants had to meet certain criteria to be able to participate: they should have significant access to the existing transport services; they should be households living in the inner city, and they should have a significant travel demand, so the UbiGo service would be financially feasible compared to their current transportation. Moreover people were stimulated to give up their private car during the pilot and therefore they were compensated for their insurance, parking costs etc. up to a fixed limit (Karlsson et al., 2016; Sochor et al., 2014a, 2014b; Sochor, Strömberg, & Karlsson, 2015b).

The results from this pilot suggest that the potential first users are the 'innovators' and 'early adopters' of the Rogers' model, as 'curiosity' was the main motivator for people to participate in the UbiGo pilot project. (Sochor et al., 2014b). The Rogers' model that is referred to is the technology adoption life cycle model developed by Everett M. Rogers (Rogers, 1995). This model is based on the different adoption processes of customers regarding the adoption of new, innovative products or services. Figure 2.2 shows the technology adoption life cycle model and as can be seen five categories of customers are distinguished.

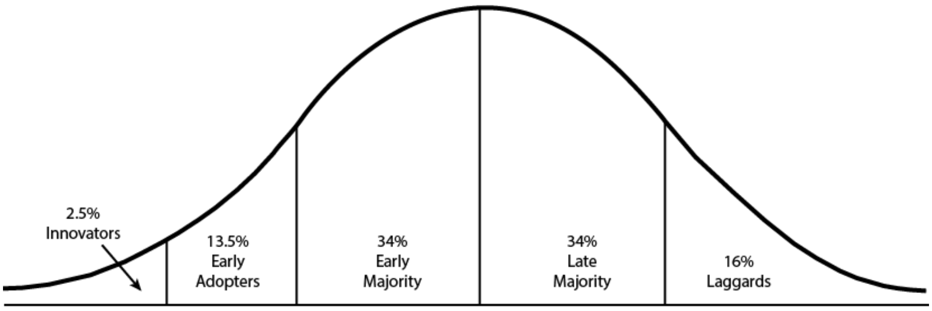

Fig. 2.2 Technology adoption life cycle; adapted from Nijssen (2014); Rogers (1995)

The 'innovators' are venturesome and enthusiastic about the newest ideas and technologies. The uncertainty and risk involved in the adoption of the technology is not an issue for them, they will buy the new technology immediately. The 'innovators' play an important role in the adoption process of the new technology, as they are the promotors for other categories of customers to follow. The 'early adopters' also adopt new technologies quite fast after launch. This group is also important for the future of the product as they already pay serious money for the product. The 'early majority' checks with the 'early adopters' if the product is successful and considers buying a new product for a longer time. The 'late majority' is skeptical about adopting the new technology and it is mostly out of necessity or peer pressure. The last category are the 'laggards', who are traditional and the last to adopt the technology or product when they are certain it will not fail (Nijssen, 2014; Rogers, 1995).

Considering the UbiGo pilot, the importance of 'curiosity' changed during the pilot towards a shared importance of 'curiosity' and 'convenience/flexibility', and also 'economy' and 'test living without a privately owned car' became more important. After the pilot, 'convenience/flexibility' even became the most dominant reason. Reasons such as 'environment' 'being a family member', 'gain access to cars' were not valued as much in all three cases (before, during, and after). For the continuity of the service, and the participation of the 'early and late majority' following the Rogers' model, it is important that 'convenience/flexibility' and 'economy' became dominant factors during the use of the service (Sochor et al., 2014b). In contrast to 'curiosity' these two factors can guarantee the extended use of MaaS. Overall, 79% of the participants expressed their satisfaction of the pilot and wanted to keep using MaaS after it stopped (Sochor et al., 2014a).

MaaS is aiming to reduce the car usage in a city, as it reduces the need for customers to own a private car (Jittrapirom et al., 2017). However, a counter-effect can be that people who normally use the public transport get access to a shared-car and use the public transport therefore less often (KiM, 2018a) or even resulting in more trips being made (Smith, Sochor, & Karlsson, 2018). As environmental friendliness was not considered one of the main motivators of adoption during the pilot in Gothenburg, it is suggested that the travel option with the least greenhouse gas emissions should also be the most convenient and accessible transport option (Sochor et al., 2014b). However, it has been argued that all groups with different car ownership situations, changed to the more sustainable transportation options in the pilot, so it did have some impact on the CO_2 emissions (Sochor, Strömberg, & Karlsson, 2015a). This pilot even resulted in a greater reduction of car usage than expected before by the customers. People overestimated their car usage by 30% when choosing a subscription level to the service and 48% of the users reported after the trial that they used their private car more seldom than before (Sochor et al., 2015b). However, there should be taken into account that during this pilot people were compensated for not using their private car.

In addition to this field operational trial, stated preference (SP) experiments have been conducted to obtain more insights in the possible adoption of MaaS; one by Ho et al. (2018), and one by Matyas & Kamargianni (2018). The study by Ho et al. (2018) is performed in Sydney Australia, and asks respondents to select their preferred customized MaaS bundle, based on their current travel behavior. Transport modes included in this experiment were public transportation, car-sharing, taxi service, and UberPOOL (ridesharing by means of Uber (Uber Technologies Inc., 2018b)). Results of this research show that almost half of the respondents is interested in MaaS bundles. Different segments can be identified and respondents using a car occasionally are more likely to adopt MaaS. The results also show that frequent public transportation users are the least interested in a MaaS bundle; it might offer them transport modes they do not need. Age and number of children in the household were socio-demographic characteristics that impacted the subscription to MaaS (Ho et al., 2018).

The study of Matyas & Kamargianni (2018a) on the other hand focuses on the city of London, and the research combines quantitative and qualitative data collection. First respondents are asked to fill-in a survey containing a Revealed Preference section about socio-demographic characteristics and current travel behavior. Next section contained a MaaS Stated Preference experiment with four alternatives: three pre-defined plans and one customizable option, including the transport modes: public transportation, bike-sharing, car-sharing and taxi. Based on the findings of the quantitative data collection, qualitative semi-structured interviews are conducted. In the end, the quantitative and qualitative data was integrated and interpreted. The main results indicate that public transportation is highly important in the MaaS system and respondents would not consider a MaaS plan without it. However, it seemed that people would consider other modes if a specific level of service was provided. Another finding is that respondents mainly favor plans with transport modes that they currently use as well (Matyas & Kamargianni, 2018a).

According to the SC study of Alonso-González, Van Oort, Cats, & Hoogendoorn (2017), current multimodal transport users are more likely to use demand responsive transport services – they focused on collective on-demand services in MaaS schemes. According to the study of Sochor et al. (2015a), previous car-sharers also thought the integration of services was a positive feature. Additionally, as MaaS is aimed to be demand-responsive, it can focus on the less connected target groups such as areas of low population, during hours of less demand, or less mobile people as well (Ambrosino et al., 2016). Special attention should be paid to less mobile people within the MaaS context, as transfers are quite challenging for these people (physical exclusion) (Giesecke et al., 2016). Other types of exclusion are also mentioned by Giesecke et al. (2016) such as geographical exclusion, as rural areas are reached less by transport services. Autonomy of people is mentioned as an important factor in the success of MaaS by the KiM, as well as flexibility and reliability. Moreover, the service should be preferably available everywhere at any time, however this might be a challenge in the rural areas mentioned (KiM, 2018a).

2.2.2.3. Conclusion

The demand side of MaaS is influenced by many factors, which come from general mode choice behavior as well for MaaS specifically. Both have to be taken into account in the development and adoption process of MaaS. The demand side of MaaS has been mostly studied in terms of qualitative studies and few empirical or quantitative results have been obtained. A knowledge gap exists in quantitative research of the potential users of MaaS and their preferences regarding (combining) transport modes and usage of the service. The introduction of additional pilot projects will provide insights in the potential adopters of MaaS. In the Netherlands several pilot projects are planned as well, which are discussed in Section 2.2.3.

2.2.3. MaaS implementation – regional MaaS pilot projects

As discussed, MaaS is still a new emerging concept and the implementation of the concept is challenging. The Delphi Study performed by Jittrapirom et al. (2018) suggests that an important policy is to implement pilot projects and enable "learning by doing". UbiGo was a meaningful example in these developments, however; it is not the only pilot project that has been introduced, for example Whim is already operational in Helsinki, it is piloted in the West Midlands and Antwerp, and planned in Amsterdam (MaaS Global Oy, 2017). Moreover, the WienMobil-Lab project for example is initiated after a previous pilot project called SMILE in Vienna (König, Eckhardt, Aapaoja, Sochor, & Karlsson, 2016).

In the Netherlands, however, no real pilot has been performed yet. There are some services that integrate several transport modes in one service, but no full MaaS service is operational. Tranzer for example integrates bus, train, tram and taxi services in one application (Tranzer, 2018). This service mainly targets tourists and people that use public transportation incidentally (Verkeersnet, 2017). The NS-Business-Card combines several transportation services well, such as trains, tram, metro, bus, OV-bicycles, Greenwheels shared-cars, and parking at Q-park; all available with one card (NS, 2018c). Mobility Mixx is a third example which integrates train, bus, tram, metro, shared-cars, rental cars, parking, OV-bicyles, and taxi services via one application for business traffic. Employers can have an agreement with them and provide their employees with this integrated transport service (Mobility Mixx, n.d.).

The first initiatives are developing towards MaaS, but a complete service for private travels is not available yet. Het PON investigated the current mobility use and the attitudes towards the future public transportation and MaaS. The results show that 53% of people living in the province Noord-Brabant would be willing to use a Mobility as a Service application. For 50% of the respondents the most important reason to use the service, is being able to manage everything in one application. For the respondents that are not willing to use a Mobility as a Service application, the most important reason (63%) is that the added value is not clear (Het PON, 2018). The Netherlands Institute for Transport Policy Analysis also indicate that the purpose of the trip has influence on the willingness to use MaaS according to their focus group discussions. MaaS seems to have most potential in serving incidental trips (KiM, 2018a).

The Ministry of Infrastructure and Water Management wants to give an impulse to the developments of MaaS in the Netherlands by launching seven regional MaaS pilots with an investment of €20,000,000 (together with the regions). The main aim of these pilots is to stimulate the developments and implementation of MaaS nationally. To achieve this, these pilots will give insight in the opportunities for national MaaS coverage and what obstacles should be handled to make it successful. From these pilots the ambition is to scale-up the implementation nationally (Dutch Mobility Innovations, 2018; Government of the Netherlands, 2018).

Seven MaaS pilots will be launched in 2019 as part of a national MaaS pilot project in Limburg, Utrecht-Leidsche Rijn, Amsterdam-Zuidas, Rotterdam-The Hague Airport, Groningen-Drenthe, Twente and Eindhoven. The pilot of the municipality of Eindhoven will start in 2019, providing their employees with sustainable mobility options exclusively via a MaaS platform. Annually, the municipality of Eindhoven has 1,500,000 kilometers of business traffic, of which 810,000 kilometers are with private cars of employees (Rijksoverheid, 2018).

As stated previously, the municipality has the ambition to have its organization 100% free of greenhouse gas emissions in 2025 and is only allowed to use sustainable energy, including energy for mobility (Gemeente Eindhoven, 2016c). The plan is to launch the pilot initiatlly with a small group of employees from different departments within the organization and have room to optimize the service and guard the availability of transport modes. The second step is to scale-up to a larger part of the employees and then potentially to other companies in the region. Eventually the service should become available to all residents of the city and should also provide target group transport (Rijksoverheid, 2018).

Moreover, at the end of 2018 two other pilot projects are planned regionally (in addition to the seven national pilots); one at the Paleiskwartier in ‘s-Hertogenbosch and one at Strijp-S in Eindhoven. Commuters, residents and students will be provided the opportunity to use a MaaS application for their daily trips (Het Innovatieprogramma Mobiele Stad, 2018).

2.2.4. Conclusion

This section gave an overview of MaaS, its functionalities and its potential future use. MaaS is a complex new mobility concept, which has potential in keeping cities accessible in the future. The supply side of the service needs to be developed in line with the preferences of the demand side. However, as limited quantitative studies have been performed, it is difficult to define these preferences. As the transfer locations realized in the built environment are crucial for the convenience of MaaS, these have to be taken into account when studying and developing the adoption of MaaS. Insights should be obtained on the deployment of these hubs, their positioning and facilities. Solely providing MaaS and hubs will not mean travelers will start using the service. Therefore the factors influencing mode choice behavior have also been elaborated, as well as studies regarding potential users of MaaS. The future pilots in the Netherlands will provide more insights in the real use of MaaS. However, in order to design the appropriate pilots, insights in these preferences by means of additional studies would be valuable. Section 2.3 provides insights in the developments of the study area of this research: Eindhoven.

2.3. Vision Eindhoven

In the South-East part of the province Noord-Brabant in the Netherlands, the Brainport region is located. An area filled with innovative start-ups and entrepreneurs across several municipalities, as shown in Figure 2.3. Within the Brainport region, Eindhoven has grown to one of the Netherlands' most important economic locations with its focus on technological innovations. Solutions for society's largest challenges are being developed by knowledge institutes and the high tech manufacturing industry within the region, on topics as healthcare, mobility and sustainability. In 2017, the city had the strongest economic growth of the Netherlands (4.9%), resulting in an increased interest in business settling in the region. As this growth also results in more employment opportunities, the city and region are now facing challenges to keep the quality of life high in the city, have high quality connections to keep the economic high priority locations accessible, provide attractive living and working environments, create a healthy city and urban culture (Gemeente Eindhoven, 2018a). This section discusses the challenges faced by the municipality and the current and future developments in the city.

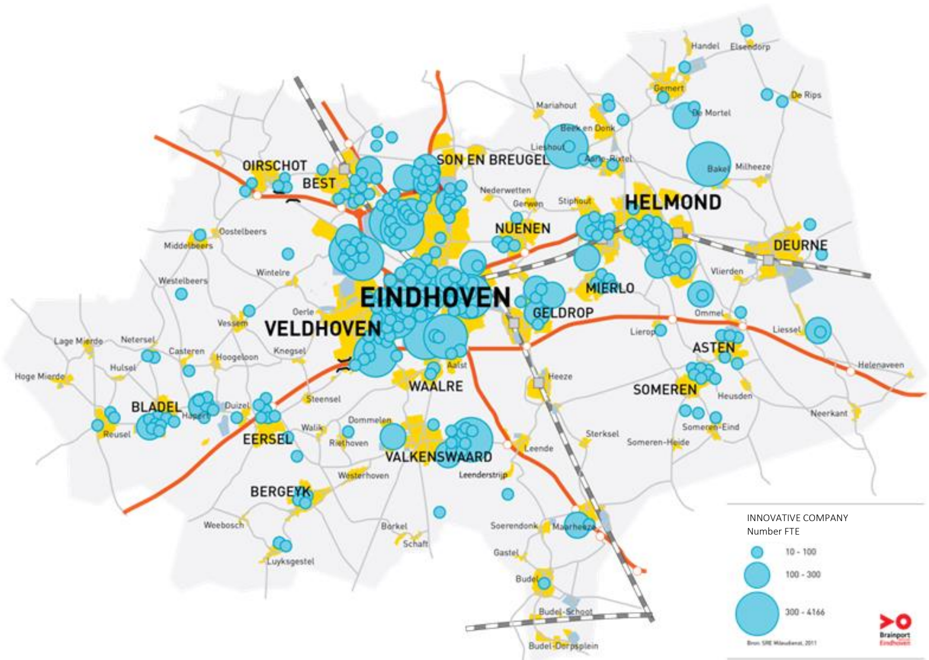

Fig. 2.3 The Brainport region's innovative companies (Brainport Eindhoven, 2018b)

Figure 2.4 shows these economically high priority locations ('Places to be') in the city, in addition to the city center (1): the High Tech Campus (2) in the South of Eindhoven the Brainport Industries Campus (3) and Strijp (4) in the North-West, Woensel XL (5) in the North, and TU/e Science Park (6) in the North-East. These campuses are the new 'places to be' for businesses. Within these campuses public facilities are developed and the areas have their own urban culture (Gemeente Eindhoven, 2013).

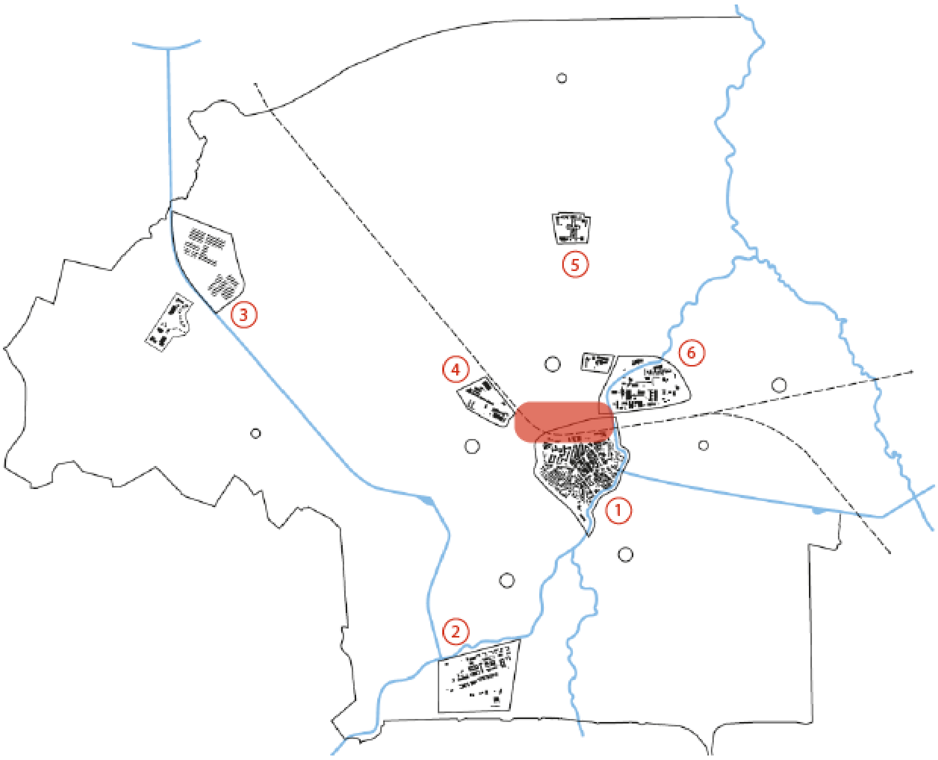

Fig. 2.4 ‘Places to be’ and ‘International Knoop XL’ in Eindhoven, adapted from Gemeente Eindhoven (2013)

As described, the current situation is already challenging and in addition, the population of Eindhoven is forecasted to grow with 8.3% between 2015 and 2030 (Statistics Netherlands, 2016), which results in an increase of approximately 20,000 inhabitants. As on average two people will live in one residence, approximately 10,000 residences need to be developed in order to facilitate this increase in population. An important plan that has been developed to realize this, is the ‘International Node XL’ (‘Internationale Knoop XL’). This plan covers the red area between the city center, Strijp-S and the TU/e Campus as shown in Figure 2.4. At the moment this area houses approximately 200 people and this number is planned to grow to 15,000 in the future. It will be a mixed area with housing, working and meeting, and leisure functionalities, which is easily accessible by train and provides an easy transfer to work, house, and the airport. The area will be green and space for interactions will be created (Brainport Eindhoven, 2018a). The parking norms will be flexible when developing, which means there can be focused on alternative/innovative transportation facilities (shared vehicles/Mobility as a Service) in the area. This will be planned in consultation with initiators and residents, which would result in fewer parking facilities in the area. Additionally, approximately 10,000 parking spots are available in the city center, these have potential to be used optimally (Gemeente Eindhoven, 2013).
Parallel to these developments, the municipality also needs to focus on reaching the climate agreements that were arranged in 2015. Section 2.3.1 will elaborate on these agreements and the strategy of the municipality regarding this task.

2.3.1. General climate challenges Eindhoven

The nationally formulated climate goals described previously should also be reflected on local level and in 2015 the municipality of Eindhoven formulated the Program of Sustainable Development (Programma Duurzame Ontwikkeling) Eindhoven 2015-2018. This program contains, amongst others, the ambition to start making traffic movements more sustainable in sectors where sustainable vehicles are not self-evident yet and the municipality has influence. The municipality wanted to be the initiator, from which the market could expand (Gemeente Eindhoven, 2015). In 2016 a new Climate Plan (Klimaatplan) Eindhoven 2016-2020 was introduced, which builds on the Program of Sustainable Development 2015. This plan includes both climate mitigation, which focusses on CO_2 reduction, and climate adaptation, which focusses on adaptation to the consequences of climate change (Gemeente Eindhoven, 2016c).

In line with the Climate Regulation (Klimaatverordening) Eindhoven 2016, the Climate Plan 2016 contains the following objectives (Gemeente Eindhoven, 2016c):

- From 1st of July 2030: 55% reduction of the greenhouse gas emissions compared to the emission levels in 1990.
- From 1st of July 2050: 95% reduction of the greenhouse gas emissions compared to the emission levels in 1990.

In line with these objectives the municipality formulated an objective for its own organization as well. In 2025 the municipal organization should be 100% free of greenhouse gas emissions and is only allowed to use sustainable energy, including the energy for mobility. This also means that all municipal buildings should not depend on natural gas (Gemeente Eindhoven, 2016c). Additionally, the municipality is aiming and developing towards a 'Smart Society'; which focuses on a more efficient functioning of the city based on the data gathered in the city. However, the 'Smart Society' focuses on the quality of life of people in the city and combines this by developing towards a pleasant society in an efficient environment (Gemeente Eindhoven, 2016c).

In 2014, the emissions in the municipality of Eindhoven were distributed according to the diagram in Figure 2.5. As can be seen, mobility, both on highways and the urban mobility, contributes to a significant part of the total CO_2 emissions in Eindhoven. The urban mobility itself has a contribution of 17% on the total CO_2 emissions in the city and this does not include the train traffic or aviation (Gemeente Eindhoven, 2016c). As stated previously, Het PON investigated the current mobility use and the attitudes towards the current and future public transportation. The results show that people living in the province Noord-Brabant use the car most often (57%) to travel to their work location. The most important reasons to use the car are the travel time (31%), travel distance (15%) and convenience (14%) (Het PON, 2018).

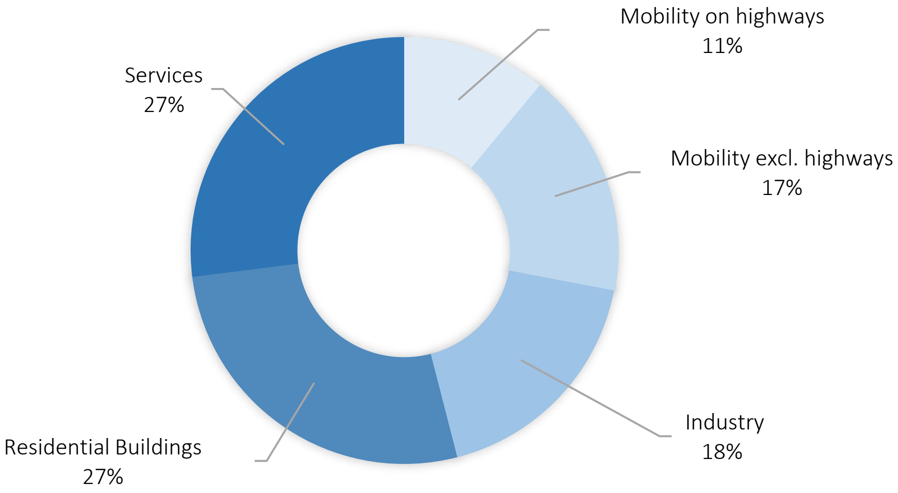

Fig. 2.5 Distribution of CO_2 emissions in Eindhoven, adapted from Gemeente Eindhoven (2016c)

In order to reach this 95% reduction of CO_2 emissions, two important structural transitions must be accomplished. Firstly, the transition towards a natural gas independent built environment; a built environment that will be heated without the use of natural gas. Secondly, the transition towards emission free mobility; arranging mobility without the use of fossil fuels (Gemeente Eindhoven, 2016c).

The developments regarding this emission free mobility are already being implemented via the three strategy lines of Trias Mobilica, which is discussed in Section 2.3.2.

2.3.2. Emission free mobility

The transition towards emission free mobility is a large challenge, as currently almost all motorized traffic is driven by fossil fuels. In order to reach the emission free mobility objectives, this fossil fuel based mobility should be changed to emission free mobility. The mobility strategy of the municipality to realize this, is based on the Trias Mobilica:

- Reduction of space for infrastructure to create space for living and leisure.
- Change in modal shift; a larger part of the modal shift should be for walking, cycling and public transportation.
- Make the remaining mobility more sustainable; no more fossil fuels.

The start will be to reduce the amount of kilometers driven by car, by means of the application of Smart Mobility concepts and the increased use of zero emission transport modes such as the bicycle, walking and public transportation (Gemeente Eindhoven, 2016c). In addition to these solutions, it is important to make the kilometers that are driven by car more sustainable. This can be achieved by using either electric vehicles, or using other types of fuel such as hydrogen or formic acid. Sections 2.3.2.1, 2.3.2.2 and 2.3.2.3, elaborate on the developments and plans of the municipality of Eindhoven regarding this Trias Mobilica.

2.3.2.1. Trias Mobilica – Reduction space for infrastructure

The first strategy is regarding the reduction of space for infrastructure to create space for living and leisure. First of all, the corridors are elaborated, then friendly streets for slow traffic and lastly the emission free zone.

Corridors

In the past, Eindhoven developed in relation to its surrounding villages and the main corridors were developed to connect these villages with the city. These corridors in combination with the ring road is characteristic for the city, as can be seen in Figure 2.6. However, at the moment it is important that the campuses or 'places to be' (discussed in Section 2.3) are accessible and these modern corridors are linked to the historical corridors and ring road for optimal access. However, a transition is necessary towards prioritizing cyclists, pedestrians and public transportation over car traffic and these historical corridors are aimed to have this function. These 'slow motion' streets are shown in red in Figure 2.6; the next paragraph elaborates on three of these streets.

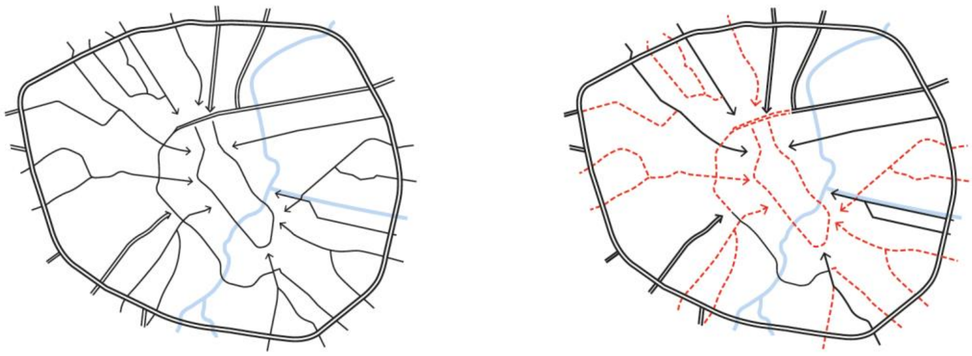

Fig. 2.6 Overview corridors Eindhoven (Gemeente Eindhoven, 2013)

Pedestrian and cyclists friendly streets

The Coalition Agreement states they want to tempt visitors to travel more by bicycle. Therefore, new designs of the public space will be focused on 'inviting people to take the bike' (Gemeente Eindhoven, 2018a). The Vestdijk is a concrete example of making a street friendlier for cycling and walking, and make it more difficult for cars to enter; developing towards a city boulevard. The Vestdijk is one of the main corridors through the city center of Eindhoven and the air quality along this road was not according to the European standards. To improve the air quality on the short term, the corridor has been changed from a two-lane road to a one-lane road, which also provided extra space for more green in the city, as well as pedestrians and cyclists (Gemeente Eindhoven, 2018e). Moreover to provide this 'slow' traffic with a pleasant environment, the speed limit has been limited from 50 km/h to 30 km/h. Lastly, intersections have been implemented to prevent the Vestdijk being used by continuous traffic. These measures have resulted in a reduction of 7,000 vehicles per 24 hours and the air quality is now according to the standards (Gemeente Eindhoven, 2018d). However, recently has been decided that this last mentioned measure, the implementation of intersections to prevent continuous traffic using the Vestdijk, will not be permanent. Nevertheless, the strong ambition to make the city center car-restricted holds and even the milestone of having a car-restricted city center in 2025 that is only accessible for destination traffic (Gemeente Eindhoven, 2019). In September 2018 the redevelopments of the Vestdijk have started in order to make it an attractive and green city boulevard (Gemeente

Eindhoven, 2016c). A similar plan has been realized at the Kruisstraat in the North and the Hoogstraat in the South-West of Eindhoven, these streets are now also prioritizing pedestrians and cyclists inviting people to use slow traffic (Gemeente Eindhoven, 2013).

Emission free zone

Since 2007 the municipality of Eindhoven has a reduced emissions zone (environmental zone) within the ring road of the city (Expertise Centrum Mileuzones.nl, n.d.). This means that lorries weighing over 3,500 kg and having an Euro 1, 2 or 3 engine are not allowed to enter the ring road of Eindhoven. (Gemeente Eindhoven, 2018b). The municipality wishes to gradually change this environmental zone towards an emission free zone, which would mean that no car driving on fossil fuels would be allowed within the ring road. However, it is a future plan and other than the ambition of moving car traffic to the edges of the city and have the inner city free for pedestrians and cyclists (Gemeente Eindhoven, 2018a), no definite decisions have been taken on the subject. It is certain however, that many challenges will emerge to keep the area within the ring road accessible when this would be realized.

2.3.2.2. Trias Mobilica – change in modal shift

The reduction of space for infrastructure as discussed in Section 2.3.2.1, already makes driving a private car less interesting. However, the change in modal shift needs more incentives, such as promoting 'slow' traffic, stimulate shared-mobility, hubs (P+R), and co-modality are discussed in this section.

Promoting 'slow' traffic

As stated in the Coalition Agreement of the municipality of Eindhoven; they are aiming to stimulate the use of slow traffic or public transportation towards the city center (Gemeente Eindhoven, 2018a). The vision on the Eindhoven city center even contains the statement that in 2025 an increase of 50% is realized of people that visit the city center by foot, bike or public transportation (Gemeente Eindhoven, 2016b). In addition to arranging the public space in an attractive way for the slow traffic, the Agenda Bicycle (Agenda Fiets) 2016-2025 of the municipality of Eindhoven contains the main points of attention regarding the cycling policy of the municipality, stimulating bicycle use (Gemeente Eindhoven, 2016a):

1. Bicycle parking: more quantity, quality and service of bicycle parking's.
2. Fast cycling lanes: realization of a network of high-quality fast cycling lanes, both local and regional. The 'Slowlane' is one of the developments; a 32 kilometer high-quality cycling lane that connects the most important economic locations in Eindhoven (e.g. TU/e, High Tech Campus, Flight Forum); shown in red in Figure 2.7. The 'Slowlane' is also important in connecting 'the last mile' from the public transportation to final destination (Brainport City, 2018).
3. Flow cycling traffic: shorter waiting times for cyclists, and changing the priority at intersections in favor of cyclists.

The following three measures have a supporting function to the previous ones:

4. *Innovation (Smart Mobility, Living Lab): give private initiatives, developments and innovations a chance and make public space available for pilots and experiments.*
5. *Cycling incentives: campaigns to stimulate cycling (example of such a campaign is B-riders), such as e-bike trainings, reward projects for cyclists into the city center.*
6. *Monitoring and evaluation: collect cycling and experiences data, GPS-data travel behavior.*

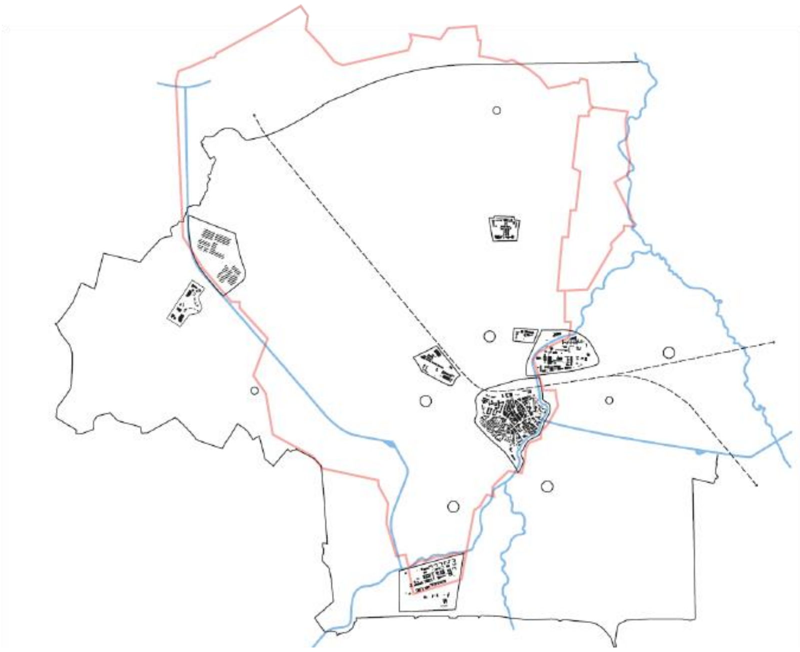

Fig. 2.7 Slowlane Eindhoven; adapted from Brainport Avenue (2013); Gemeente Eindhoven (2013)

Stimulate use of public transportation and shared-mobility

The province of Noord-Brabant has defined a broader definition of shared-mobility in their vision on public transportation: shared-mobility is mobility which is accessible to all and is often used collectively. This includes public transportation such as bus (HOV) and train, which are believed to stay essential in the functioning of the public transportation, which is the backbone of MaaS. The recent introduced Flex concepts such as Bravo Flex also contribute to this shared-mobility, as well as shared-car and shared-bike, including ride-sharing concepts (Provincie Noord-Brabant, 2018).

As mentioned previously, Het PON investigated attitudes towards public transportation within the province Noord-Brabant. People who use public transportation already, state they use it most often when the desired location is easily accessible by public transportation (65%) and when they travel to a city center (54%). 30% of the respondents state that they would use public transportation as a replacement of the car when the service would be door-to-door and 26% when the tariff would be lower. In general, 74% of the respondents think however public transportation is too expensive (Het PON, 2018).

The province focusses on strengthening the main corridors of rail and bus connections, providing passengers with a better supply of public transportation that fits their demand (Provincie Noord-Brabant, 2018). In Eindhoven, HOV-lines (high-quality public transportation) are developed to stimulate the use of public transportation. The first line (HOV1) is realized from Eindhoven Central Station via Meerhoven, Zonderwijk and Eindhoven Airport/Veldhoven. The second (HOV2) is being realized from Nuenen to the High Tech Campus and should be ready by the end of 2019. This line will connect passengers to Eindhoven WoenselXL, Catharina hospital, Genneper Parken, the city center, the Central Station and eventually the line will be extended to Aalst and Valkenswaard (Gemeente Eindhoven, 2018c). Additionally, HOV3 is now being planned and would be connecting Eindhoven Central Station, Eindhoven WoenselXL, Huizingalaan, Anthony Fokkerweg, Brainport Industries Campus (BIC) and Eindhoven Airport (Brainport City, 2018; Verboeket, 2018). An overview of the HOV lines is shown in Figure 2.8.

Solely offering new shared-mobility does not immediately result in people changing their travel behavior. Additional stimulating measures have to be taken. The Province Noord-Brabant is stating in their vision on public transportation that flanking policies in parking tariffs might be necessary, to make the use of shared-mobility more attractive (Provincie Noord-Brabant, 2018). As mentioned previously as well, the Coalition Agreement of the municipality of Eindhoven also states possibilities might exist in experimenting with differentiated parking tariffs to stimulate the use of bicycles and public transportation towards the city (Gemeente Eindhoven, 2018a).

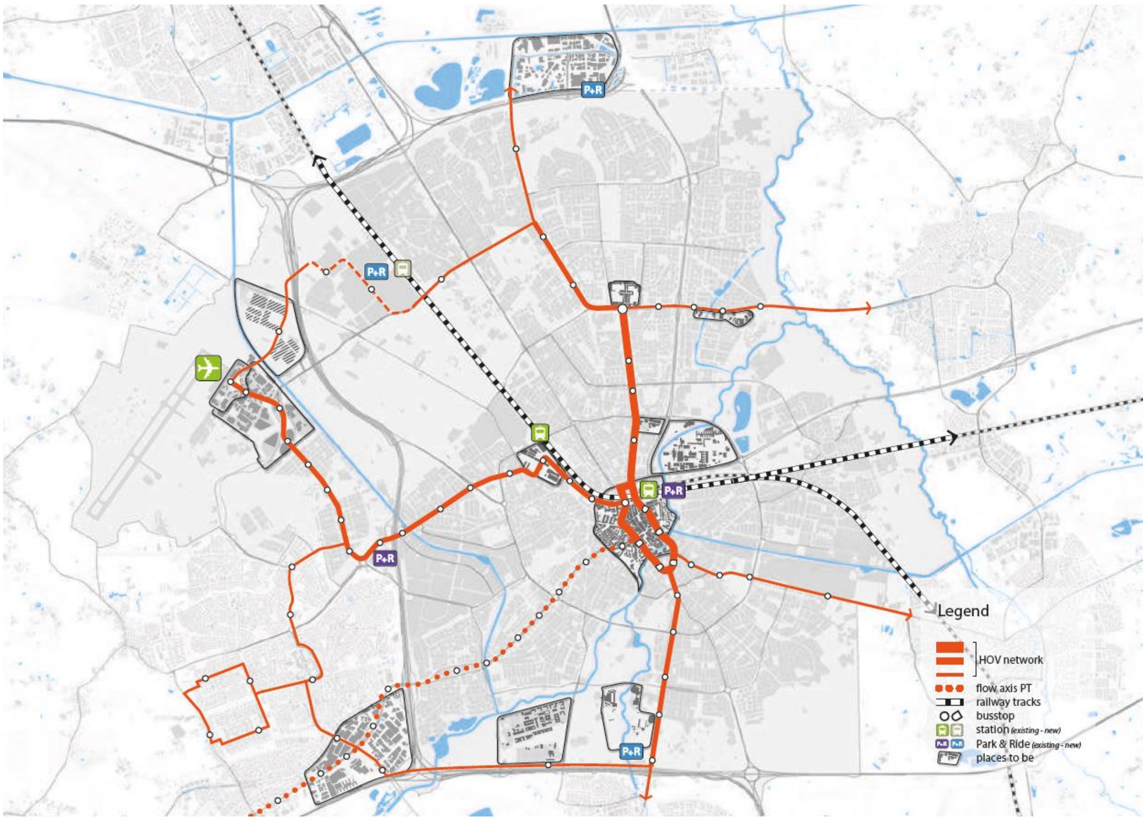

Fig. 2.8 (Planned) P+R's and (future) HOV lines; adapted from Gemeente Eindhoven (2013)

Hubs and co-modality

The connection of this shared-mobility to the mobility network is essential in stimulating the use of these shared-modalities. Hence, attention should be paid to the transfer locations for these modalities; the province Noord-Brabant considers them crucial in the system of shared-mobility. These locations are referred to as mobility hubs, where multiple facilities can be incorporated serving a broader purpose than the current P+R's where you can takes a bus or bike to the center. These mobility hubs are planned to function as a node for many shared-modalities such as shared-(cargo)bikes, shared electric cars and (self-driving) bus shuttles. Co-modality is defined as the combined use of multiple transport modes in order to use them as efficient as possible. These planned hubs will serve as facilitators of this co-modality and provide a location for seamless transfers between multiple modalities. Hence, travelers can move freely throughout the whole region according to their personal preferences regarding costs, time, and their attitude towards sustainability (Metropool regio Eindhoven, 2016). In addition to multiple shared-modalities, a mobility hub can contain additional services as well, a pick-up point where you can pick up a parcel you ordered or an open-office location where you can meet and work (Provincie Noord-Brabant, 2018).

In the future, the train stations are planned to be transformed to mobility hubs, as well as (current) smaller transfer locations at the edge of the city (Provincie Noord-Brabant, 2018). On a shorter term in Eindhoven, P+R's at Ekkersrijt and Genneper Parken will be realized and connected to the HOV lines to reduce the amount of cars entering the city center and meanwhile keeping the city center accessible (Brainport City, 2018). Figure 2.8 also shows the (planned) hubs (P+R's).

2.3.2.3. Trias Mobilica – Sustainable remaining traffic

The reduction of infrastructure and stimulating the change in modal shift will not eliminate all fossil fuel based vehicles from the city, and the CO_2 emissions will therefore not be reduced sufficiently. Therefore, the remaining traffic needs to become sustainable as well. The focus of the municipality is on increasing the number of electric vehicles as well as upgrading the charging infrastructure. Moreover, the public transportation sector and taxi services are a point of attention and the municipality also focusses on making the city logistics more sustainable.

National policy electric vehicles

The Netherlands strives to have 200,000 electric vehicles for passenger traffic nationally by 2020 (Gemeente Eindhoven, 2016c). By 2030 all new cars need to be electric (ANWB, 2017). For Eindhoven this is translated to having 8,000 electric vehicles registered by 2020, in 2016 this number was 1,500 (Gemeente Eindhoven, 2016c). Eindhoven is striving to stimulate driving electrically further by providing a network of fast-charging stations across Eindhoven and additional advantages for electric cars such as lower parking tariffs for sustainable (electric) vehicles (Gemeente Eindhoven, 2013, 2018a).

Electric bus and taxi traffic

When stimulating people to use public transportation and shared-mobility, it is important to guarantee that these transport modes are zero emission. Therefore all bus traffic in the province Noord-Brabant and therefore also in Eindhoven should be electric by 2025 (Gemeente Eindhoven, 2016c; Provincie Noord-Brabant, 2018). In December 2017 the first 43 busses on the HOV lines (high-quality public transportation) were already operational (Stroecken, 2017). In 2020 the share of electric busses should be 70% of the total. Moreover, the taxi's in Eindhoven should be all electric by 2026, and the municipality is striving to realize this by 2020 already for 70% (Gemeente Eindhoven, 2016c). Moreover, BravoFlex has been introduced in Helmond and Eindhoven and is a flexible service that drives without a fixed schedule. The service is operated based on the demand, and passengers decide between which stops they wish to travel. The service is introduced in areas that had a low occupation, and replaces the fixed schedule busses that were driving empty. This new service should be better in line with the demand in those areas (Bravo, n.d.-a).

Infrastructure electric charging

As there is being strived to make passenger traffic, bus and taxi's (mostly) electric by 2020, the charging infrastructure for these vehicles should also be developed accordingly (Gemeente Eindhoven, 2016c). As stated previously, this network of (fast-)charging stations is also used to stimulate electric driving.

Green Deal Zero Emission Stadslogistiek (City Logistics) (ZES)

The municipality is taking a step in the right direction in reducing the CO_2 emissions from mobility by signing the Green Deal ZES (TLN, 2018). The Green Deal ZES is an agreement between the government, local authorities, municipalities, companies, and entrepreneurial organizations which aims to create an emission free city supply by 2025 (Gemeente Eindhoven, 2018a). This will be realized by driving zero emission vehicles as well as reducing the amount of kilometers driven in the city. (Green Deals, 2014).

2.3.3. Conclusion

As elaborated in this section, the city of Eindhoven is growing, which brings challenges regarding the accessibility of the city. As discussed, many solutions are being implemented to reduce the car traffic in the city and stimulate emission free mobility. Introducing the emission free zone in the city is the most drastic measure, but it might be a crucial one when the city wishes to reach its emission targets. However, until that happens other measures such as the facilitating and promoting of slow traffic; introduction of hubs; upgrading the public transportation and shared-mobility; having a covered network of charging stations and introducing differentiated parking tariffs might stimulate people in using more sustainable transport modes to the city center, which can be either 'last mile' from a hub or for the entire trip.

2.4. Conclusion

This literature review elaborated on the current national climate goals, and more specifically for the mobility sector in Section 2.1. Solutions are proposed, of which Mobility as a Service is one. As discussed in Section 2.2, this concept has potential in reducing the private car use in cities and at the same time keeping cities accessible by a seamless and on-demand offering of multiple transport modes via one application. As Mobility as a Service is still a new concept, the preferences regarding the service and the consequences of usage are an important subject of research. Hence, pilot projects are planned in the Netherlands for 2019 and the municipality of Eindhoven, the study area of this research, is hosting one of these pilots with its own employees, as elaborated Section 2.3.

Eindhoven has an urgent problem in keeping the city accessible, and this will only grow the coming years as the city is planning to densify even further. Its mobility sector therefore focuses on creating an emission free multimodal traffic network to keep the city and its economic high priority locations accessible. This means the focus will lay on making sure the different emission free transport modes are well-connected in the city, and making the switch towards sustainable and shared transport modes as convenient as possible. The emission free zone might be one of the strategies in keeping the city healthy and accessible. However, appropriate transport modes should then be provided as a feasible alternative to travel to the city center. MaaS might be part of the solution, and this new service will have its consequences in the built environment as well. Mobility hubs will provide the supply of transport modes preferred by travelers, and these hubs need to be positioned at strategic locations and should be appealing to use. Current train stations will be mobility hubs in the future, but also smaller transfer locations can be transformed into mobility hubs, serving multiple purposes. However, no quantitative research has been performed on the preferences regarding the transition towards MaaS and the specifications of these hubs. How can people be stimulated to use the service and is sustainable shared-mobility an appropriate replacement of the private car? Flanking policies such as differentiating parking tariffs are proposed to stimulate people to travel by bike or public transportation to the city center, but will this stimulate people to make a more sustainable choice? If hubs along the ring road would be implemented, what criteria should these hubs meet? And will people living not too far away use these hubs, or will their preference be to use public transportation for their entire trip or will they even take their bike?

Therefore, it is useful to gain knowledge on forehand on the preferences regarding the shared-mobility service in combination with the possible future implementation of the emission free zone and (differentiating) parking tariffs. The method selected for this study is a Stated Choice (SC) experiment. This experiment serves two purposes: i) In general more insight is generated in the willingness to use the hubs depending on their position in the city and the facilities they provide, and ii) for the city of Eindhoven specifically insight is gained regarding flanking policies on parking tariffs in order to stimulate travelers switching to sustainable (shared) transport modes in the transition towards MaaS. The methodology is further elaborated in Chapter 3.

CHAPTER 3

METHODOLOGY

As discussed in the literature review, insights in the introduction of a MaaS service in relation to the introduction of hubs and reducing the car traffic in the city are necessary to determine the best strategy in keeping Eindhoven city center accessible while keeping it emission free. The city needs to stay accessible and attractive for its residents and visitors, in order to keep its economic position strong and the city a healthy place to stay. Hence, the preferences of these visitors regarding hubs and other sustainable transport modes should be analyzed to determine the best strategy for the implementation. This research aims to provide knowledge on the choices of visitors when they are stimulated to switch to sustainable (shared) transport modes.

The method selected for this study is a Stated Choice (SC) experiment. This type of experiment is useful for studying new mobility concepts, as people's choices regarding given hypothetical situations can be tested. This SC data and other approaches to measure choice data are discussed in Section 3.1, as well as modeling the data. This study investigates the preferences regarding the introduction of hubs in a city where people are not familiar to this system yet. Increased parking tariffs are used to stimulate the use of sustainable modalities from these hubs, as well as other sustainable forms of transport from people's home location towards the city center, such as cycling or public transportation. The way this is included in the study is discussed in Section 3.2. Section 3.3 provides an introduction into choice modeling, which is used to understand and predict the choice behavior of individuals. Section 3.4 concludes this chapter.

3.1. Choice behavior

Individuals consciously and subconsciously make decisions in everyday situations (Hensher, Rose, & Greene, 2015). This study focusses on mode choice behavior, and as mentioned in Chapter 2 Literature review, this choice behavior is influenced by a divers set of factors that comprise habitual, socio-demographic, economic, prejudice, attitudinal and situational components.

In order to have the possibility of making a choice, more than one alternative should be available to choose from. Hence, the set of alternatives is also referred to as the *choice set*. The characteristics of the alternatives that describe the alternative and influence the choice between the alternatives are called *attributes*. By comparing the attributes of the alternatives in the choice set, a choice can be made. Measuring and modelling this choice behavior is required in order to disclose the underlying factors influencing the behavior which is helpful in determining the right policy strategies for example. These factors can be both linked to the decision-maker himself and to the characteristics or attributes of the alternatives in the choice set (Hensher et al., 2015).

Measurement approaches

Several approaches exist to measure this choice behavior and Figure 3.1 provides an overview hereof, composed by Kemperman (2000). The main differentiation among the approaches is between revealed and stated choice data. Revealed choice data is based on previous (observed or reported) actual behavior and the utility values and weights of the attributes are determined based on this data. The stated choice data is used when the data has not been observed or reported from a real-life situation. In this approach, the respondents evaluate hypothetical alternatives, and this approach can again be sub-divided between stated preference and stated choice data. Compositional preference data is obtained when the respondents are asked to evaluate the attractiveness of the levels of the attributes within an alternative by means of a rating scale. Next, the respondents need to express their opinion on the relative importance of each attribute describing the alternatives. The decompositional preference and choice data is used to predict respondents' preferences and choices. For this, importance weights of the attributes are derived based on respondents' answers given under controlled experimental conditions. For the decompositional preference approach, respondents are asked to rate alternatives on a scale or in order of preference. The decompositional choice approach asks respondents to choose between two or more alternatives in a choice set and this is repeated for a number of choice sets for each respondent (Kemperman, 2000). This last approach has been selected for this study, which is further elaborated in Section 3.2 Stated Choice experiment.

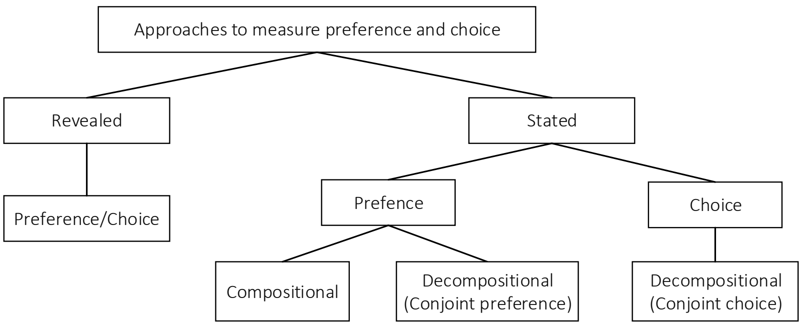

Fig. 3.1 Approaches to measure preference and choice; adapted from Kemperman (2000)

3.2. Stated Choice experiment

As mentioned in the previous Section 3.1, the stated choice experiment has been selected for this study. Figure 3.2 shows an overview of the experimental design process of stated choice experiments composed by Hensher et al. (2015) and the stages will be elaborated in this section. This process starts with specifying the problem, such that the experiment will achieve the right purpose in the end. When the problem has been specified, the identification of alternatives, attribute and attribute levels to use in the SC experiment is the next step. This can be an iterative step to the first step; refining the problem even further. These iterations can be made throughout the first five stages as can be seen. The next stage considers the statistical properties for the final design, followed by generating the experimental design by means of a statistical package. The next step is to allocate the attributes that are identified in stage 2 to the design columns. This is followed by constructing the choice sets which are used in the questionnaire. The choice sets are then randomized to eliminate the concern of the biases from the order of display of the choice sets to the respondents. The final stage is the construction of the survey instrument, which includes constructing the choice sets accompanied by other questions that are necessary for answering the research problem.

Sections 3.2.1, 3.2.2, 3.2.3 and 3.2.4 address these stages in more detail.

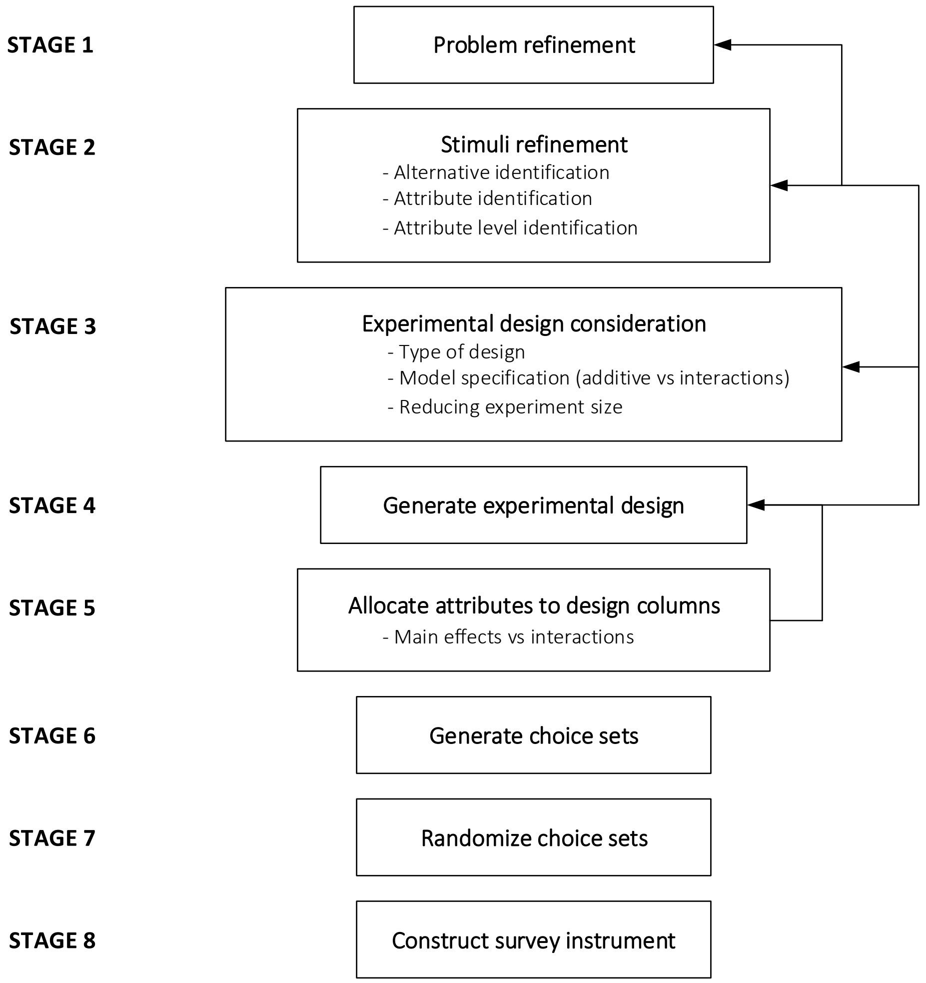

Fig. 3.2 Experimental design process of stated choice experiments adapted from Hensher et al. (2015)

3.2.1. Experimental design stage 1

The first stage is the problem refinement, which has been specified to MaaS in the built environment. As discussed in Chapter 2, there has been focused on the future accessibility and the emission free mobility in Eindhoven. In order to reach the climate goals in the city and guaranteeing the accessibility in the future, it is important to reduce the car traffic in the city and let people enter the center area exclusively with sustainable and shared traffic. However, this is not reality yet. Hence, in the mean-time flanking policies (such increasing parking prices) in combination with the realization of MaaS and the well-positioning of hubs might stimulate the transition towards emission free mobility.

In order to measure the effect of the flanking policies (and other attributes which will be specified in a later stage), the stated choice experiment is designed. The hypothetical situation in the SC experiment is the situation that respondents want to conduct a trip to Eindhoven city center. They conduct this trip from their home location, and their 'usual' travel time by car is used as context for the respondent, as well as the purpose they usually have for this trip and the duration of stay in the center. It is assumed they normally make this trip by car and in the experiment they are offered certain travel alternatives (via a hub, by public transportation or by (e-)bike).

3.2.2. Experimental design stage 2

The next stage is the stimuli refinement which involves the alternative identification, attribute identification and attribute level identification. This was an iterative process, as the alternatives presented to the respondent should be as realistic as possible, and increasing the number of attributes also increases the number of respondents needed. This stage is discussed in sub-sections Alternatives and Attributes.

Alternatives

Initially, all possible transport modes and multimodal combinations from home to the final destination were included in the alternatives. The base alternative was defined as a direct trip to Eindhoven city center by car and walking to the final destination. The second type of alternatives were the hub + MaaS options, implying that people drive with their private car to a mobility hub at the edge of Eindhoven city center (outside the ring road), and transfer to a sustainable (shared) transport mode to travel the 'last mile' to their final destination. The third type of alternatives was a 'full' MaaS option, in which a future scenario was imagined. In this scenario every city and village would have mobility hubs from which travelers could take any (shared-car, shared (e-)bike, bus, train) to Eindhoven city center. Once again, they could change to another transport mode at the edge of the city center to travel the 'last mile' to their final destination in the city center by (Flex) bus, shared (e-)bike, electric step/scooter or walking. With this last type of alternatives the reverse effect of offering people a number of (new) transport modes could be studied as well. For example when people who normally do not possess a car, get access to one, this might result in more people using cars instead of the aimed reduction. However, these initial types of alternatives resulted in too many combinations of transport modes and therefore in too many alternatives to evaluate in the stated choice experiment.

Therefore, the scope of the study has been limited to the situation applicable to and achievable in Eindhoven on the short term. Resulting in the inclusion of the initial function of the hub; parking the private car outside the ring road and take a sustainable transport mode towards the city center, hereby focusing on the first stages of the implementation of MaaS in Eindhoven. It would not be realistic to assume every city and village surrounding Eindhoven will have mobility hubs available in the near future. Moreover, for respondents this might be confusing to assess in a stated choice setting, as they might have difficulty imagining this will be a realistic situation in the future. This was one of the reasons the shared (e-)car was eliminated from this research as well. Another reason was that people would also have to consider selling their private car when considering this option, which could be a study in itself. It would have been possible though, to include the shared e-car as one of the mobility options at the hub. However, as the distances within the ring road of Eindhoven are quite short, this would not be a desirable option to offer people for this study. This also relates to flexible bus services; the transport service that can be called on-demand. From hub to city center this would unlikely to be implemented, as the scheduled bus services would be more efficient in transporting travelers to the center; having shorter waiting times and delivering people at a specific location in the center. Shared-bicycle services have been introduced already in a many-to-many system in Eindhoven, so the bikes do not necessarily have to be returned to their original location, but can be left at a bicycle station or another allocated space. Shared e-bikes could even offer more potential as longer distances can be traveled more easily, however these are not implemented yet. The scope of this research is limited to the use of public transportation and shared-bikes, but more innovative 'last-mile' services such as e-scooters, e-steps or e-skateboards might be added to the system as well. However, this research focuses on the transport modes applicable to and achievable in Eindhoven in the short term, and for these transport modes it is not sure yet they will be introduced in Eindhoven or even allowed by national law. Therefore, the scope is limited to the reduction of car use by stimulating public transportation and providing (shared) bikes and bus services. Moreover, besides using a hub, people can also decide to take public transportation or their (e-)bike from home to travel to the city center in the future. Therefore, these alternatives have been included in this research as well.

This results in the following six alternatives, see Figure 3.3 for the presentation of the alternatives in a choice task in the design:

- Alternative '**car**' – Park car in city center with higher parking tariffs.
- Alternative '**car + bus**' – Park car at hub with lower parking tariffs; transfer to the bus (in italic the waiting time for the bus is given).
- Alternative '**car + shared-bike**' – Park car at hub with lower parking tariffs; transfer to shared bike.
- Alternative '**public transport + walk**' – Take public transportation from home location to the city center; walk to your final destination (this walking time has been approximated as 7 minutes for the respondent to reach their final destination). Note that the bus may be left at any bus stop in or near the city center without using the hub.
- Alternative '**public transportation + shared-bike**' – Take public transportation from home location to the city center; take a shared bike to your final destination (this cycling time has been approximated at 2 minutes for the respondent to reach their final destination). Also in this case, the bus may be left at any bus stop (which are assumed to provide shared-bikes).
- Alternative '**(e-)bike**' – This alternative is only shown when it is a relevant alternative for the respondent. It is supposed to be relevant when: people own an e-bike and live within 25 km from the city center of Eindhoven, or people own a regular bike and live within 20 km from the city center.

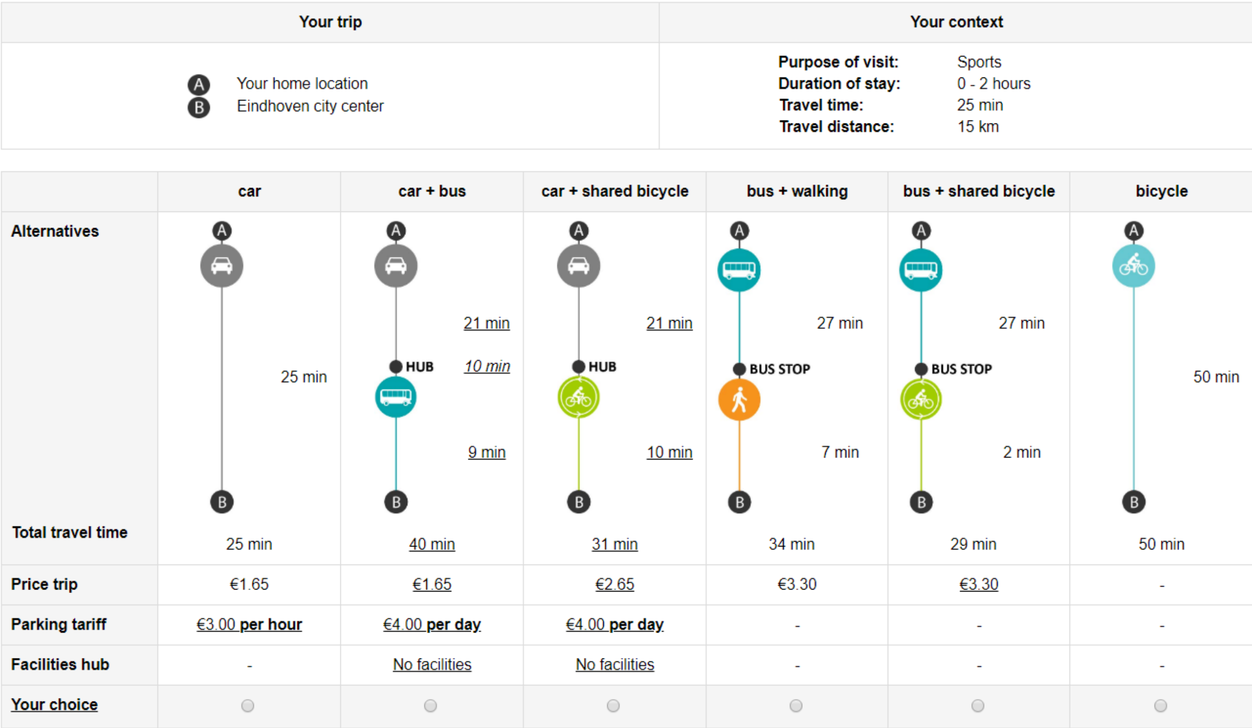

Fig. 3.3 Choice task example

Attributes

The attributes describing the alternatives have also been limited to the essential ones and can be divided into the 'context attributes' and the 'alternative attributes'.

Starting with the context attributes, these are based on the current situation of the respondent and are provided at the top of the choice task shown in Figure 3.3 as a reference for the respondent. These values are based on answers to the questionnaire accompanying the SC experiment, which asks questions on the respondents current travel time by car from their home location to Eindhoven. Moreover, the questionnaire asks about their purpose for visiting the city center and how long they would usually stay. These attributes are selected based on the literature review, as the purpose of the trip seems to have influence on mode choice (and even the use of MaaS) (KiM, 2018a; Limtanakool et al., 2006; Yang et al., 2018). Duration of stay can be cost related, as more parking costs need to be paid the longer the stay, and parking costs seem to be important. This was also found by Strategy Development Partners (2019) as parking policies seems to affect commuters more than leisure travelers, as they usually have a longer duration of stay.

Regarding the 'alternative attributes', the factors travel time, parking tariffs, costs, and hub facilities have been taken into account for the research. Travel time for example has been found an essential influencer of mode choice between train and car (Limtanakool et al., 2006), as well as the relation of travel time with certain purposes seems important (Yang et al., 2018). The distance and the travel duration, impact mode choice on short versus long distances in 'slow' and 'fast' transport modes (Strategy Development Partners, 2019).

Initially, the travel time was divided in the in-vehicle time and out-of-vehicle time in the study. The in-vehicle time was subdivided into the travel time by 'main' transport mode of the trip, the congestion time and time to find a parking spot. The out-of-vehicle time was subdivided in the ‘first mile’ time (the time it took to get to the ‘main’ transport mode), the waiting time, and the ‘last mile’ time (the time from the ‘main’ transport mode) to the final destination. However, this list of different times would work confusing in a stated choice experiment. Therefore the congestion time and time to find a parking spot have been removed, because the situation of both these attributes is difficult to estimate in the future. As there will be aimed for a reduction in car traffic in the city, the congestion time and the time to find a parking spot will be reduced as well. Moreover, congestion time seems to have little influence on mode choice behavior (Strategy Development Partners, 2019). Waiting time was identified as an important influencer on the perceived convenience of public transportation (OECD/ITF, 2014) and, as well as walking time, seems to negatively influence travelers’ preferences for public transportation (Strategy Development Partners, 2019), therefore this factor has been included.

The ‘first mile’ travel time has also been removed from the study, as this would introduce again more travel times in the experiment, making it difficult to assess. In the stated choice design has been aimed for making the list of remaining time attributes as straightforward as possible for the respondents, visualizing it like a route planner and giving a clear overview of the possibilities. As e travelers it is important in mode choice decisions to be aware of the possibilities available (Schneider, 2013). The ‘first mile’ has been implied in the design by adding a longer distance between the home location (A) of the respondent and the first transport mode of public transportation. This can also be seen in Figure 3.3.

The other attributes, different than travel times, are the parking tariffs, the costs for the trip and hub facilities. Parking tariffs seem to have an effect on the use of hubs (Habibian & Kermanshah, 2013; Hounsell et al., 2011; Molin et al., 2014), also the relation between parking tariffs and different purposes seems to exist (Strategy Development Partners, 2019). This effect should be investigated for the Eindhoven situation as well, because solely offering hubs might not stimulate travelers in changing their behavior, but the increased parking tariffs might be the push factor in order reduce the car traffic in the city center (Habibian & Kermanshah, 2013; Provincie Noord-Brabant, 2018). Related to the parking costs, the travel costs are also included in the study as these are assumed to influence the choice as well.

The hub facilities mostly relate to convenience and waiting time, as these facilities might influence the way the waiting time is perceived. For example, when a coffee corner would be available, travelers can grab a coffee and make their waiting time more pleasant. The Province of Noord-Brabant also names a parcel pick-up, so people can pick up a parcel on their way home providing some convenience to the users (Provincie Noord-Brabant, 2018). For future strategies on the implementation of hubs surrounding Eindhoven, insights in the preferences regarding these facilities are useful.

In total, ten attributes have been selected to define the hubs and modalities in the choice experiment. These attributes all have three attribute levels and can be divided into two sub-categories: ‘hub-specific attributes’ and ‘mode-specific attributes’. The attributes on travel time and travel costs, are based on the personal situation of the respondent. In the questionnaire accompanying the SC experiment, the respondents are asked to fill-in their usual travel time by car and public transportation (if they are aware of this) to Eindhoven and their travel costs for transport modes. Section 3.2.4 elaborates on the questionnaire accompanying the SC experiment. These values are used to compute the personal experiment for the respondent, including the attribute levels discussed in the next two sections.

Hub specific attributes

For this research, hubs are described as locations at the edge of the city (outside of the ring road of Eindhoven), where visitors can park their car and change to other (sustainable and/or shared) transport modes to travel to the city center.

1. Reduction car travel time to hub

The first attribute takes into account the possible reduction on travelers' car travel time when they park their car in a hub. It is expected that from home to a hub takes relatively less time as it avoids driving into the city center. However, this is not necessarily the case, as some people also have to make a detour to reach the hub. Additionally, the transition to the other modality also takes some time. Therefore, the levels of reduction in car travel time when parking in a hub have been set to 0, 2, and 4 minutes; the travel time by car from the ring road to the city center is 7 minutes on average.

2. Parking tariffs hub

The second attribute concerns parking costs at the hub with levels €0.-, €4.-, and €8.- per day. These parking tariffs are respectively based on current P+R facilities in Eindhoven (Pop-up P+R Eindhoven South) and P+R facilities of the neighboring city 's-Hertogenbosch, which is a good example of a well-working P+R system (Parkeren Den Bosch, 2018). The last value of €8,- is defined to measure the effect of a quite high parking tariff at the hub.

3. Hub facilities

The third and last hub-specific attribute defines the hub facilities. For this study the facilities of a Coffee & Sandwich store, a Parcel Pick-up point, or none have been selected as attribute levels. It might for example be the case that people want to wait longer for the bus when a coffee corner is present at the hub or think it is convenient to pick up their parcel on the way. These facilities are expected to be relevant for most of the respondents, in contrast to for example a daycare, which might also be a convenient facility to have at a hub, but this is not relevant for people with no or older children. The three hub-specific attributes are the same for both "car + bus" and "car + shared bike" within one choice task.

Mode specific attributes

These attributes do not specifically relate to the hubs, but are applicable to the various transport modes.

4. Parking tariffs city center

As the municipality of Eindhoven aims at keeping the city center accessible by stimulating people to travel by public transportation or bike (Gemeente Eindhoven, 2018a), the levels of parking costs within the ring road in non-hub facilities are set in this study at €3.-, €5.-, or €7.- per hour. €3.- is on average the current parking tariff (between €2.40 and €3.30) within the ring road of Eindhoven (Parkeren in de stad, 2018). An increase of €2,- or even €4,- is considered to be of interest for future parking policies; staying under the new parking tariff of Amsterdam; €7.50 per hour (Rottier, 2018).

5. Bus travel time from hub to city center

The fifth attribute is the travel time from the hub to the city center by bus, which takes on average 6, 9, or 12 minutes, based on measurements on Google Maps from the current P+R locations in Eindhoven (Google, 2018). These locations have been selected as these will most likely serve as the first (MaaS) hub locations as well, and from there the municipality can expand.

6. Waiting time for bus at hub

Also the waiting time for the bus has been based on the current frequencies for busses from these P+R locations, resulting in 2, 6, or 10 minutes waiting time as the attribute levels of the sixth attribute (OV9292, 2018).

7. Bus travel costs from hub to city center

The seventh attribute represents the travel costs by bus from the hub to the destination in the city center. The levels are €0.-, €0.5, and €1,-. This is a little lower than the normal bus tariff, but a particular deal together with the parking price is expected to stimulate people using the hubs, like at the moment the pop-up P+R providing free transportation to the city center.

8. Bike travel time from hub to city center

The travel time from hub to city center by shared bike has again been based on measurements from Google Maps from the current P+R's in Eindhoven, resulting in levels of 5, 10 or 15 minutes for the eight attribute (Google, 2018).

9. Bike travel costs from hub to center

The ninth attribute concerns the travel costs from hub to the city center by bike. The levels have been set to €0.-, €0.5, and €1.-. They vary according to prices set by the municipality of Eindhoven and the private bike-sharing company providing the shared-bikes at the pop-up P+R Eindhoven South; €1.- for 30 minutes (Eindhoven365, 2018; FlickBike, n.d.).

10. Bike travel costs from public transport stop to final destination

For the tenth attribute, travel costs for a shared-bike from a public transport (PT) stop, which can be the train station, or a bus stop in the city center are similar to the ninth attribute.

An overview of the ten attributes is shown in Table 3.1. In addition to the attribute levels, the last column also shows the relation of the attribute to the personal variables of the respondent, for example the levels of the first attribute will be subtracted from the respondents' current travel time by car to Eindhoven, and this new value will be shown in the choice tasks.

Tab. 3.1 Attributes and levels

	Attribute	**Units**	**Attribute levels**	**Relation to personal variables**
1	Reduction car travel time to hub	min	0, 2, 4	Subtracted from current car travel time
2	Parking costs at hub	€/day	0, 4, 8	-
3	Hub Facilities	-	Coffee & Sandwich, Parcel Pick-up, None	-
4	Parking costs in center	€/hour	3, 5, 7	-
5	Travel time from hub - center by bus	min	6, 9, 12	Added to current car travel time
6	Waiting time at hub for bus	min	2, 6, 10	Added to current car travel time
7	Travel costs bus from hub	€	0, 0.5, 1	Added to current car travel costs
8	Travel time from hub center by bike	min	5, 10, 15	Added to current car travel time
9	Travel costs bike from hub	€	0, 0.5, 1	Added to current car travel costs
10	Travel costs bike from PT stop	€	0, 0.5, 1	Added to current PT travel costs

3.2.3. Experimental design stages 3, 4 and 5

The third stage of the design process concerns the experimental design consideration, in which the type of design and model specification is discussed and stage four is the generation of the experimental design itself (Hensher, Rose, & Greene, 2005). In this study, a labeled experiment on transport mode alternatives has been used. By labeled is meant that the alternatives have labels that provide the respondent with some information on the alternatives. In this study the transport modes represent the alternatives, which gives a certain image to the respondents when thinking about the alternatives. The full factorial design consists of 3^10 possible combinations, which is not manageable. Therefore an orthogonal fractional factorial design has been used, generated from SAS in 54 treatments, see Appendix A.2. Each treatment defines the attributes of a choice set as shown in Appendix A.1. Each respondent is presented 9 randomly selected choice sets, implying that 6 respondents are required to evaluate all 54 choice sets once. Effects coding is used to allow for non-linear effects to be detected in the attribute levels and the base attribute level is not entangled with the overall mean of the utility function. In order to effects code, a set of new variables is created for each attribute coded. The number of new variables created, is equal to the number of attribute levels of the attribute, minus one. Since all attributes in this experiment have three attribute levels, two variables are created for each attribute, this can also be seen in Table 3.2. This table shows the effects coded attribute parking costs in the city center, and the variables PC Center 1 and PC Center 2 are newly created for this attribute. As can be seen, for the attribute level of 3 per hour, a 1 is placed in the column of the variable PC Center1, and a 0 is placed in the column of the variable PC Center 2. For the attribute €5 per hour the exact opposite is done. The third level is the base level, and is coded -1 for both of the new variables (Hensher et al., 2005).

Tab. 3.2 Example effects coding

	PC Center1	PC Center2
€ 3 per hour	1	0
€ 5 per hour	0	1
€ 7 per hour	-1	-1

3.2.4. Experimental design stages 6, 7 and 8

Stage six, seven and eight are respectively the generation of the choice sets; randomization of the choice sets; and the construction of the survey instrument (Hensher et al., 2005). These stages all have been performed in the Berg enquête system; developed especially for SC experiments by Eindhoven University of Technology. The next section elaborates further on the design of the entire questionnaire including the experiment.

Construction questionnaire

The choice experiment in the Berg system has the lay-out similar to a route planner with all possible travel alternatives respondents have, as explained previously. These alternatives are accompanied by a personal context for each respondent. These are based on answers they provided in the questions preliminary to the SC experiment.

The questionnaire starts with questions on current (travel) behavior when visiting Eindhoven city center by car (see Appendix B for the complete questionnaire). First is determined if the respondent falls within the target group of the study. The target group for this Stated Choice experiment has been defined as visitors of Eindhoven city center that do visit the city center at least sometimes by car for incidental or regular purposes. Incidental purposes are for example shopping, visiting friends or family, events or going out/going for dinner. Regular purposes are defined as work, study, doing sports or going for groceries. Literature suggests that MaaS has most potential in serving incidental trips, which was concluded from the focus group discussions performed by the Netherlands Institute for Transport Policy Analysis (KiM, 2018a).

The respondents meet the target group requirement when:

1. They sometimes visit the city center of Eindhoven by car.
2. They have no constraints in their ability to cycle or use public transportation, as the alternatives offered in the SC experiment contain bike and public transportation.

When the respondent does not meet the requirements, a screen is provided with the message that he or she does not fall in the target group of the study (see Appendix B.3). If the respondent fits within the target group of the study, he will be presented with the rest of the questionnaire.

The second page of the questionnaire (Appendix B.4) asks questions on respondents' purpose, the duration of stay, their postal code, their car travel distance and travel time, the costs for this trip, the type of parking facilities they use and their parking costs. The answers to these questions (except parking costs) are used to shape the choice tasks for each respondent individually. Respondents are obliged to fill in the questions on purpose, duration and postal code. For the questions on the travel distance, travel time and parking costs, the option "I don't know" is provided. When respondents are not aware of how far their home is located from the city center of Eindhoven or the travel time for this trip, this is calculated for them based on their postal code. A list of all 4-digit postal codes in the Netherlands with the accompanying travel distance and travel time by car is generated using Bing Maps. When respondents have filled in the travel distance and/or time, these values are used in their SC experiment. This does not mean this is always the actual distance, but according to Hensher et al. (2005) it is important to pay attention to the perceived level of an attribute by the individual to make it the most realistic choice for them.

This also applies to the travel costs by car; these have been specified to the fuel costs as people can relate to this easier than when also their maintenance costs, depreciation, insurance and tax would be included. When the costs for the trip are unknown to respondents, these have been calculated based on their kilometers (which they either filled in themselves or have been generated based on their postal code). The average fuel consumption of a gasoline car is 1 liter on 14 kilometers and of an diesel car 1 liter on 20 kilometers (Gemiddeld Gezien, 2019). The price for one liter of gasoline is €1.684 and of one liter of diesel is €1.440 (UnitedConsumers, 2019). This means that on average a gasoline car drives for 12 cents per kilometer and a diesel car on average for 7 cents per kilometer. In the Netherlands, 79% of the cars are gasoline cars and 16% of the cars are diesel cars, so an average of 11 cents per kilometer is believed to be a realistic price.

The purpose, duration of stay, travel time and distance are provided as context of their 'usual' trip to Eindhoven city center by car. As mentioned previously, the type of purpose (incidental or regular) might influence the choices people make. Moreover, the duration of stay might influence the amount they want to pay for parking. The car travel time and travel costs both serve as input for the alternative 'car'.

The third page (Appendix B.5) in the questionnaire asks respondents on their use of public transportation. To provide the respondents with the most realistic alternatives in the choice task, they are requested to indicate if they would travel by bus or train when they would travel by public transportation to Eindhoven. When they use both train and bus for their trip, there is indicated that they should check the transport mode that they spend the longest time in during their trip. Nearby cities such as Best and Helmond have a train station for example, so these people might prefer using the train over the bus. When people would say they do not know, the alternative bus or train provided for public transportation is based on the distance they live from Eindhoven city center. Within 25 kilometers people are expected to travel by bus and people living further away are expected to travel by train.

The next question indicates how far respondents live from the first public transport stop they would use to travel to Eindhoven, this can indicate how long they have to travel for their 'first-mile' to the public transport stop, which could be influencing their choice despite it has not been mentioned that explicitly in the SC experiment. The respondents are then requested to indicate their travel costs to Eindhoven and here as well the 'I don't know' box can be checked. When they are not aware of their costs, the costs are generated for them based on the bus and train tariffs. The bus ticket is computed by 0.90 + 0.157 * *km* (Bravo, n.d.-b) for OV-chipkaart, however a single ticket can be bought as well in the bus for €4.24, so at a certain moment it is cheaper to buy a single ticket than checking-in with your OV-chipkaart. This moment is at (4.24-0.90)/0.157 = 21 kilometers, so from there the price is frozen to €4.24 in the SC experiment. for the train, the list of prices per kilometer is uploaded to the Berg system and for each kilometer a price is generated from the list (NS, 2019).

The travel time by public transportation is also asked to the respondent from the first public transport stop used. When a respondent indicated that the travel time of his trip was unknown, this travel time was calculated by a pre-determined formula. This formula is a simple linear formula, which uses a person's distance (in km) to a destination to compute the travel time to that location. As such, this formula has the form y=a+b*km, where y represents the travel time to be estimated, and coefficients a and b the weights. These coefficients were computed by regressing the travel time on the travel distance. For the bus formula, trips starting from 26 different towns in the North-Brabant region were selected as input for this regression, resulting in y = 8.4 + 1.34**km*. For the train, trips starting from 16 different cities were selected as input for this regression, resulting in y = 2.20 + 0.60**km.* However, it might be the case that people usually never use public transportation, which might be influencing their choice as well. Therefore a question is asked on how often the respondent uses public transportation. If they choose any answer but 'Never' the question pops-up if they have an OV-chipkaart and what subscription they have on the card.

Table 3.3 provides an overview of the previous mentioned input for the Stated Choice experiment when respondents checked the box 'I don't know' to certain questions. As can be noted from the previous elaboration, the questionnaire has been set up in such a way that respondents have a low effort of filling it in, trying to reduce the drop-out rate.

Tab. 3.3 Input questions Stated Choice experiment

Question	Units	When checked 'I don't know'
Travel distance by car	km	Based on postal code distance by car to Eindhoven center
Travel time by car	min	Based on postal code travel time by car to Eindhoven center
Travel costs by car	-	0.11**travel distance by car*
Bus/train to Eindhoven	-	≤ 25 km → bus > 25 km → train
Public transport costs	€	Bus → 0.90 + 0.157 * *km* Train → generated from pricelist NS
Public transport travel times	min	Bus → 8.4 + 1.34**km* Train → 2.20 + 0.60**km*

The next page (Appendix B.6) of the questionnaire provides the respondents with an introduction on the concepts 'mobility hub' and 'shared mobility'. 'Mobility hubs' are defined as locations where you can transfer to various (sustainable) transport modes. You can compare them with a transferium/P+R at the edge of a city where you park your car and you travel by bus or bike to the center. At these mobility hubs other facilities such as a coffee- & sandwich store, or parcel pick-up point can be present as well. 'Shared mobility' are transport modes that you do not own personally, but that can be used by everyone against payment. This can be the train or bus, but also shared bicycles and shared cars. To give people a better understanding on these concepts, a short movie from the Province of Noord-Brabant on shared mobility is provided. Respondents that are not familiar with the concepts and need some more explanation to understand the concepts are requested to watch the movie before continuing to the SC experiment.

The next part is the SC experiment (Appendices B.6, B.7 and B.8), which has been elaborated previously. Based on the answers of the respondent a specific SC experiment is generated for them. Figure 3.4 shows how the alternatives are assigned to the respondents. Six different SC experiments are composed, which vary in: bus + bike; bus + e-bike; bus + no bike; train + bike; train + e-bike and train + no bike. What experiment respondents get is based on their travel distance, their preference for train or bus, and the fact if they own a bike or an e-bike.

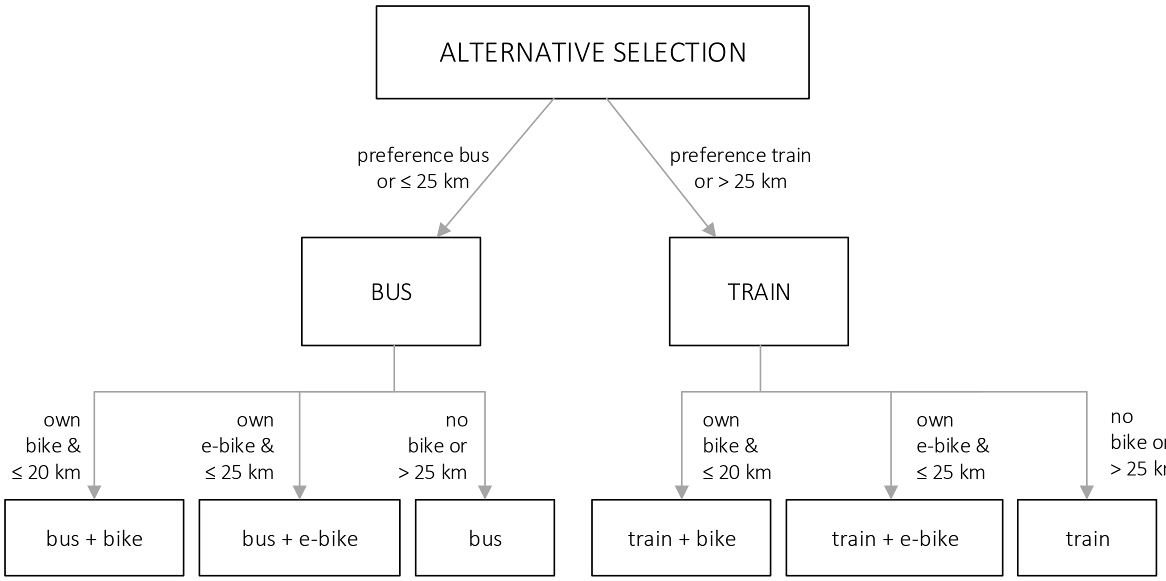

Fig. 3.4 Alternative selection

Within the specific SC selection, the alternatives have been constructed with the personal situation of the respondent, as elaborated previously. Their own perceived (or generated) travel times, costs, purpose and duration framed the alternatives they received in their choice task. After the nine choice tasks, the questionnaire continues by asking the respondents about their consideration of using a more innovative transport mode when these would be available in a mobility hub (Appendix B.9). Several 'innovative' transport modes (electric two-person car, electric car, electric step, electric scooter and electric bicycle) were offered to respondents and they could check which one(s) they would consider using when these would be available in the mobility hub in addition to bus and bike.

The questionnaire ends (Appendix B.10) by the socio-demographic characteristics gender, education level, year of birth, yearly net income, household size, living environment, and work situation.

3.2.5. Conclusion

This section provided an overview of the design process of the SC experiment and the accompanying questionnaire following Hensher et al. (2015). Respondents are asked to imagine they want to travel to Eindhoven city center, and they are offered a number of transportation alternatives based on their personal situation, which they filled in at the accompanying questionnaire. Attribute levels are varied using a orthogonal fractional factorial design of 54 treatments, and each respondent is given nine choice tasks to evaluate. These choice tasks have been generated based on their personal situation.

Section 3.3 describes how the data collected in the stated choice experiment is modeled in order to understand and predict the choice behavior of travelers.

3.3. Choice modeling

Discrete choice models aim to describe individuals' choices between a choice set containing a number of alternatives (Train, 2009). In order to understand and predict this choice behavior, the variability in reasoning between individuals should be captured in the data collected, in the stated choice experiment. This variability is also referred to as *heterogeneity*. In general individuals derive a certain satisfaction from the attributes associated with an alternative. This satisfaction is more commonly referred to as *utility* and it is assumed that an individual will choose the alternative from a choice set that provides the individual with the highest level of utility from its attributes. This is captured in the generally assumed behavioral rule 'utility-maximizing behavior', which believes that an individual will act as if they are maximizing their overall utility when choosing an alternative (Hensher et al., 2015).

The goal of discrete choice modelling is the identification of the contribution of a certain attribute to the overall level of utility associated with every alternative in a choice set. The overall utility of an alternative is represented by U_{iq}, in which i represents a specific alternative, and q an individual. U_{iq} represents the utility of alternative i for individual q. It should be noted that this is the utility associated with an alternative relative to the utility of another alternative in the same choice set. As mentioned previously, there is aimed to capture as much heterogeneity in the data as possible, but in reality a part will stay unobserved (Hensher et al., 2005). Actually, this is the theory underpinning the Random Utility Model, in which V_{iq} represents the structural utility (observed) and ε_{iq} the random utility (unobserved) (Hensher et al., 2005; Kemperman, 2000):

$$U_{iq} = V_{iq} + \varepsilon_{iq} \quad (1)$$

The structural utility V_{iq} is explained by the following expression:

$$V_{iq} = \sum_n \beta_{in} X_{inq} \quad (2)$$

Where, β_{in} is the parameter representing the weight of attribute n for alternative i and , X_{inq} is the score of alternative i on attribute n for individual q. In which β_{i0} is the alternative specific constant, which is not associated with any of the observed attributes, and represents on average the role of all unobserved utility. The random utility ε_{iq} represents the unobserved component of the utility, but behaviorally nothing is known about these influences. Each individual will have some utility in the unobserved component and a distribution is assumed to exist of such unobserved components of utility across the sampled population.

The probability that alternative i will be chosen by an individual is equal to the probability that the utility of alternative i is greater than the utility of alternative j after evaluating all alternatives J in the respondents' choice set ($j = 1, \dots i, \dots J$). This can be written as (Hensher et al., 2015):

$$p_i = p(U_i \geq U_j) \; \forall \; j = 1, \dots i, \dots J \quad (3)$$

3.3.1. Multinomial Logit (MNL) model

If the random utility components (ε_{iq}'s) are assumed to be Independently and Identically and Distributed (IID) following a double exponential (Gumbel) distribution, this results in the most common and easy to use choice model; the multinomial logit (MNL) model (Hensher et al., 2015). This means that the unobserved terms are not correlated (Independent) and they have the same variance (Identical) (Train, 2009). The probability that individual q will choose alternative i from the choice set of J alternatives, is equal to (Hensher et al., 2005):

$$p_{iq} = \frac{\exp(V_{iq})}{\sum_{j=1}^{J} \exp(V_{jq})}; \quad j = 1, \dots, i, \dots, J \tag{4}$$

The probabilities of all alternatives sum up to one, which means that an increased probability for choosing one alternative, inevitably means a decreased probability for choosing the other alternatives (Train, 2009). The ratio of choice probabilities for an individual are therefore assumed to be unaffected by the systematic utilities of other alternatives (Ben-Akiva & Lerman, 1991). This is also known as the Independence from Irrelevant Attributes; the IIA-property. This property makes the MNL model easy to use and provides an approximation to reality (Train, 2009).

For the MNL model, the parameters are estimated through a maximum loglikelihood estimation:

$$LL(\beta) = \Sigma_q \Sigma_i y_{iq} \ln(p_{iq}) \tag{5}$$

Where y_{iq} is 1 when the alternative is chosen by individual q and 0 otherwise. This results in an average parameter estimation across the entire population for each attribute level. Only taste variation that relates to the observed variables can be handled in with MNL, not allowing for taste variation in the unobserved variables (Train, 2009).

The Goodness-of-fit of the model can be determined by McFadden's Rho-Square:

$$\rho^2 = 1.0 - [LL(\beta) \; / \; LL(0)] \tag{6}$$

Where LL(0) is the loglikelihood assuming equal choice probabilities for all alternatives in the choice set. The closer to 1 the ρ^2 is, the better the model explains the data. In general a ρ^2 between 0.3 and 0.4 is considered a decent model-fit (Hensher et al., 2015).

Adding more parameters to the model will result in a higher ρ^2, however, this does not always mean that the gain in performance of the model is worth the increased number of parameters. Therefore the AIC (Akaike Information Criterion) is used, as this criterion takes into both the log likelihood LL and the number of parameters K estimated in the model (Fabozzi, Focardi, Rachev, & Arshanapalli, 2014):

$$AIC = -2LL + 2K \tag{7}$$

The AIC value on itself does not provide any information, but it can be compared to the AIC of other models. The model with the lowest AIC value is considered to be the best model as it estimates the relative amount of information lost by the model, which should be as small as possible.

3.3.2. Mixed Logit (ML) model

The Mixed Logit (ML) model is a more generalized form of the MNL model, as it allows for individuals to have different β's, in contrast to the MNL logit model where one β is estimated representing the entire population (Hensher et al., 2005). Equation 8 provides the ML model (Hensher et al., 2015):

$$p(choice_{qt} = i | x_{qt,i}, z_q, v_q) = \frac{\exp(V_{qt,i})}{\sum_{j=1}^{J_{qt}} \exp(V_{qt,j})}; \quad j = 1, \dots, i, \dots, J_{qt} \qquad (8)$$

Where, $V_{qt,j} = \beta_q' x_{qt,j}$ and $\beta_q = \beta + \Delta z_q + \Gamma v_q$

$x_{qt,j}$ = the K attributes of alternative j in choice set t for individual q;

J_{qt} = the J alternatives in choice set t for individual q;

z_q = set of M characteristics of individual q that influence the mean of taste variation parameters (reflects the observed heterogeneity);

v_q = a vector of K random variables with zero means and known variances and zero covariances.

However, as can be seen this model is comprehensive, and it eliminates the three limitations of the MNL model. Firstly, it allows for similarities to exist between alternatives in the unobserved part of the utility and hereby relaxing the IIA-property of MNL (Error Components Model). Secondly, the model can measure the effects of multiple observations on choices per individual, which is useful for panel and, in this case, SC data (Repeated Choices model). Thirdly, it can also measure heterogeneity in the parameters of an attribute across the population (Random Parameter Model) (Borgers, 2017; Hensher et al., 2015; Train, 2009).

Both the Error Components Model and the Random Parameter Model will be applied in this study. As mentioned, the Error Components Model allows for common components to exist between alternatives. This means that for example between the public transport alternatives the unobserved factor of 'traveling with other passengers' is not measured in the observed utility, but can influence the choices for these alternatives. Therefore random components representing the effect of 'other passengers' are added to the model and these have been dummy coded according to those assumed common components. The standard deviation σ of the random component reflects the similarity between the alternatives. When the standard deviation σ increases, the similarity between the public transport alternatives increases and therefore the probabilities these alternatives will be chosen decrease. The Random Parameter Model is estimated as it is expected that variance exists within the sample for the attribute-parameters measured. In Equation 8, β shows the averaged parameter for an attribute over the sample population (like estimated by the MNL model).

The Random Parameter model shows the variance of the sample population for this attribute, by adding a random extra value (v_q in Equation 8) to the attribute parameters to measure the taste variation. For example when we look at mode choice behavior, some individuals attach more value to travel time than others. The variance is expressed by the additional random value, which have zero mean and a certain standard deviation σ (Borgers, 2017).

When variance within the sample population exists for certain attribute-parameters, it is valuable to measure if a certain structure exists in that variance. This brings us to the Latent Class model, which groups the individuals with similar preferences (parameters) into classes.

3.3.3. Latent Class (LC) model

The theory on the LC model supposes that the behavior of an individual depends on both observable attributes and on latent (unobserved by the researcher) attributes. The latent class model takes the latent heterogeneity into account by grouping the individuals in the population into a finite number (C) of groups (classes). The classes are heterogenous, but have similar β's for the individuals in the group. The classes themselves differ from each other. Equation 9 provides the LC model for discrete choice among J_q alternatives (the size of the choice set may vary per individual), by individual q observed in T_q choice observations (this number may also vary per individual) (Hensher et al., 2015):

$$p\left(choice_{qt} = i \,\middle|\, class = c\right) = \frac{\exp(V_{qt,i})}{\sum_{j=1}^{J_{qt}} \exp(V_{qt,j})}; \quad j = 1, \dots, i, \dots, J_{qt} \tag{9}$$

The classes are unknown at first, so these have to be estimated using the data. The probability that individual q belongs to class c is estimated using the MNL model form:

$$H_{qc} = \frac{\exp(z\prime_i \theta_c)}{\sum_{c\prime=1}^{C} \exp(z\prime_i \theta_{c\prime})}; \;\; c = 1, \dots, c', \dots, C, \quad \theta_c = 0 \tag{10}$$

Where z_i is the set of observable characteristics. Among the classes, similarities might exist in socio-demographic characteristics, identifying a certain 'type' of group.

3.3.4. Conclusion

In order to analyze the problem of this research, a Stated Choice experiment is performed to understand and predict the mode choice behavior of travelers to Eindhoven city center. The goal is to capture as much variability in reasoning in the data, but in reality parts will stay unobserved; resulting in the Random Utility model. Several choice models exist to measure probability of an individual choosing a certain alternative. The MNL model is the most widely applied and easy to use, but it has its limitations. Therefore the ML logit model was introduced, allowing for similarities to exist between alternatives; the effect of repeated choices per individual can be measured; and it allows for heterogeneity in the parameters estimated across the population. Lastly, the Latent Class model is introduced, which allocates individuals to classes based on their choice behavior. With this model certain groups can be identified exhibiting the same behavior, which might be interesting for policy strategies.

3.4. Conclusion

This chapter gave an introduction to choice behavior and choice modeling. The Stated Choice experiment has been selected as measurement approach for this study, as it can be used to study people's choices regarding given hypothetical (new or non-existing) situations and facilities. Following the design stages of Hensher et al. (2015), the SC experiment has been constructed, as well as the accompanying questionnaire. In this research, the design of the SC experiment is not as straight-forward as common SC experiments, in which usually two (or more) alternatives with varying attribute levels are presented to a respondent. This choice task would then be repeated a number of times and in each choice task the attribute levels differ per alternative. However, in this study respondents were given five or six transportation alternatives, each having certain attributes relating specifically to one or two of the alternatives. This made the choice tasks quite challenging for the respondents, and a more critical reflection upon this is provided in Section 5.3.

The MNL model, the ML model and the LC model have been introduced as well, and these models are used to understand and predict the choice behavior of individuals, which are used to study the data in Chapter 4. This chapter furthermore extensively discusses the data collected.

CHAPTER 4

RESULTS

As explained in the previous chapter, a SC experiment is selected in order to investigate the preferences of the travelers towards Eindhoven city center regarding sustainable transportation. This chapter provides insights in the data collected for this SC experiment in Section 4.1, as well the preparation of this data. Section 4.2 presents the results of the model estimations of the discrete choice models: Mutinomial Logit model, Mixed Logit model and Latent Class model. In Section 4.3 a practical examining of the results is provided by means of scenario sketching. Lastly, Section 4.4 concludes this chapter by summarizing the main findings.

4.1. Data

This section provides an overview of the data collection and preparation in Section 4.1.1. Section 4.1.2 gives insights in the descriptives of the data and the origin of the respondents.

4.1.1. Data collection

People that sometimes visit Eindhoven city center by car are the target group for this study, which is a quite specific group to capture. In order to stimulate questionnaire response, an Escape Room Voucher and 20 Koffiekaartjes were raffled among the respondents who belonged to the target group and finished the questionnaire completely. These visitors were recruited as respondents between the 12th of February and 11th of March by means of the following channels:

- 200 SmartwayZ.NL panel members of the South of the Netherlands; a selection was made of people that work in Eindhoven and live outside of Eindhoven.
- Intranet of the municipality of Eindhoven.
- Emailing by the secretary of CME to CME students and the research group ISBE.
- Own network of family and friends, and their networks.
- LinkedIn, at which the post was shared 28 times by friends, family, colleagues and second link network contacts.
- Facebook, at which the post was shared 10 times by friends, family and colleagues.

The questionnaire has been constructed in threefold, one Dutch version for SmartwayZ.NL, one Dutch version for own network spreading, one English version. Table 4.1.1 shows the clicking, opening, finishing and within target group respondents.

Tab. 4.1.1 Descriptives completion questionnaire

Questionnaire	# clicked	# started	# finished	# In target group
Dutch	769	494	382	341
Dutch SmartwayZ.NL	84	73	49	43
English	44	10	7	5
Total	850	542	421	389

This total of 389 finished and within target group responses resulted in all 54 profiles having been evaluated between 62 and 65 times each. The responses have been checked on strange values, outliers and incompleteness. In total, ten values have been modified and fourteen respondents have been removed from the dataset for various reasons; see Appendix C for more details. Some respondents were quite quick in filling in (seven respondents needed only four minutes). However, the data did not provide evidence of wrongly filled-in questionnaires. Moreover, sixteen people probably paused during the completion of the questionnaire, as their duration was longer than 45 minutes. However, also this data did not provide evidence of wrongly entered values. In the end 375 correct responses were obtained.

4.1.2. Descriptives

The data of 375 respondents was found valid after data preparation. As can be seen in Figure 4.1.1, 215 respondents got the SC experiment with the bus alternatives, and 160 respondents the train alternatives. Of those 215 respondents facing the bus alternatives, 110 also got the bike alternative, 37 got the e-bike alternative and 68 people did not have a bike or lived too far away to cycle. Those facing the train alternatives, 37 got the bike alternative, 6 the e-bike and 117 were living too far away to bike or did not have a bike to their possession.

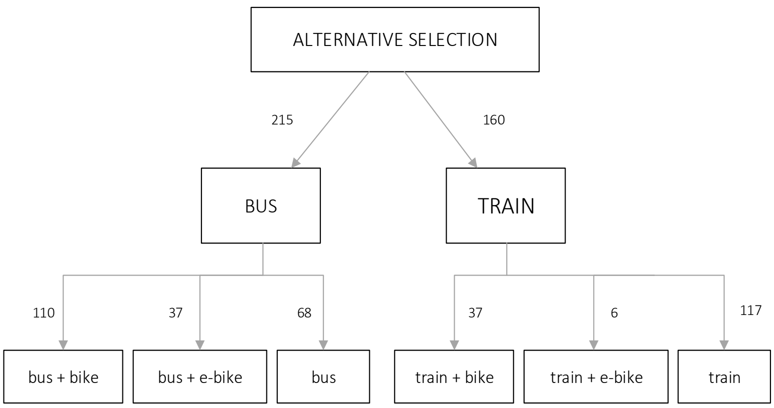

Fig. 4.1.1 Respondents per alternative

The socio-demographic characteristics of these respondents are shown in Table 4.1.2. The variables have been recategorized into fewer levels, resulting in more observations per level for further analyses.

Tab. 4.1.2 Socio-demographic characteristics

Variable	Categories	Freq.	%	Prepared categories	Freq.	%
Gender	Male	191	50.9	Male	191	51.5
	Female	183	48.8	Female	183	48.9
	Neutral	1	0.3	*removed*		
Age	≤ 20	3	0.8	≤ 30 years	106	28.3
	21 – 30	103	27.5	31 – 50 years	118	31.5
	31 – 40	41	10.9	> 50 years	151	40.3
	41 – 50	77	20.5			
	51 – 60	111	29.6			
	61 – 70	34	9.1			
	> 70	6	1.6			
Education level	Primary/special education	1	0.3	Low education level	81	21.6
	Secondary education	27	7.2	Middle education level	145	38.7
	Vocational education (MBO)	53	14.1	High education level	149	39.7
	Undergraduate (HBO)	145	38.7			
	University (WO, PDEng, PhD)	149	39.7			
Yearly net Income	Not more than €10.000	47	12.6	Low income level	72	19.2
	€10.001 till €20.000	25	6.7	Middle income level	128	34.1
	€20.001 till €30.000	51	13.6	High income level	118	31.5
	€30.001 till €40.000	77	20.5	Not provided	57	15.2
	More than €40.000	118	31.5			
	I'd rather not say	57	15.2			
Household size	1	62	16.5	1	62	16.5
	2	123	32.8	2	123	32.8
	3	47	12.5	3 or 4	143	38.1
	4	95	25.6	5 or more	47	12.5
	5	34	9.1			
	6	9	2.4			
	8	3	0.8			
	> 10	1	0.3			
Living situation	Single, no children	62	16.6	Single	62	16.5
	Single with residential children	14	3.7	Family + Children	163	43.5
	Married/living together without residential children	120	32.0	Family, no Children	120	32.0
	Married/living together with residential children	149	39.7	Other	30	8.0
	Living with (grand)parents/family	15	4.0			
	Living with others (no family)	14	3.7			
	Other	1	0.3			
Work status	Working part-time	73	19.5	Part-time work	66	17.6
	Working full-time	239	63.7	Full-time work	236	62.9
	Student/internship	48	12.8	Other	73	19.5
	No job	1	0.3			
	Retired	10	2.7			
	I'd rather not say	9	2.4			
	Other	8	2.1			

Much like reality, the male/female ratio of the sample is about 50/50. One person responded with 'neutral' to this question. The age groups show three peaks, one in the group between 21 and 30 years (27.5%), one between 41 and 50 years (20.9%) and one between 51 and 60 years (29.6%). In order to do further estimations, age levels have been categorized into three groups (≤ 30 years, 31 – 50 years and > 50 years), such that the groups are more evenly spread (respectively 28.3%, 31.5% and 40.3%). The education levels show high peaks at HBO (38.7%) and WO (39.7%) levels, and lower at secondary (7.2%) or vocational education (14.1%). Compared to reality, the sample has an overrepresentation of people with higher education, which might influence the results. This attribute has also been categorized into three levels to make the groups more evenly spread. Note that the middle educational level are the people with HBO level, which could be considered highly educated as well.

The yearly net incomes of the sample shows peaks at the higher income categories. This has to be taken into account when interpreting the results; for example the sample might therefore be less sensitive to increasing parking tariffs. This variable has been recategorized as well into four levels. The low income level are the levels 'Not more than €10,000' and '€10,000 till €20,000'. Levels '€20,000' till €30,000' and '€30,000 till €40.000' have been recategorized as middle income level. 'More than €40,000' is considered high income level. 57 respondents responded to this question with 'I'd rather not say', which is reflected in the 'Not provided' category.

Regarding the household size, most respondents have a household including one to five persons, with peaks at two and four person households. This variable has been recategorized into four levels as can be seen in the figure. Their living situation varies, and the peaks at married/living together with and without residential children relate to the household sizes. This variable is recategorized into four levels, by combining the categories 'Single + children' and 'Married/living together with residential children' to the category 'Family + children'. As well as 'Living with family', 'Living with others' and 'Other' has been recategorized to 'Other'.

Most respondents have a full-time job (63.7%), followed by the part-time workers (19.5%) and quite some students or interns as well (12.8%). It should be noted that these categories are overlapping as they add up to 103.5%. When recategorizing, the students with a part-time job have been considered students. This group of 'Students/internship' has been recategorized to 'Other', together with retired respondents, respondents without a job, and respondents who rather not responded to this question. The part-time workers that also filled in 'I'd rather not say' and 'Retired' are considered part-time workers. The full-time workers that also filled in 'Student/internship' are considered full-time workers. This results in the three new categories 'Part-time work (17.6%)', 'Full-time work' (62.9%) and 'Other'(19.5%).

Focusing on the trip towards Eindhoven, based on the respondents' postal code, Figure 4.1.2 is plotted. As can be seen, most of respondents' origins are concentrated around Eindhoven (the red circle) and some exceptions in the rest of the country and even from Belgium. Two respondents filled in a unidentifiable postal code and could therefore not be plotted.

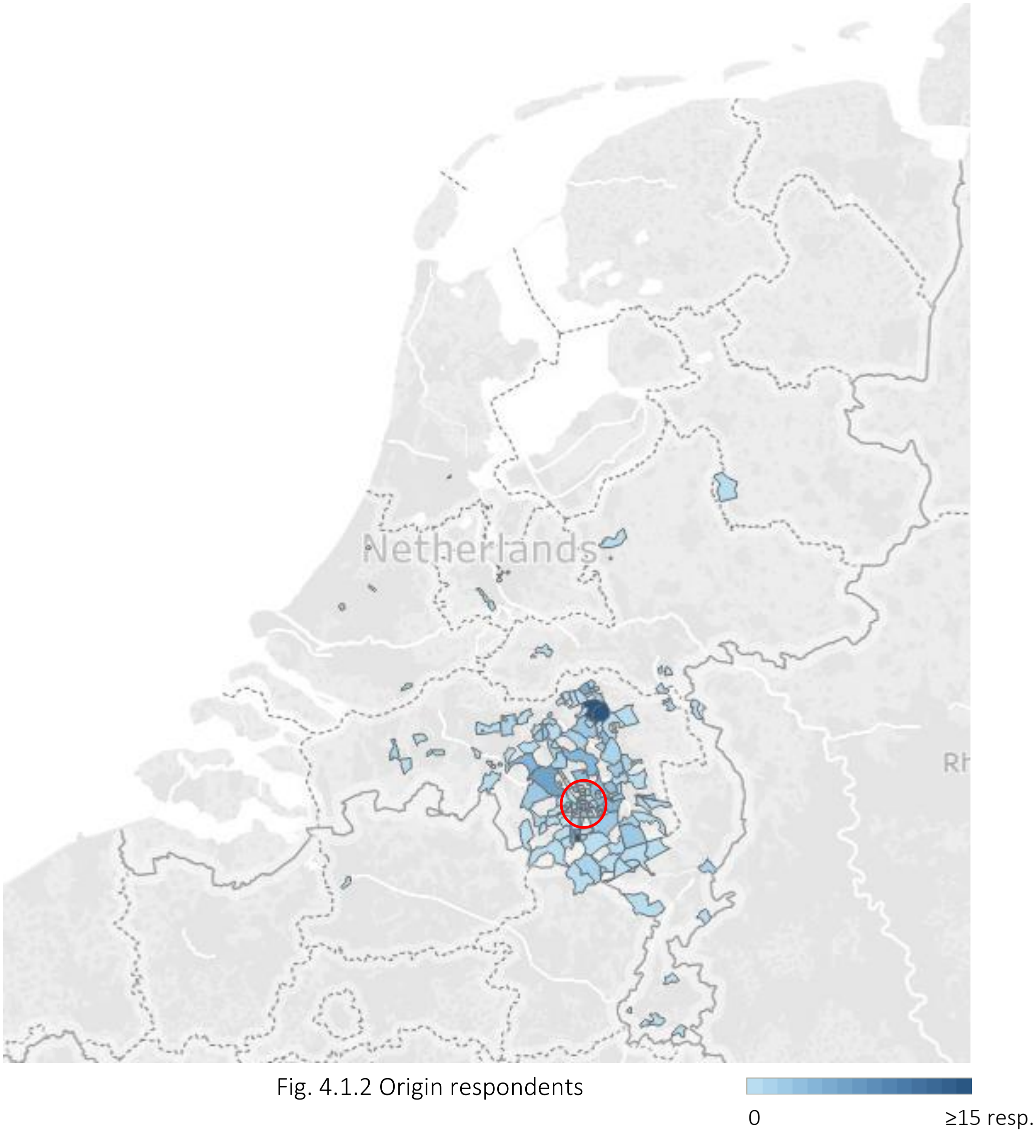

Fig. 4.1.2 Origin respondents

Zooming in on the Eindhoven region (Figure 4.1.3), the spread of the respondents surrounding Eindhoven can be seen more clearly. As can be seen many of the postal codes surrounding Eindhoven have been represented in the sample. Three postal codes have been represented fifteen times or more: Nistelrode, Heesch and Valkenswaard, which is due to the network of the researcher.

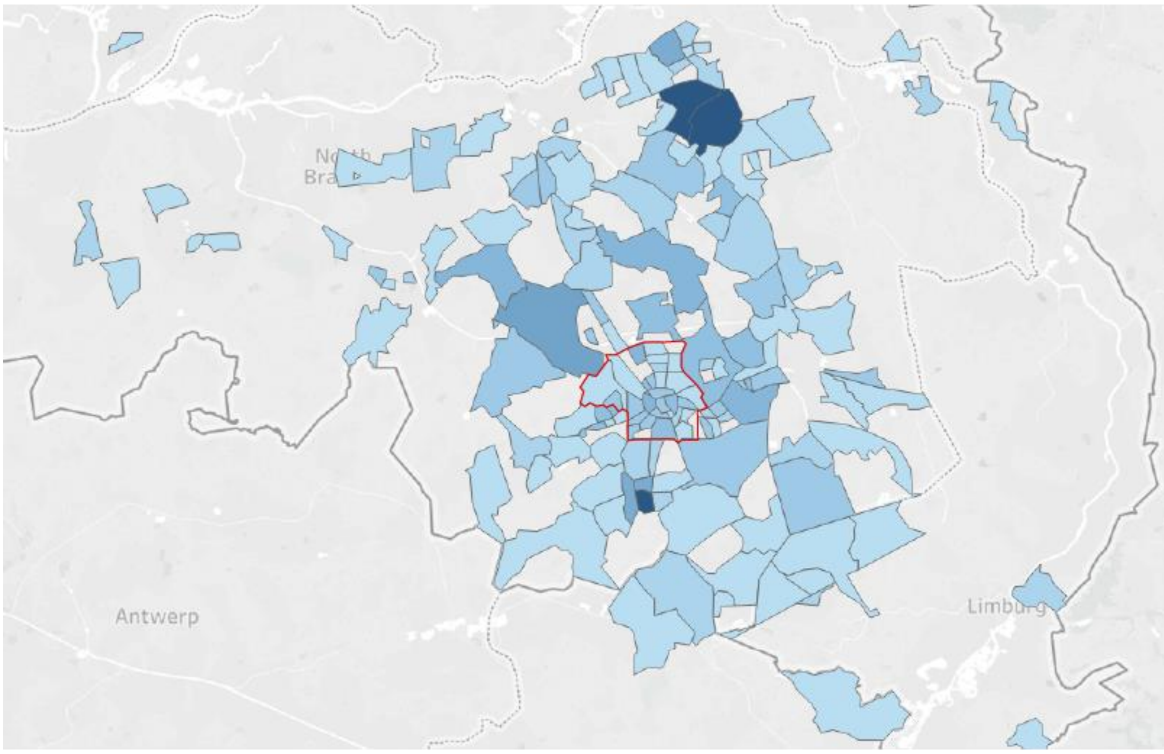

Fig. 4.1.3 Origin respondents zoomed in on Eindhoven region

0 ≥15 resp.

Respondents were asked to indicate the travel distance from their home location to Eindhoven. As can be seen in Figure 4.1.4, the respondents are quite nicely spread for the perceived distances between 0 and 40 kilometers, which also corresponds to Figure 4.1.3. In the categories between 11 and 40 kilometers, by far most people are living in villages. This makes sense, since for people living at this distance in a village, Eindhoven might be a feasible option for going shopping or work for example. However, people living further than 30 kilometers away from Eindhoven, might also be orientated towards another city. This variable has been recategorized into four levels: 0 – 10 km (30.9%), 11 – 30 km (37.6%), 31 – 50 km (20.3%) and more than 50 km (11.2%). Another recategorization is made for this variable, namely ≤ 10 and >10 km, which are respectively groups of 30.9% and 69.1%.

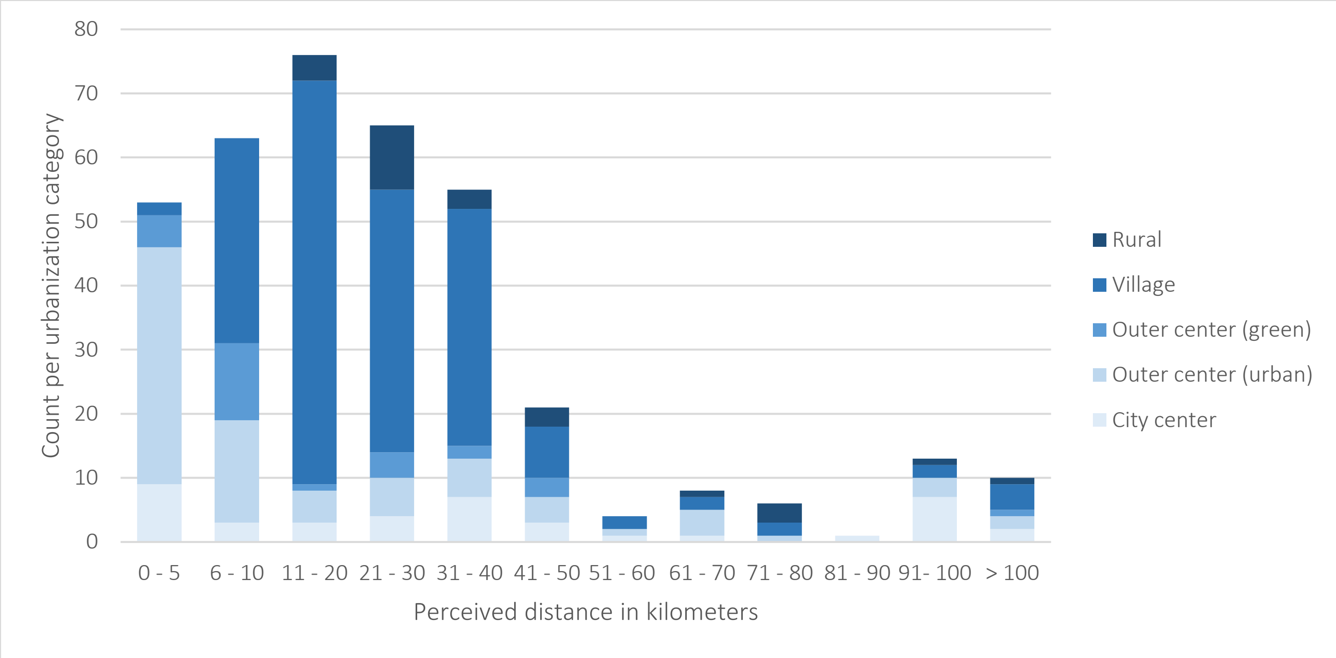

Fig. 4.1.4 Perceived kilometers home location from Eindhoven and urbanization category

In order to use the level of urbanization in further estimations, this variable has been restructured into two levels: city (center and outer) and village (and rural), resulting in more observations per level respectively 154 (41.1%) and 221 (58.9%). In Figure 4.1.4 can be seen that quite some respondents are living in Eindhoven (living within 10 kilometers from the center and living in a city or outer center). This number of respondents living in Eindhoven is 82 (21.9%) and 72 (19.2%) of the respondents are living in a city which is not Eindhoven.

The distance discussed in the previous figure might not be the determining factor in mode choice, but rather how their home location is connected to Eindhoven. Comparing these two levels with the public transportation use in Figure 4.1.5, one can see that people in villages use public transportation relatively less often; 66.5% only uses it a couple of times a year or less, compared to 37.7% in cities.

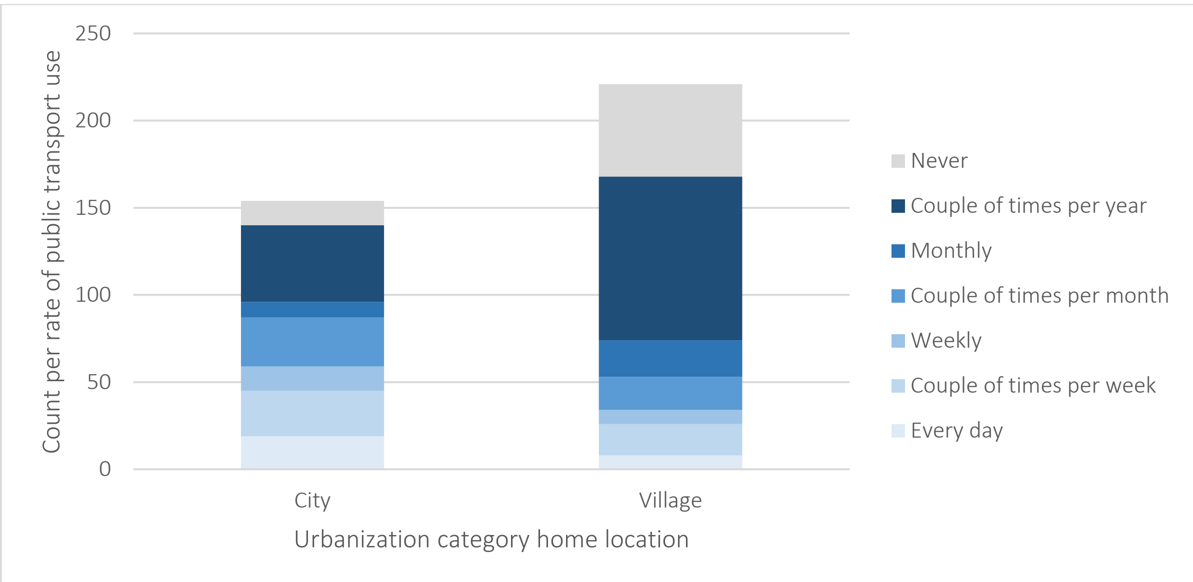

Fig. 4.1.5 Urbanization and the rate in which respondents use public transportation

Another determinant for the use of public transportation might be the distance from home to the first stop. However, as can be seen in Figure 4.1.6, this does not really seem to make a difference for the respondents, as the usage is relatively equal among the different categories, taking the decreasing number of respondents per category into account. In general, quite some people in the sample use public transportation only a couple of times per year.

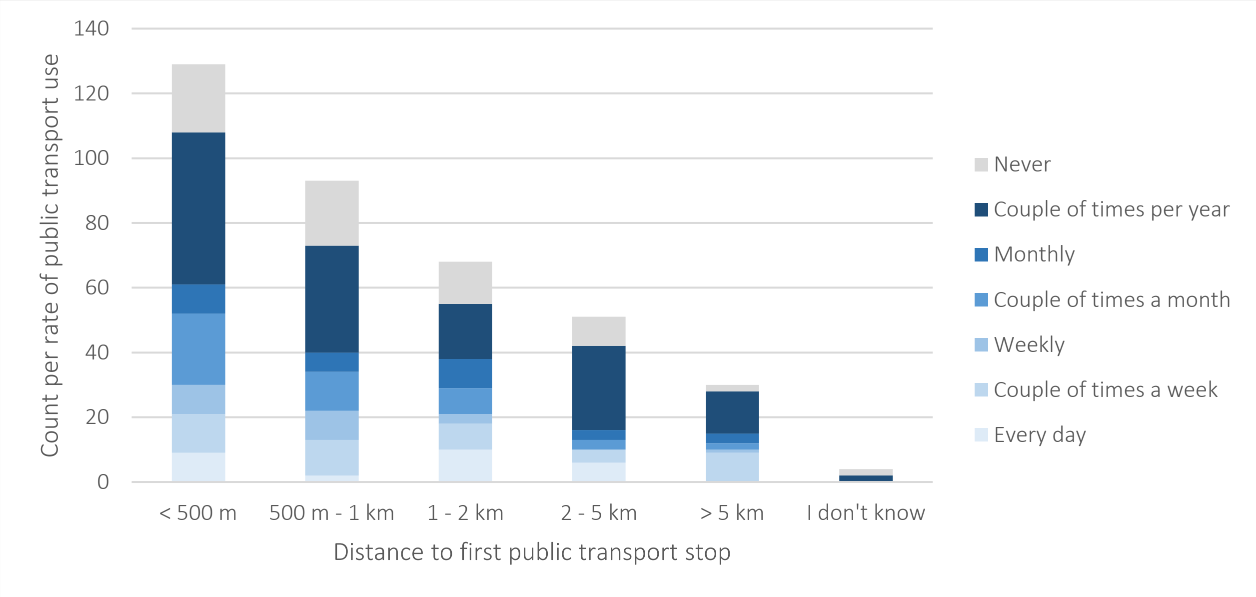

Fig. 4.1.6 Distance to the first public transport stop and the rate in which respondents use public transportation

When the type of car used to travel to Eindhoven is compared to public transport subscription, there can be seen that by far most people own a private (lease) car and the majority of them does not have PT subscription (see Figure 4.1.7). This is also the case with people having a business (lease) car. Respondents that borrow a car, or use a shared car or rental car for their trip also have a public transport subscription.

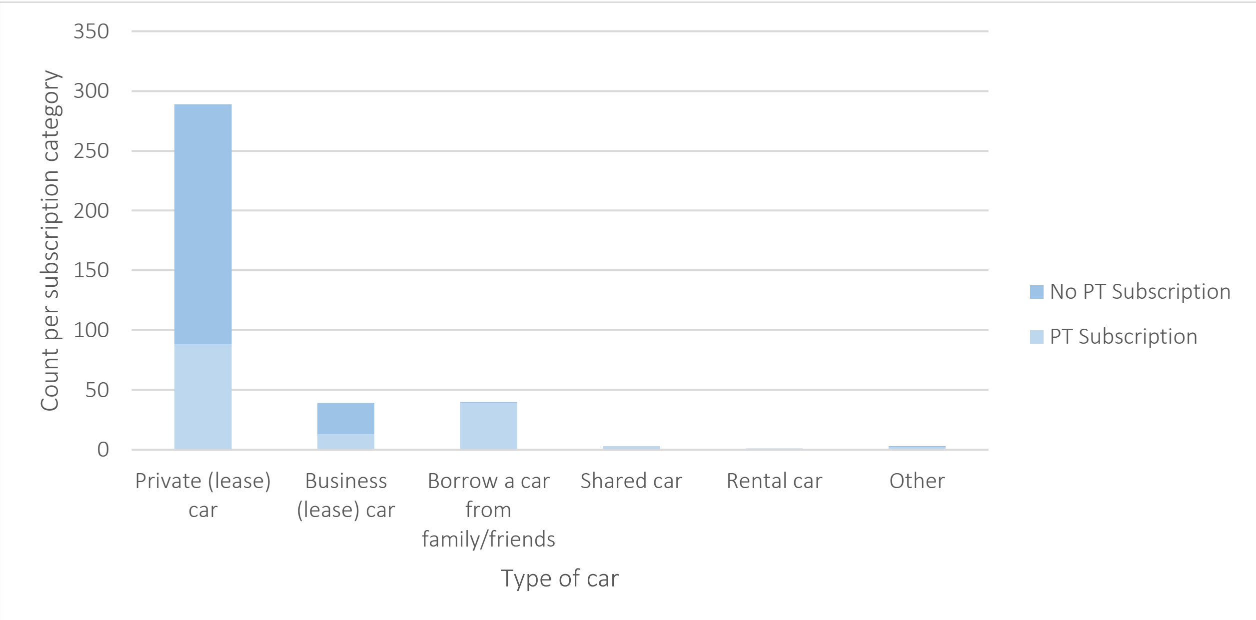

Fig. 4.1.7 Type of car use towards Eindhoven and public transport subscription

Figure 4.1.8 shows the parking spaces used for visiting Eindhoven. As can be seen in the figure, most people use a paid parking area, of which 60.8% a parking garage or open-air parking lot and 10.7% uses paid parking on the streets. 26.7% uses a free parking area, and only seven people (1.9%) use a P+R. Two of those seven state they always use a P+R; one of them uses P+R Meerhoven and the other Eindhoven Zuid. Three people state they often use a P+R for their visit, of which two use P+R Fuutlaan, and one does not know which one he/she uses. One person sometimes uses a P+R, of which he/she does not know which one. Lastly, one person rarely uses P+R Eindhoven Zuid.

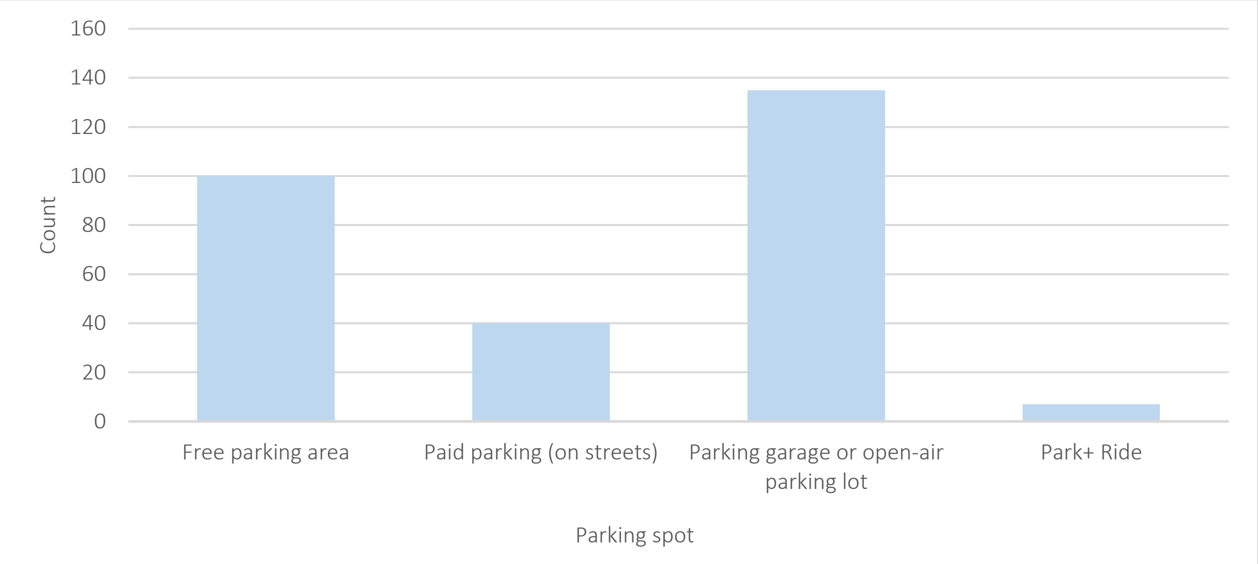

Fig. 4.1.8 Parking spot when visiting Eindhoven

The purpose people have for visiting Eindhoven might as well be an influencing factor for their mode choice. Figure 4.1.9 shows the purpose the respondents most often have for visiting Eindhoven. As can be seen most people visit the city for shopping or work purposes.

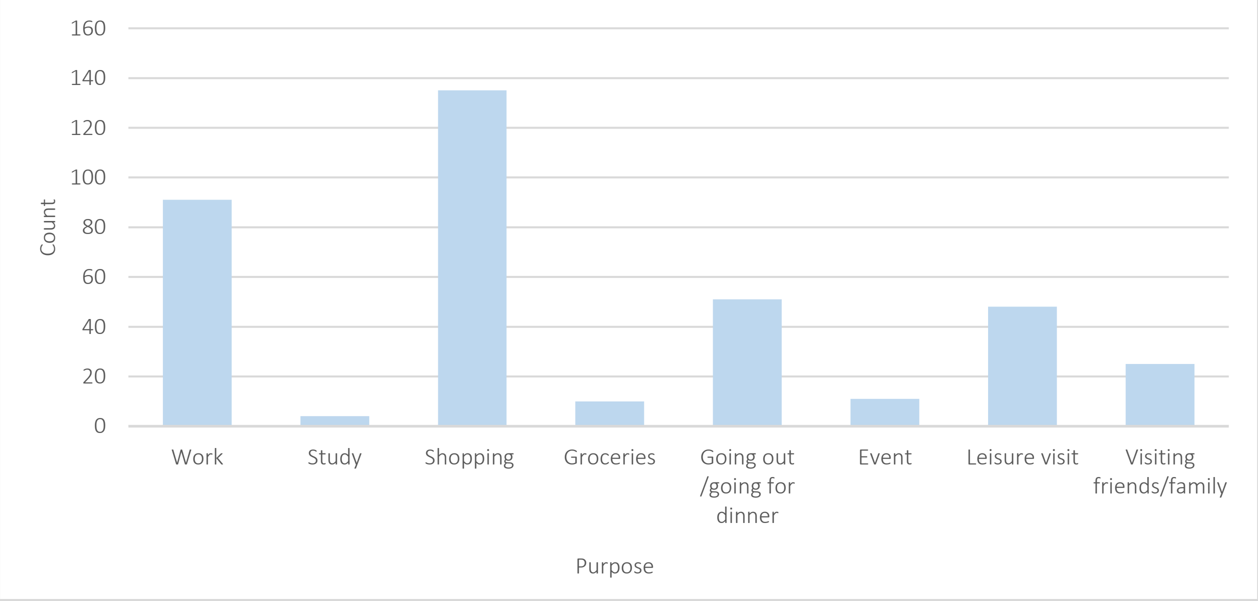

Fig. 4.1.9 Purpose for visiting Eindhoven

For further estimations this variable has been recategorized into three levels: work (and study); shopping (and groceries); and leisure (and going out, event, visiting friends/family), to make the categories more evenly spread. Figure 4.1.10 shows these purpose categories in comparison to how often a respondent visits the city center by car. Respondents that most have work purposes seem to be regular visitors of the city center, however, only a couple seem to be full-time workers. Respondents that most often have a shopping or leisure purpose only visit the city center occasionally.

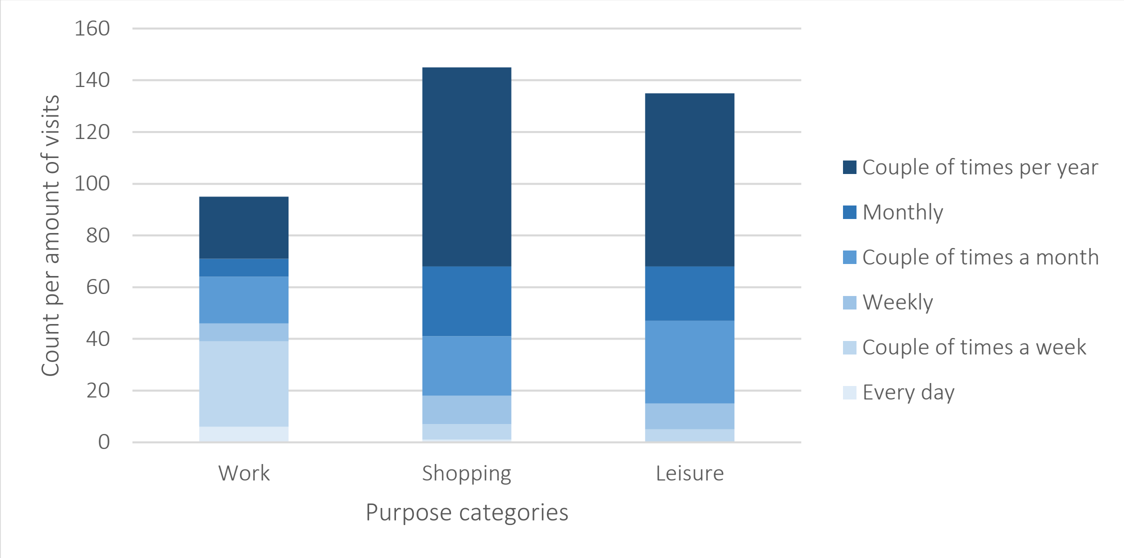

Fig. 4.1.10 Combined purpose in relation to amount of visits of Eindhoven

Looking into the purpose categories in more detail for further estimations, Figure 4.1.11 shows the purposes per age category in the sample. The work purpose is mostly selected by respondents in the age category between thirty and fifty years (45.3%). The shopping purpose applies mostly to people over fifty (46.2%) and the leisure purpose also mostly by people over fifty years (37.8%), followed by 36.3% under thirty years.

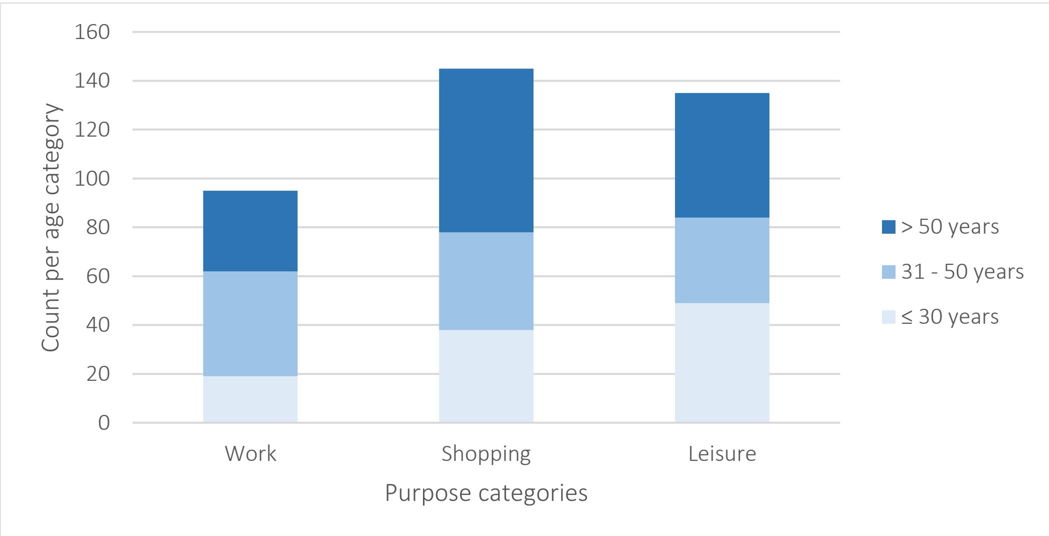

Fig. 4.1.11 Age categories in relation to purpose categories

Figure 4.1.12 shows the duration of people's visit to the city center. As can be seen, most visitors stay for 2 – 4 hours. These duration levels also have been recategorized into two durations: shorter and longer than 4 hours to have a larger number of observations per level.

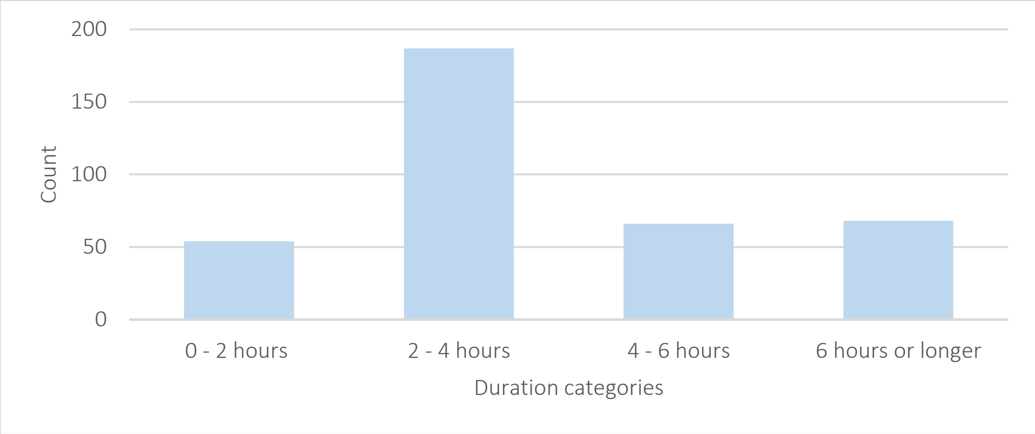

Fig. 4.1.12 Duration of stay

After the SC experiment, the respondents were asked if they would consider using a more innovative transport mode for their trip from the hub towards Eindhoven city center when these would be available at the hub in addition to the shared-bike and the bus service (see Appendix B.10). Figure 4.1.13 shows the results to this question, there should be noted that the respondents could check more than one box. As can be seen, the electric bicycle and electric car are chosen most often (respectively 184 and 133 times). The reason that these transport modes are favored, might for example be caused by the fact that these are most familiar to people. The electric two person vehicle, electric step and electric scooter are chosen by respectively 58, 50, and 67 people. Only 9 people indicated they would consider using the electric skateboard. And 79 people indicated they would not consider using any of the transport modes offered.

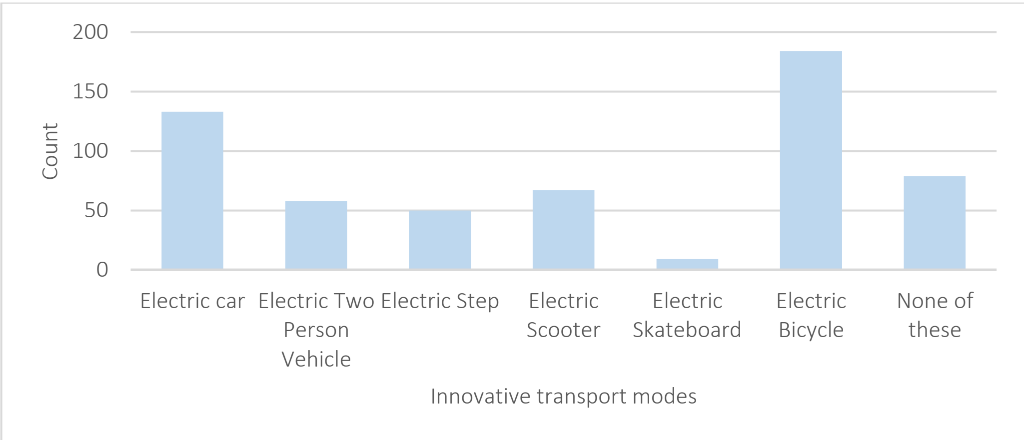

Fig. 4.1.13 Innovative transport modes

4.1.2.1. Conclusion

The sample is nicely represented by people with home locations surrounding Eindhoven. Therefore the target group of visitors has been reached. However, many of the respondents visit the city center occasionally. The group that visits the city center more regularly, are the people with a working purpose, of which 43% in the age group 30 – 50 years. Moreover, the sample is overrepresented by people with high incomes and high education levels. Regarding the use of public transport, people from villages seem to travel by public transportation less often than people living in villages. The distance to the public transport stop on the other hand does not seem to influence the public transportation usage that much.

4.2. Model estimations

This section describes the estimations of the Multinomial Logit, Mixed Logit and Latent Class models on the data. These estimations have been performed using NLogit; a package from Econometric Software Inc. (ESI) and includes estimators for models of multinomial choice (Hensher et al., 2015). Section 4.2.1 discusses the estimations of the Multinomial Logit model. Section 4.2.2 the estimations of the Mixed Logit models and Section 4.2.3 the estimations of the Latent Class models.

4.2.1. MNL models

Figure 4.2.1 shows an overview of the MNL models estimated for this study. As can be seen, a general MNL model is estimated, which is discussed in this section. Furthermore, four MNL models per category are estimated in Section 4.2.1.1, in order to analyze the differences between pre-defined groups. As can be seen in the figure, this is performed for the purpose categories, urbanization, distance to Eindhoven city center and age categories. These categories have been selected as it assumed that these groups might show different behavior and these categories are of interest to the municipality to adjust target their policy to.

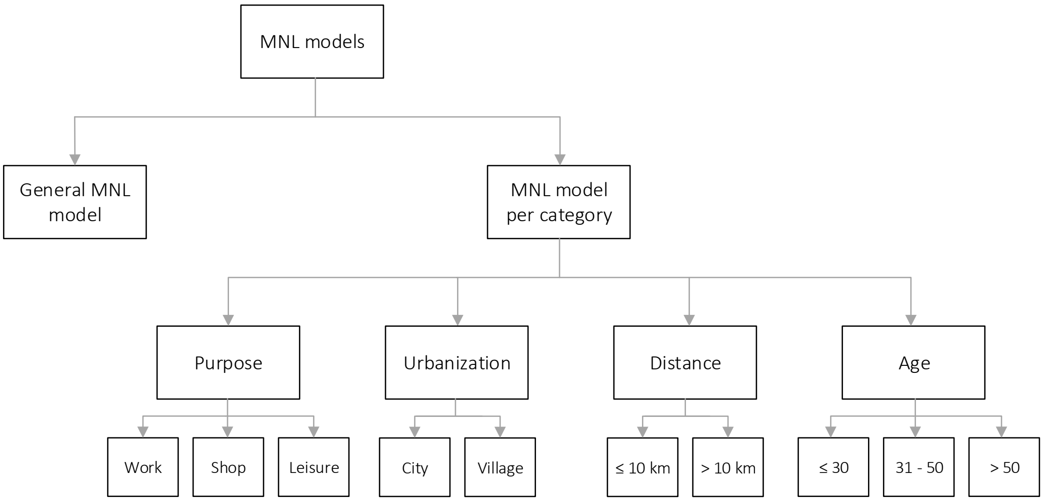

Fig. 4.2.1 Overview MNL models

The general MNL model containing the entire sample, is estimated first and the results of this estimation are shown in Table 4.2.1 and Figures 4.2.2 till 4.2.14. Appendix D.1 shows the complete output of NLogit. The ρ^2 has been calculated using Equation 6, resulting in a ρ^2 of 0.11. This is quite low, since the closer to 1, the better the model fit as discussed in Section 3.3.1. Implying that the model does not explain the data very well. From the MNL model estimation, two parameters for each 3-level attribute are provided in the output. Since effects coding is used (Section 3.2.3), the parameter of the third level of the attributes has been calculated manually by summing up the parameters of the first two estimated parameters and multiplying it by -1, making the mean of the parameters zero. The light grey attributes in Figures 4.2.2 till 4.2.14 are found not significant, which means that there is no indication that these coefficients differ from zero. In other words, no evidence exists for an effect for these variables.

The constants estimated in the MNL model show their coefficient compared to the base alternative, which was the car alternative. As can be seen in Table 4.2.1, in general the contribution of the alternative bike to the overall utility is considerably higher than the contribution of the car alternative to the overall utility. The contribution of the alternative public transportation + bike is also somewhat higher than the contribution of the car alternative to the overall utility. Striking is that the three constants with a negative sign are the three alternatives for which the travelers have to transfer between transport modes, which was expected considering the literature, as this is often seen as a hassle (Chowdhury & Ceder, 2016).

Tab. 4.2.1 Coefficients MNL model

Attributes	Coefficient	Sign.
Constant Car + Bus	-0.50088	***
Constant Car + Bike	-0.73076	***
Constant Public Transport + Walk	0.11877	**
Constant Public Transport + Bike	-0.91088	***
Constant Bike	1.00024	***
Car + Bus TT Reduction car: -4	0.15493	**
Car + Bus TT Reduction car: -2	-0.00314	
Car + Bus TT Reduction car: 0	-0.15179	-
Car + Bike TT Reduction car: -4	0.01233	
Car + Bike TT Reduction car: -2	-0.07911	
Car + Bike TT Reduction car: 0	0.06678	-
Car + Bus PC Car at Hub: 0	0.53494	***
Car + Bus PC Car at Hub: 4	-0.00238	
Car + Bus PC Car at Hub: 8	-0.53256	-
Car + Bike PC Car at Hub: 0	0.65338	***
Car + Bike PC Car at Hub: 4	-0.26586	***
Car + Bike PC Car at Hub: 8	-0.38752	-
Car + Bus Hub fac.: Coffee & Sandwich	0.12071	*
Car + Bus Hub fac.: Parcel Pick-up	-0.09266	
Car + Bus Hub fac.: None	-0.02805	-
Car + Bike Hub fac.: Coffee & Sandwich	-0.03918	
Car + Bike Hub fac.: Parcel Pick-up	0.06243	
Car + Bike Hub fac.: None	-0.02325	-
Car PC Center: 3	0.50649	***
Car PC Center: 5	-0.11661	*
Car PC Center: 7	-0.38988	-
Car + Bus TT Bus: 6	0.19796	***
Car + Bus TT Bus: 9	0.0013	
Car + Bus TT Bus: 12	-0.19926	-
Car + Bus WT Bus: 2	0.28466	***
Car + Bus WT Bus: 6	-0.03324	
Car + Bus WT Bus: 10	-0.25142	-
Car + Bus TC Bus: 0	-0.05029	
Car + Bus TC Bus: 0.5	-0.01095	
Car + Bus TC Bus: 1	0.06124	-
Car + Bike TT Bike: 5	0.30949	***
Car + Bike TT Bike: 10	0.02084	
Car + Bike TT Bike: 15	-0.33033	-
Car + Bike TC Bike: 0	0.00935	
Car + Bike TC Bike: 0.5	-0.0057	
Car + Bike TC Bike: 1	-0.00365	-
PT + Bike TC Bike: 0	0.25361	***
PT + Bike TC Bike: 0.5	-0.06377	
PT + Bike TC Bike: 1	-0.18984	-

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

Considering the hub-specific attributes: the attribute travel time (TT) reduction to hub in the alternative car + bus shows the expected relation to the overall utility, as a shorter travel time to Eindhoven is expected to be preferred. This can be seen in Figure 4.2.2. However, when compared to the other attributes, this is not a very strong effect. No significant effect is found for the car + bike alternative (Figure 4.2.3).

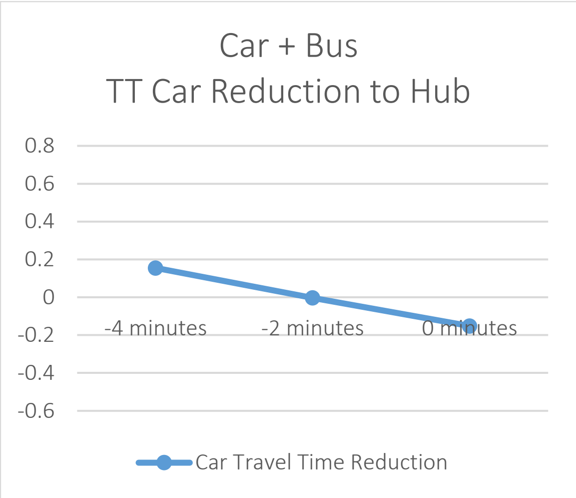

Fig. 4.2.2 Visualization Car + Bus TT Reduction Car to Hub

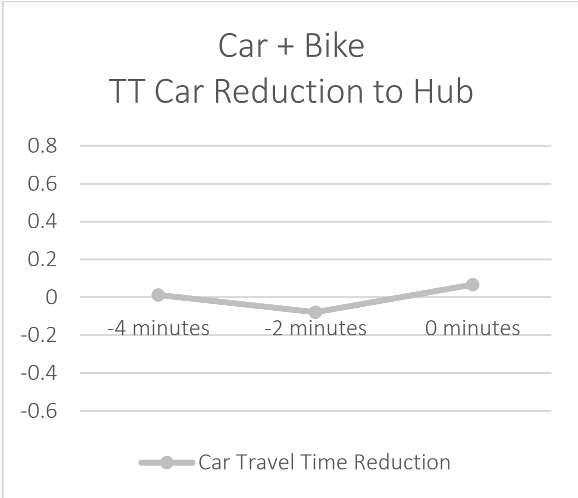

Fig. 4.2.3 Visualization Car + Bike TT Reduction Car to Hub

When considering the parking costs at the hub for the car + bus and car + bike alternatives in Figures 4.2.4 and 4.2.5, the effect of the attribute seems to be stronger than the travel time reduction, considering the steepness. The effect is as expected; positive coefficients at the €0 parking costs and negative coefficients at the € 8 parking costs per day. As can be seen, the effect differs between car + bus and car + bike, as for the last one the coefficient of the second attribute level has also been found significant. Both €4 and €8 parking costs per day have a negative effect for the car + bike alternative and therefore their contribution to the overall utility for this alternative is negative.

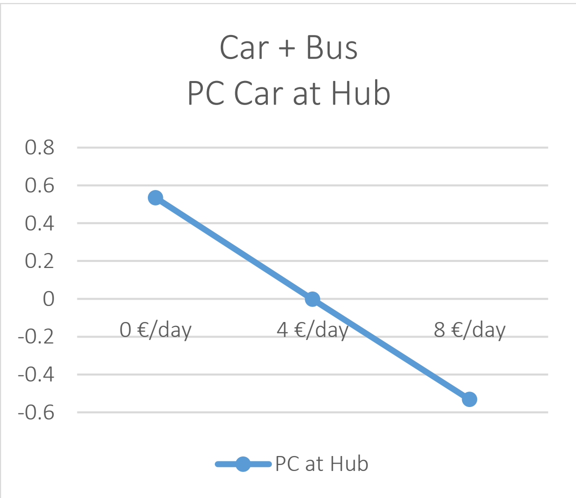

Fig. 4.2.4 Visualization Car + Bus PC Car at Hub

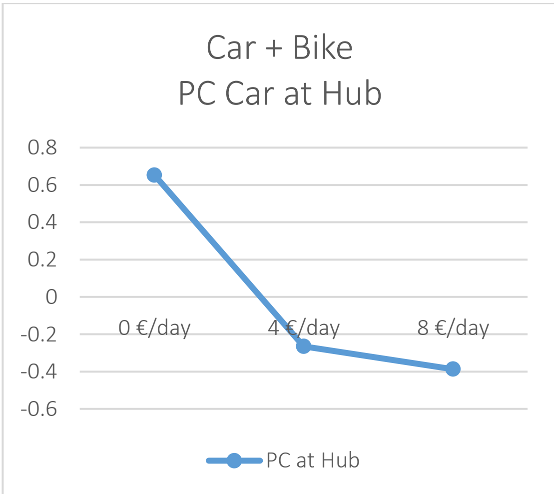

Fig. 4.2.5 Visualization Car + Bike PC Car at Hub

Figures 4.2.6 and 4.2.7 show the coefficients of facilities at the hub for both the car + bus and car + bike alternative. The hub facilities for the car + bike alternative have not been found significant, and for the car + bus alternative only at 10% (therefore the lighter blue color has been used). For this attribute can be seen that the coffee & sandwich facility has a positive contribution to the overall utility, and the parcel pick-up shows a negative contribution to the overall utility; even more negative than no facilities. This would indicate that people seem to prefer having none facilities over having the parcel pick-up, which does not immediately make sense. However, as the attribute is only significant at a 10% level no strong conclusions can be drawn from this.

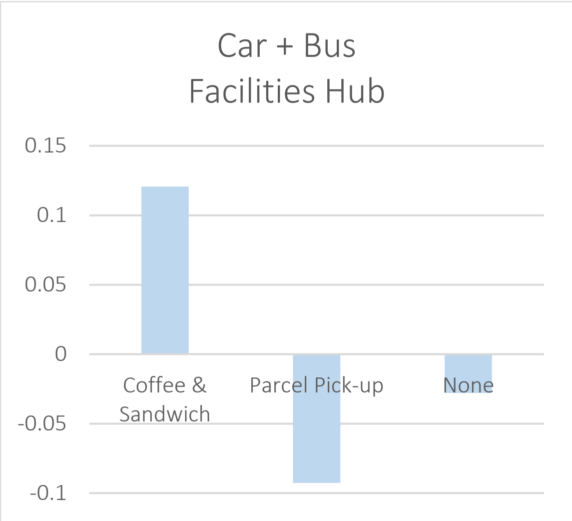

Fig. 4.2.6 Visualization Car + Bus Facilities Hub

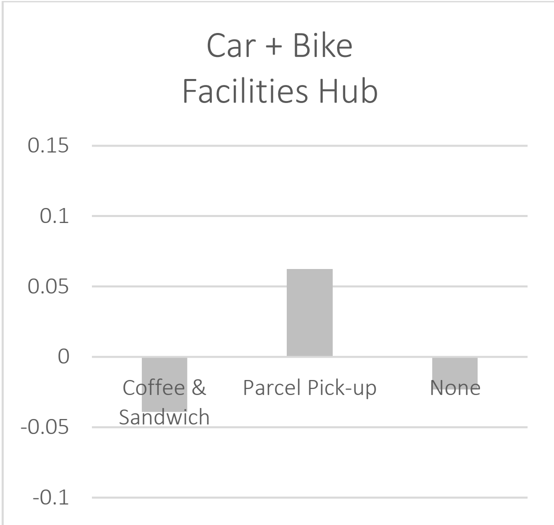

Fig. 4.2.7 Visualization Car + Bike Facilities Hub

Considering the alternative specific attributes, the attribute parking costs in the city center (Figure 4.2.8) shows the expected coefficient directions. Parking costs of only €3 are positively contributing to the overall utility. These lower costs have a stronger effect than the opposite higher costs of €7 to the overall utility.

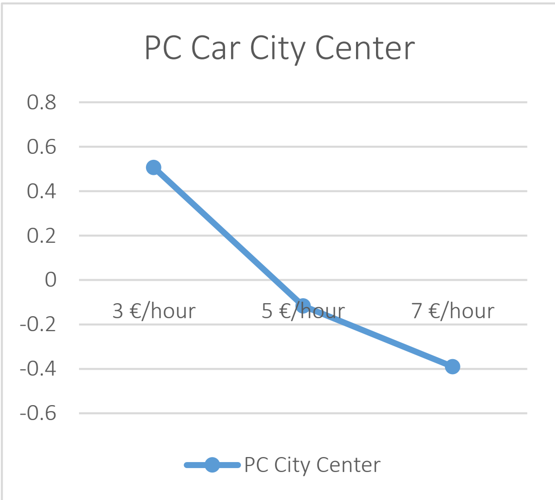

Fig. 4.2.8 Visualization PC Car City Center

Figure 4.2.9 shows the travel time of the bus in the car + bus alternative. As expected, a shorter travel time is preferred over a longer travel time. However, when this figure is compared to Figure 4.2.10, the effect of the waiting time seems slightly stronger to the overall utility. As expected, the shorter waiting time is preferred over the longer waiting times. In literature this effect was already identified (OECD/ITF, 2014). The travel time of the bus is compared to the travel time by bike in Figure 4.2.11; the travel time of the bike in the car + bike alternative. There can be seen that here as well the effect is a little stronger than for the travel time of the bus in Figure 4.2.9. From these three figures can be concluded that for the adoption of the hubs, the travel time should be as low as possible to let travelers have a positive utility for these alternatives. This could be achieved by having a hub located close to the city center, or have a fast 'last mile' service. The latter can be achieved by operating the bus service at a high frequency on fast routes or provide good cycling facilities, making the shared-bike a convenient alternative. Or even provide e-bikes at the hub reducing the travel time from the hub.

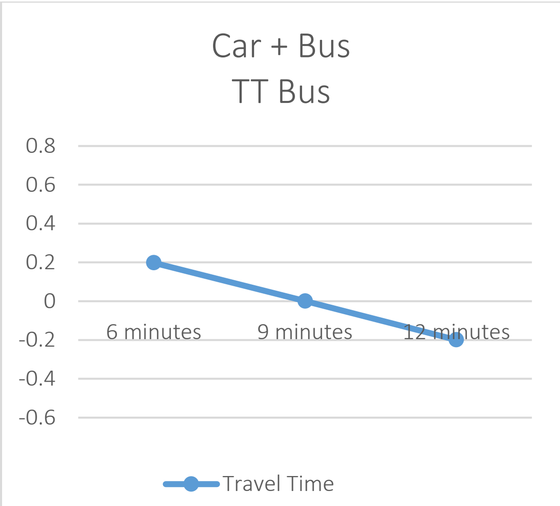

Fig. 4.2.9 Visualization Car + Bus TT Bus

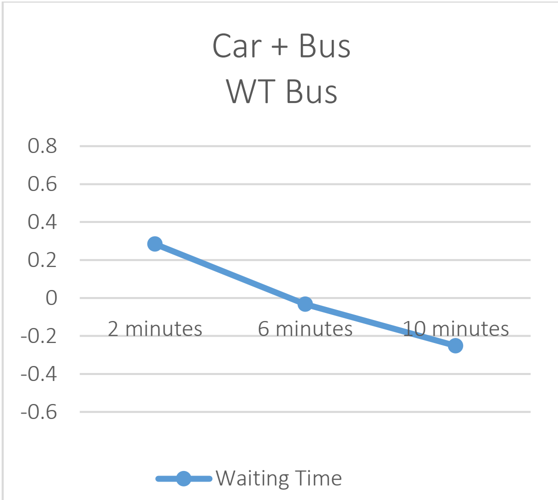

Fig. 4.2.10 Visualization Car + Bus WT Bus

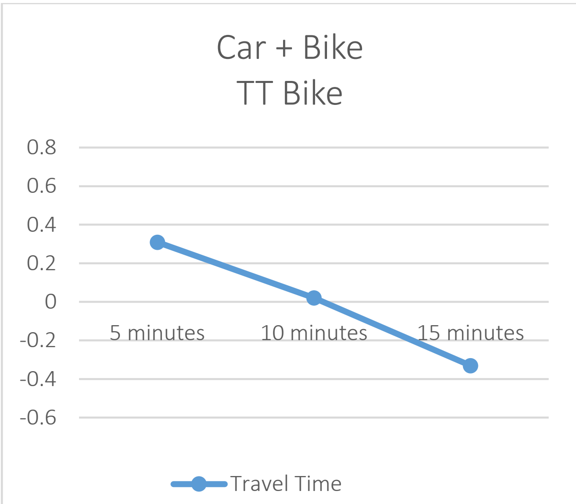

Fig. 4.2.11 Visualization Car + Bike TT Bike

The travel costs for bus and bike at the respectively car + bus (Figure 4.2.12) and car + bike (Figure 4.2.13) alternatives have not been found significant. The reason might be that the attribute levels do not differ considerably and respondents therefore did not base their choice on this variable. Figure 4.2.14 shows the bike travel costs after public transportation. As can be seen, this variable is significant and shows the €0 costs positively contribute to the overall utility. A reason might be that in general public transportation is more expensive, and when they have to pay for a second transport mode, they are not willing to do this. However, this reason cannot be confirmed.

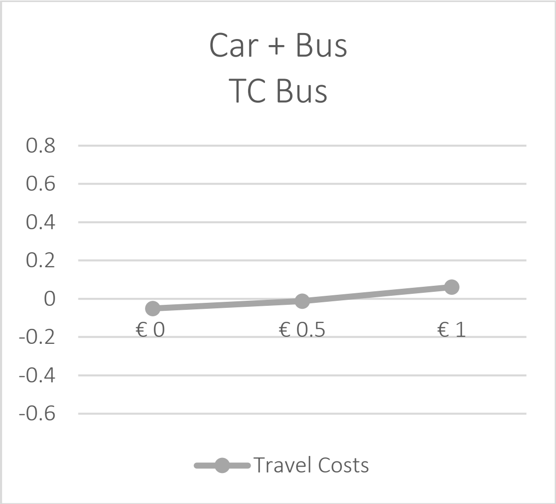

Fig. 4.2.12 Visualization Car + Bus TC Bus

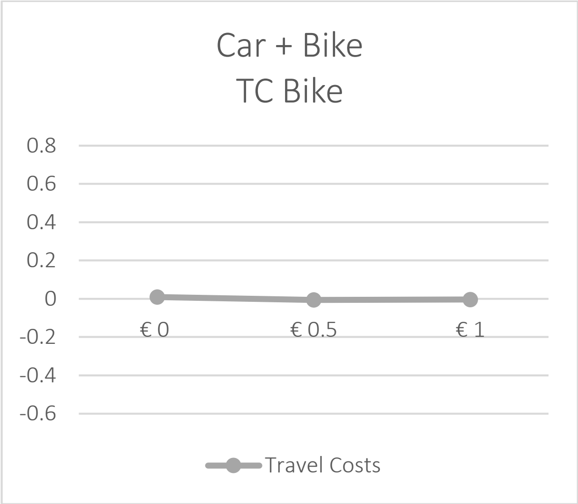

Fig. 4.2.13 Visualization Car + Bike TC Bike

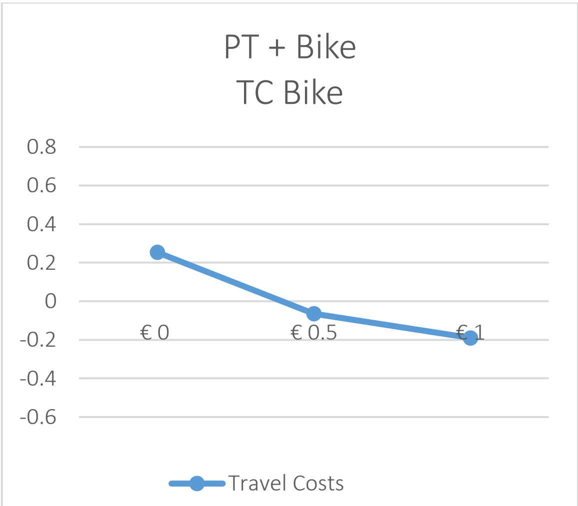

Fig. 4.2.14 Visualization Car + Bike TC Bike

4.2.1.1. MNL model per category

This section contains the estimation of various MNL models per category in order to analyze the differences between pre-defined groups. The models are analyzed for four different categories: purpose (grouped into work, shopping and leisure), urbanization (grouped into city and village), distance (grouped into ≤ 10 km of Eindhoven city center and > 10 km), and age (grouped into ≤ 30, 31 – 50, > 50).

Purpose categories

As discussed in Section 4.1.2, the purpose groups have been recategorized into three groups: work, shopping and leisure purposes. Differences are expected to exist between the various categories, and therefore these groups have been further analyzed using the MNL model estimates.

In order to estimate these differences, two extra sets of variables are added to the model. These sets allow for interaction between the variables and the purpose categories by using effects coding on the purpose categories. The parameters are estimated using the MNL model, resulting in extra coefficients γ_{in} and δ_{in}, in addition to the β_{in}. The γ_{in} and δ_{in} indicate the parameter difference from the average for each of the three purposes. The structural utility for the workers can be determined as shown in Equation 11, and for the shoppers by Equation 12. The parameter differences for leisure are calculated by subtracting both the γ_{in} and δ_{in} from the β_{in}, as can been seen in Equation 13.

Work: $$V_{iq} = \sum_n (\beta_{in} + \gamma_{in})\, X_{inq} \quad (11)$$

Shopping: $$V_{iq} = \sum_n (\beta_{in} + \delta_{in})\, X_{inq} \quad (12)$$

Leisure: $$V_{iq} = \sum_n (\beta_{in} - \gamma_{in} - \delta_{in})\, X_{inq} \quad (13)$$

The complete set of parameters can be seen in Table D.2.1 in Appendix D.2. The ρ^2 is 0.131, which is a little higher than the general MNL model, which means this model explains the data a little better, but it is still not a very good fit. The AIC of this model is 10122.3, which is better compared to the general MNL model with an AIC of 10238.7. As the AIC estimates the relative amount of information lost by the model; the lower AIC, the better.

Table 4.2.2 shows the significant coefficients of the constants for the alternatives compared to the base level: car to city center. The complete NLogit output is shown in Tables D.2.2 (β's), Table D.2.3 (γ's) and Table D.2.4 (δ's) in Appendix D.2. Again, overall the alternatives that require a transfer are less preferred. The constant of car + bus for work and leisure purposes (respectively -1.03116 and -0.62773) is strongly negative compared to car. For shopping purposes this coefficient is still negative, but less strong (-0.30377). The reason for this might be that the respondents feel dependent on the bus, and for work and leisure purposes you often have to be somewhere at a certain time. Additionally, going out or going to an event might end quite late and uncertainty might exist if the bus is still operating at that time. Regarding shopping purposes this is often not the case, as it does not really matter at what time you arrive and the shops will close around 18:00 or 21:00 h. The constant for the car + bike alternative is again negative for all three purposes, but the most negative for the shopping purpose (-1.08341) followed by leisure (-0.86471) and lastly work (-0.16904). This might be explained by the fact people have to take shopping bags with them after shopping, which will be quite cumbersome when transferring to an (unfamiliar) bicycle. Regarding the constant for public transportation + walk, the purpose categories work and leisure are quite similar (and positive, respectively 0.34316 and 0.30096), but the coefficient for the shopping purpose is negative (-0.18542). Having shopping bags to carry might be a reason here as well for not going by public transportation, as for the other two purposes this is not an issue. The walking gives people a certain freedom and the shopping area of Eindhoven is near the station, which might be the difference in coefficients compared to the public transportation + bike alternative, as these are all negative. Again, shopping purpose is the most negative (-1.49773), followed by the leisure purpose (-0.76176) and then the work purpose (-0.35105). The constants for the bike alternative are positive compared to the car alternative. The coefficient for the purpose work is largest (1.77924), followed by leisure (0.85794) and then shopping (0.66327). Apparently there is a difference between using a shared bike and using a private bike, as this effect is positive for the shopping purpose.

Tab. 4.2.2 Constants purpose categories

Alternatives	Constant Work	Constant Shopping	Constant Leisure
Car + Bus	-1.03116	-0.30377	-0.62773
Car + Bike	-0.16904	-1.08341	-0.86471
Public Transport + Walk	0.34316	-0.18542	0.30096
Public Transport + Bike	-0.35105	-1.49773	-0.76176
Bike	1.77924	0.66327	0.85794

Figures 4.2.15 till 4.2.19 show the attributes that seem to have a significant effect. Figures 4.2.15 and 4.2.16 show the graphs of the travel time reduction of the car for both the car + bus, and car+ bike alternative. However, no univocal interpretation can be derived from the graphs.

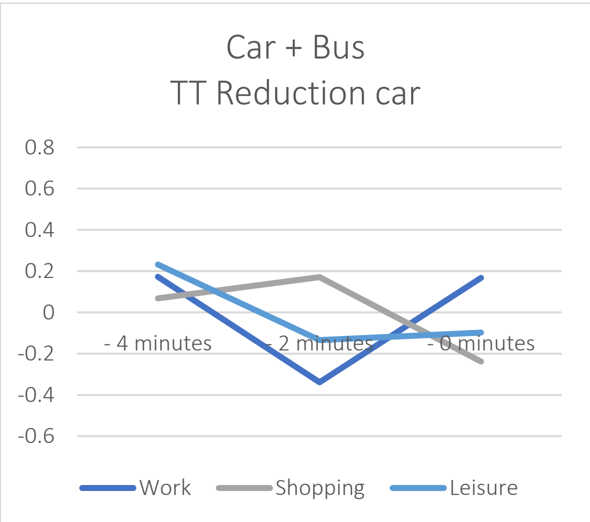

Fig. 4.2.15 Attribute parameters TT Reduction Car (in Car + Bus) for purpose categories

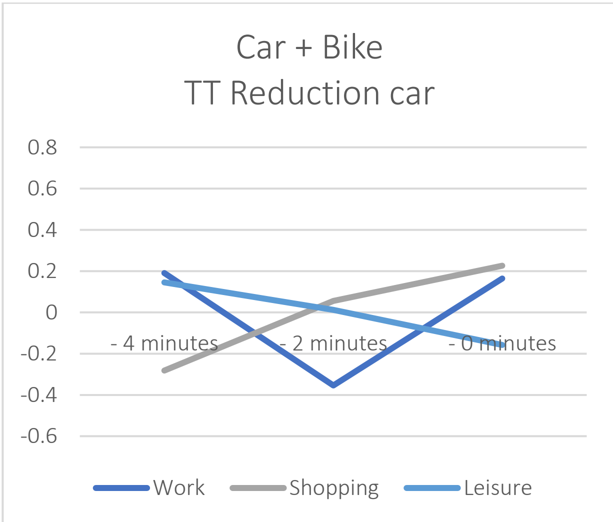

Fig. 4.2.16 Attribute parameters TT Reduction Car (in Car + Bike) for purpose categories

As can be seen in Figure 4.2.17, people having a work purpose are less sensitive to a change in parking costs than people with a shopping or leisure purpose. A possible explanation might be that the parking costs for workers are paid by their employer, so this increase does not affect them personally.

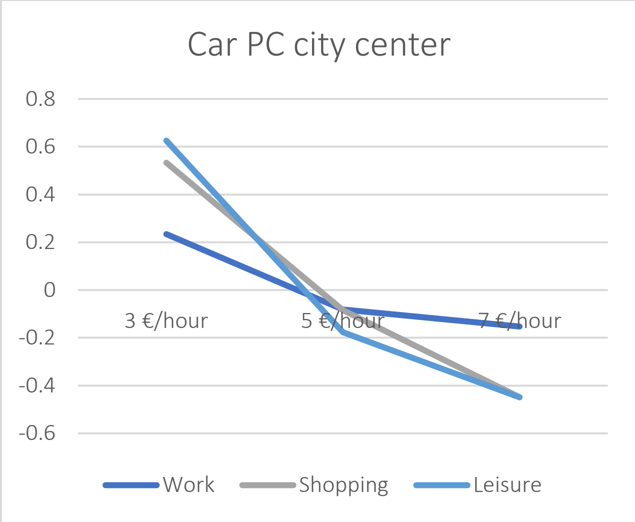

Fig. 4.2.17 Attribute parameters PC Car City Center for purpose categories

Looking at the travel time and waiting time for the bus, as can be seen in respectively Figures 4.2.18 and 4.2.19, the people with working purpose are more sensitive to these changes in time.

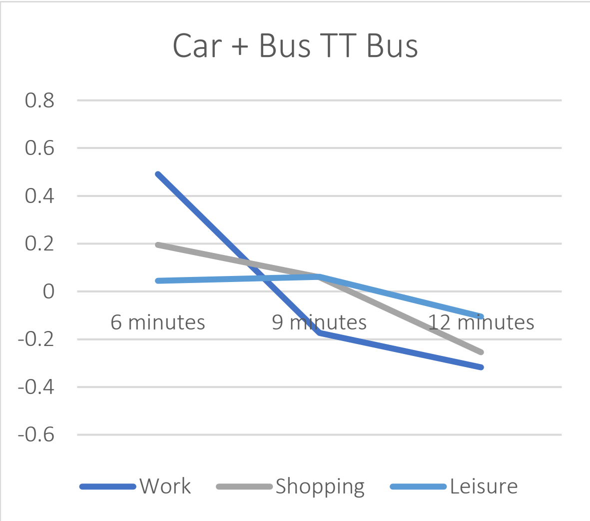

Fig. 4.2.18 Attribute parameters TT Bus (in Car + Bus) for purpose categories

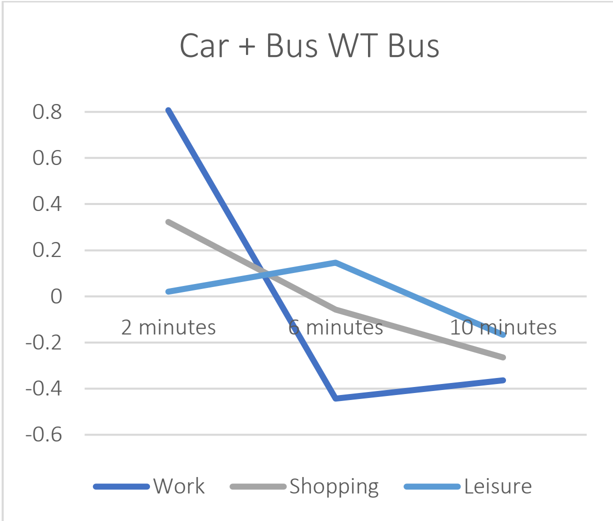

Fig. 4.2.19 Attribute parameters WT bus (in Car + Bus) for purpose categories

All in all, especially the people with work purposes differ from the average. They seem to be less sensitive to increased parking tariffs than people with shopping or leisure purpose. Moreover, they seem to have a time constraint, as they are more sensitive to increased travel and waiting times; which makes sense.

Urbanization categories

The attribute urbanization has been recategorized into two levels: city and village, based on the question about the urbanization level of their home location (explained in Section 4.1.2). In this section possible differences between these two groups are analyzed. In order to estimate these differences, only one extra set of variables is added to the model. Estimating the coefficients β_{in} and γ_{in}. The γ_{in} indicates the parameter difference from the average for the categories city and village. The structural utility for the city can be determined as shown in Equation 14, and for the village by Equation 15.

$$\text{City:} \qquad V_{iq} = \sum_n (\beta_{in} + \gamma_{in}) \, X_{inq} \tag{14}$$

$$\text{Village:} \qquad V_{iq} = \sum_n (\beta_{in} - \gamma_{in}) \, X_{inq} \tag{15}$$

The entire set of parameters can be seen in Table D.3.1 in Appendix D.3. The ρ^2 for the model is 0.137, which is a little higher than the general MNL model and the MNL model per purpose category. The AIC of this model is 9990.5, which is also better compared to the general MNL and the MNL model per purpose category with respectively an AIC of 10238.7 and 10122.3.

Table 4.2.3 shows coefficients of the constants for the alternatives relative to the base level: car to city center, which have been calculated from β's and the γ's. For the alternative public transportation + bike the constants do not differ significantly from each other, and are therefore shown in grey. The complete NLogit output is shown in Tables D.3.2 (β's) and Table D.3.3 (γ's) in Appendix D.3. As can be seen, the constants for the hub alternatives (car + bus and car + bike) are negative for both groups. For both these hub alternatives the people living in cities have a stronger negative constant. An explanation might be that almost half of the people from the sample live in Eindhoven (as specified in Section 3.3) and for these people it is not efficient to park their car in a hub and then go by bus or bike to the city center. Considering the constants for public transportation + walk for people living in a city this alternative might be feasible and therefore the constant might be positive (0.44386). The bike alternative shows positive constants for both city (1.70404) and village (0.32966), the large difference might again be related to the fact that the sample contains quite some people that live in Eindhoven and for them the bike might be the most feasible alternative. And, on the contrary, for people living in villages, it can be quite a distance to cycle to Eindhoven.

Tab. 4.2.3 Constants urbanization categories

Alternatives	Constant City	Constant Village
Car + Bus	-1.00861	-0.33141
Car + Bike	-1.03175	-0.65773
Public Transport + Walk	0.44386	-0.09288
Public Transport + Bike	-0.91875	-0.91283
Bike	1.70404	0.32966

Looking at the attributes in detail provides more insights in the differences between people living in a city or village, shown in Figures 4.2.20 till 4.2.24. Figure 4.2.20 shows the attributes of travel time reduction by car for the car + bus and car + bike alternatives. The people living in cities are more sensitive to the reduction in travel time by car. As the majority of the people living in cities is from Eindhoven, this makes sense as it is a relatively larger part of their total travel time. For people living in villages no univocal interpretation can be given for Figure 4.2.20 as it shows a peak at the zero minute reduction in travel time.

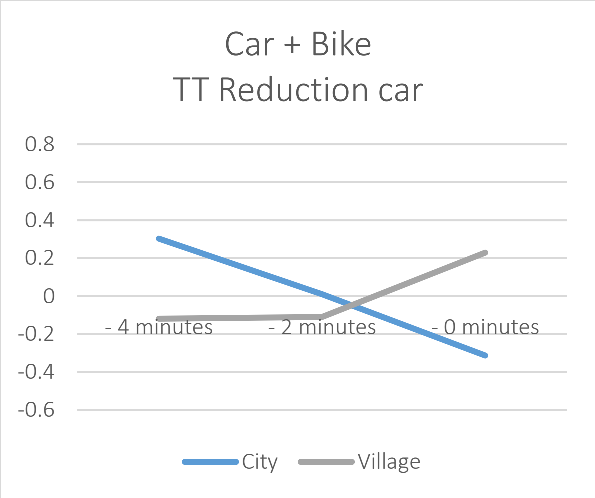

Fig. 4.2.20 Attribute parameters TT Reduction Car (in Car + Bike) for urbanization categories

As can be seen in Figure 4.2.21 people living in villages seem to be less sensitive to varying parking tariffs. This makes sense as almost half of the people living in cities lives in Eindhoven and they might have other means, such as their bike, to go to the city center, which has free parking. Those living in villages might be more car dependent and taking the bike might be less self-evident when travelling from a village towards Eindhoven.

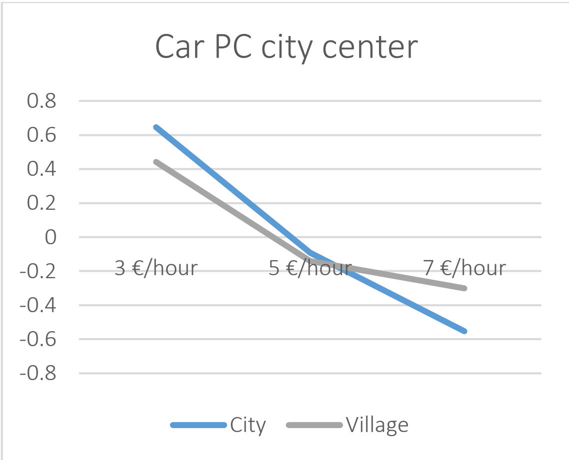

Fig. 4.2.21 Attribute parameters PC Car City Center for urbanization categories

Considering Figures 4.2.22 and 4.2.23, respectively for the travel time of the bus and bike from the hub; for the people living in villages the graphs make sense as the longer the travel times, the more negative the contribution to the overall utility of that alternative. Meaning that when the travel time is too long (respectively 12 and 15 minutes for bus and bike) from the hubs to the center, the people living in villages will have a lower probability of using the hubs. However, for the people living in cities, the graphs cannot be interpreted unambiguously.

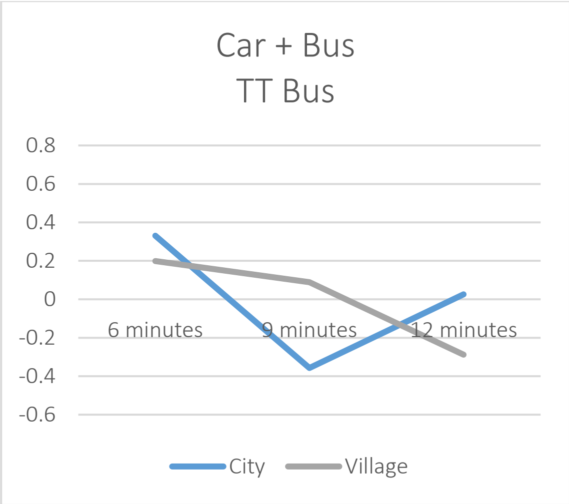

Fig. 4.2.22 Attribute parameters TT Bus (in Car + Bus) for urbanization categories

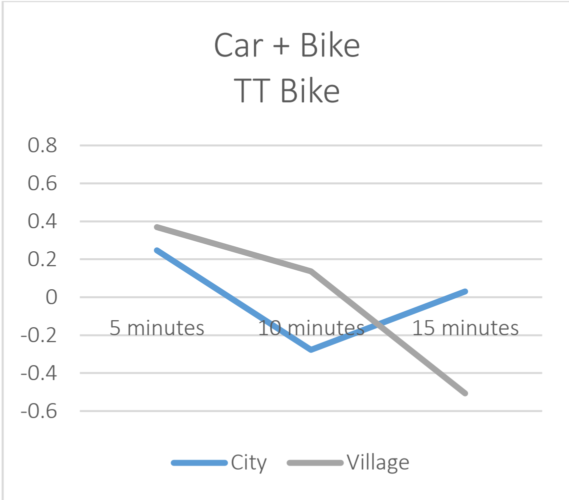

Fig. 4.2.23 Attribute parameters TT Bike (in Car + Bike) for urbanization categories

Figure 4.2.24 shows the travel costs for the bike in the car + bike alternative, however no clear interpretation can be given to the graph.

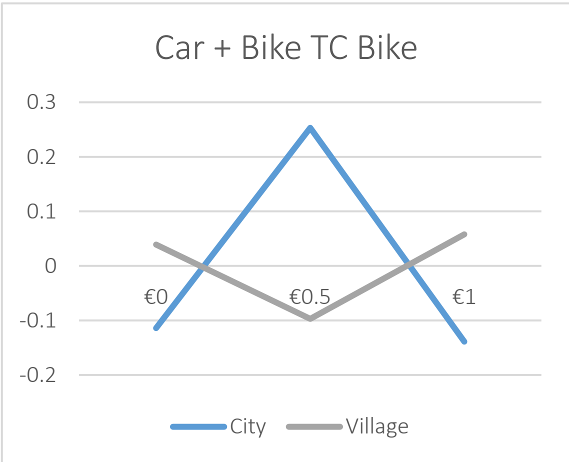

Fig. 4.2.24 Attribute parameters TC Bike (in Car + Bike) for urbanization categories

Concluding for this model, it can be stated that differences do exist between people living in cities and villages. However, there should be noted that the majority of the city sample is living in Eindhoven, probably resulting in different results than when the sample would have come from other cities. People coming from villages seem to be less sensitive to changing parking tariffs and more sensitive to increasing travel times by the second transport mode (the bus after the car from the hub or the bike after the car or public transportation). To let the alternative hub + bus or hub + bike alternative be a feasible one, the travel time should therefore be as low as possible for them.

Distance categories

Zooming in more specifically to the urbanization groups, the attribute distance has been recategorized into two categories: living ≤ 10 km from Eindhoven city center (116 respondents) and > 10 km from Eindhoven city center (259 respondents). This distinction has been selected as the municipality of Eindhoven already has collected GPS data and distinguished the participants based on these two categories. This model estimation will be used for the visualization of scenarios in Section 4.3. The ρ^2 for the model is 0.139, which similar to the MNL model per urbanization category. The AIC of this model is 9919.3, which is a bit better than the MNL model per urbanization category.

As this model also contains two categories, the MNL model has been estimated similarly to the urbanization categories. However, as this model will be used for visualizing the implications of various scenarios, the attributes with no significant difference between the two groups have been eliminated from the model. Therefore a stepwise deletion has been applied, and in twelve steps, twelve of the γ's have been removed from the model. Only the constants and the attribute for the parking costs in the city center seem to differ significantly between the two groups. Using Equations 14 and 15, the effect sizes have been calculated, resulting in Table D.4.1 in Appendix D. As can be seen, apart from the constants, eight attributes seem to have a significant effect on the mode choice. The complete output of the MNL model per distance category can be found in Tables D.4.2 (β's at step 0), D.4.3 (γ's at step 0), D.4.4 (β's at step 12), D.4.5 (γ's at step 12) in Appendix D.

Table 4.2.4 shows the differences in constants between the distance categories. People living within 10 kilometers of the city center have a stronger negative constant for using a hub (for car + bus and car + bike respectively -2.56421 and -2.66873) than people living further away (respectively -0.18219 and -0.41117). Even stronger than the constant for people living in a city in the previous MNL model, probably since now the people coming from other cities have been filtered out. People living further than 10 kilometers from Eindhoven city center, prefer walking over cycling after using public transport (constants respectively 0.25089 and -0.716). However, they do have a positive constant for using their private bike (0.2472). People living within 10 kilometers have a stronger positive constant for using their private bike (0.66338) which makes sense. However, this group is not keen on using public transport for their visit to Eindhoven city center.

Tab. 4.2.4 Constants distance categories

Alternatives	Constant ≤ 10 km	Constant > 10 km
Constant Car + Bus	-2.56421	-0.18219
Constant Car + Bike	-2.66873	-0.41117
Constant Public Transport + Walk	-0.22597	0.25089
Constant Public Transport + Bike	-1.6369	-0.761
Constant Bike	0.66338	0.2472

Figure 4.2.25 shows the only attribute that showed a significant difference between the groups, the parking costs in the city center. As can be seen, people living within 10 kilometers are more sensitive to an increase in these parking tariffs. This makes sense as they can probably easily switch to cycling or take a bus. Those living further from the city center, are probably more car-dependent for their visit, as taking the bike is not convenient for longer distances.

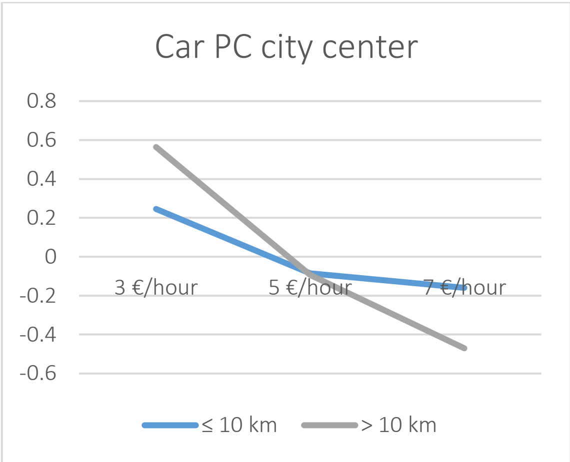

Fig. 4.2.25 Attribute parameters PC Car City Center for distance categories

All in all, the hubs seem to be less preferred by people living within 10 kilometers from the city center. This group is also less sensitive to increased parking costs in the city center. They do have a preference for using their (e-)bike over the car. People living further than 10 kilometers from the city center have a less strong negative constant for the hub alternatives, and as they are more sensitive to increased parking tariffs in the city center, they have potential for switching.

Age categories

As described previously, the age groups have been recategorized into ≤ 30, 31 – 50 and > 50. This MNL model has been estimated to investigate if the various age groups show different preferences. The municipality might then be able to target different measures at these groups.

The MNL model has been estimated similarly as for the purpose categories. The complete set of parameters can be found in Table D.5.1 in Appendix D.5. The ρ^2 of this model is 0.127, which is a little higher than the general MNL model, but lower than the MNL model per purpose, urbanization and distance categories. The AIC of this model is 10166.7, which is better compared to the general MNL model with an AIC of 10238.7, but again a little higher than the MNL models per purpose, urbanization and distance (respectively an AIC of 10122.3, 9990.5, and 9919.3).

Between the various age groups differences are expected to be found, due to differences in life stage and values. As can be seen in Table 4.2.5, the coefficients of the constants show some differences, such as the bike is most preferred by younger people (1.78613) compared to the age groups 31 – 50 (0.55376) and > 50 (0.85016). However, all three have positive coefficients. All three categories have a negative contribution to the overall utility for the alternative car + bus, car + bike and public transportation + bike. The age group 31 – 50 has the strongest negative coefficients for all these three alternatives compared to the base level; the car alternative (respectively -1.3279, -1.15477, -1.12263). Looking at the constant for public transportation + walk, it is also negative for the age group 31 – 50, but positive for the younger (≤ 30 years) and older (> 50) groups. Considering the age group 31 till 50 years, this group might have more complex activity patterns and might therefore be more car dependent. For example bringing children to daycare, going to work, doing groceries and picking up the children again.

Tab. 4.2.5 Constants age categories

Alternatives	Constants ≤ 30 years	Constants 31 – 50 years	Constants > 50 years
Car + Bus	-0.43031	-1.3279	-0.13881
Car + Bike	-0.52407	-1.15477	-0.60134
Public Transport + Walk	0.43569	-0.2568	0.23205
Public Transport + Bike	-0.73152	-1.12263	-0.86127
Bike	1.78613	0.55376	0.85016

Considering the attribute effect differences, the interpretable attributes have been plotted in Figures 4.2.26 till 4.2.28. The other ones have been checked, but no univocal interpretation can be given to the coefficients. Starting with Figure 4.2.26, which shows the parking costs in the city center, and as can be seen older people (> 50 years) seem to be somewhat less sensitive to increased parking tariffs. Respondents under the 30 years seem to be most sensitive to these parking costs.

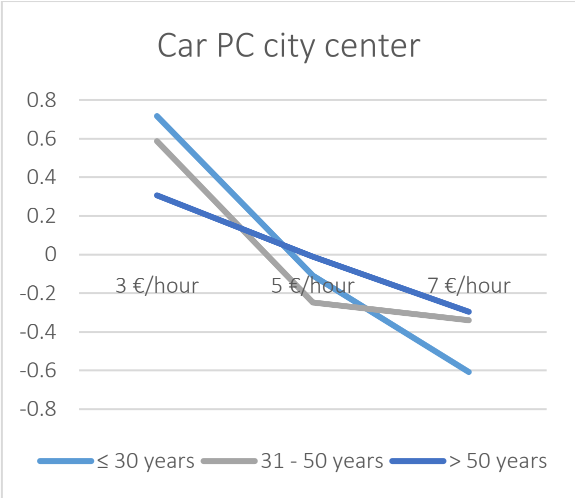

Fig. 4.2.26 Attribute parameters PC Car City Center for age categories

The travel time for the bus in Figure 4.2.27 shows to be most important for people in the age category of 31 – 50 years and least important to people older than 50 years.

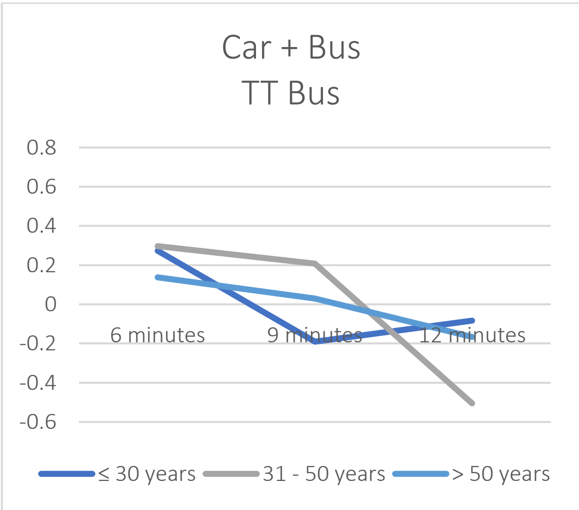

Fig. 4.2.27 Attribute parameters TT Bus (in Car + Bus) for urbanization categories

Considering Figure 4.2.28; the travel costs for the bike in the public transportation + bike alternative, again the people older than 50 years seem to be least sensitive to changes in the travel costs.

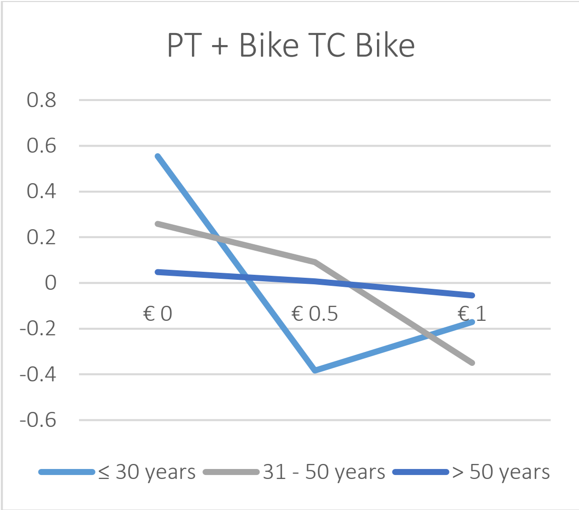

Fig. 4.2.28 Attribute parameters TC Bus (in Car + Bus) for urbanization categories

Summarizing, the people older than 50 years seem to be less sensitive to changes in travel and parking costs, and travel time. Moreover they are already favoring public transport and the private (e-)bike over the car. This is also the case for respondents till 30 years, and they seem to be most sensitive to the parking costs. Respondents within the category 31 – 50 years seem to be most sensitive to the travel time by bus from the hub, and they prefer all alternatives over the car, except for private (e-)bike. The municipality of Eindhoven might be able to use this information for targeting different campaigns at different age groups.

4.2.1.2. Conclusion

The general MNL model shows overall the expected coefficients for the constants and the attributes. In general, the alternatives that do not require a transfer of transport mode (public transportation + walk and bike) have a positive contribution to the overall utility. This was expected considering the literature, as transfers are often seen as a hassle (Chowdhury & Ceder, 2016; OECD/ITF, 2014). The bike alternative has the strongest positive contribution to the overall utility compared to car.

Regarding the attributes, the parking costs seem to have most impact on the overall utility. In the city center, the lowest parking costs of €3 per hour have a positive effect on the utility of the car alternative. This effect is stronger than the opposite effect of the higher parking costs of €7 per hour. However, both €5 and €7 per hour seem to negatively affect the utility for the car alternative. The parking costs at the hub seem to have a similar effect, however, these parking costs were per day and therefore was expected that these effects would be less strong. This might indicate that people did not notice the difference between de attributes. This will be checked with a Random Parameter ML model. When a high variance will be identified for the random parameters, this might indicate that some people might have not noticed the difference. The effect of waiting time seems to be slightly stronger than for the travel times of bus and bike from the hub. This was expected considering the literature, as waiting time is experienced as a longer duration (OECD/ITF, 2014). Comparing the travel time for bus and bike, the travel time for the bike has a stronger effect on the utility, which might have to do with the fact that people have to put some effort to cycle. Moreover, in general the bus is preferred as 'last mile' transport mode over the bike from the hub. From these attributes can be concluded that there should be focused on reducing the time of the transport mode from the hub to the city center. This could be achieved by locating the hub as close to the city center as possible. However, this might have other negative consequences, such as increased traffic near the ring road. Another possibility is to have a frequent and fast bus service operating, making the bus trip as seamless as possible. Or, for the hub + bike alternative, making the cycling facilities more convenient. Therefore the strategy of the municipality of realizing the 'slow lane' is important for these hubs as well. It could therefore be recommended to position the hubs along the 'slow lane'. Another possibility would be to offer electric bicycles at the hub.

Regarding the MNL models per category, people with working purposes seem to differ from the average. They seem to have a time constraint in their travel, as they are more sensitive to increased travel and waiting times. On the other hand, they are less sensitive to increased parking costs in the city center than people travelling with other purposes. This might have to do with the fact that their parking costs are paid by their employers.

Considering the MNL model per urbanization category, differences seem to exist between people living in cities and villages. People from villages seem to be less sensitive to changing parking tariffs and more sensitive to increasing travel times for the 'last mile' transport mode from the hub to the city center. To let the hub + bus or bike alternative be a feasible one, this travel time should therefore be as low as possible. Especially for people living in villages this effect exists; when the travel time to the city center is longer, the people living in villages will have a lower probability of using the hubs. Regarding the people living in a city, they have a strong positive constant for the bike alternative, which might be caused by the fact that the majority of the 'living in cities' sample is living in Eindhoven.

Regarding the MNL model per distance category, people living within Eindhoven seem not interested in using the hubs and this group is also less sensitive to increased parking costs in the center. This makes sense as they also seem to prefer using their (e-)bike and this is a feasible option at that distance. The other group, of people living more than 10 kilometers from the city center, have potential for switching as they seem to prefer public transport and have a less strong negative constant for the hubs.

The MNL model per age category indicates that people older than fifty years seem to be less sensitive to changes in costs and travel time and seem therefore less flexible in changing their travel behavior. However, they are already preferring public transportation and private (e-)bike over the car, which is positive. People under thirty are most sensitive to the increasing parking costs in the center and the middle age category (31 – 50) is most sensitive to an increased travel time by bus from the hub. This might relate to the work purpose category as well, as almost half of the respondents with a work purpose belong to the age category of 31 till 50 years as explained in Section 4.1.2. These people might have complex activity patterns and have a time constraint during their trip.

4.2.2. ML models

Three types of Mixed Logit models have been estimated as can be seen in the overview in Figure 4.2.29. The Random Parameter ML model to measure taste variation (Section 4.2.2.1) and the Error Components ML model to measure for similarities to exist between alternatives (Section 4.2.2.2). A combined ML model (Random Parameter + Error Component) is estimated in Section 4.2.2.3.

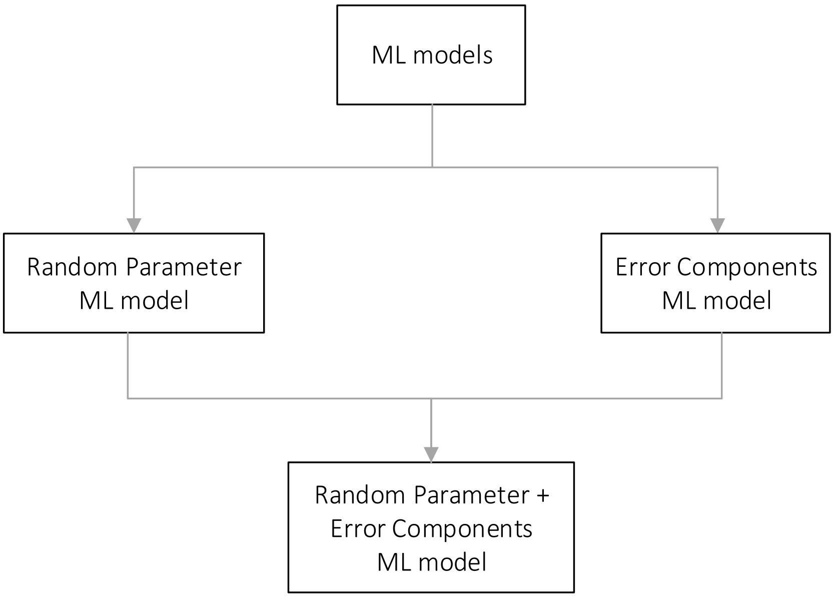

Fig. 4.2.29 Overview ML models

4.2.2.1. Random Parameter model

The Random Parameter Mixed Logit (ML) model is estimated to check for taste variation within the sample. Since Nlogit restricts the number of random parameters to be less than 25 in one model, not all attribute levels have been specified as a random parameter. For the random parameters, an extra parameter, the standard deviation σ, has to be estimated to express the taste variation. The random parameters are assumed to follow a normal distribution (approximated using 1000 Halton draws), hence for each individual a random value β_i is drawn from $N(\beta, \sigma)$. The ρ^2 of the model is 0.556, which means that a relatively large part of the variance seems to be explained by the model. The AIC is 5446.6, which is much better than the general MNL model (AIC of 10238.7). The complete output can be found in Table E.1 in Appendix E. Overall, the ML shows similar effects as the MNL model (see comparison in Table E.4 in Appendix E), however, the effects seem more extreme for the ML model.

Table 4.2.6 shows the taste variation by means of the standard deviations of the random parameter for most of the attributes. As can be seen, the constants all have a relative high taste variation, which makes sense since some people will have a strong intrinsic preference for this alternative and others have not. The standard deviation for the bike alternative is quite high (11.2054), the reason for this might possibly be the fact that both people with an e-bike and with a normal bike are in this category and therefore their preferences differ.

When looking at the attributes, quite some taste variation exists for the attributes. As can be seen, for the parking costs at the hub and in the center, the taste variation is quite large (standard deviation of (almost) 1.0). This might indicate that some respondents did not notice the difference in units for these attributes in the SC experiment. This would mean that a measurement error exists in the data. For the travel costs of €0 for the bike after using public transportation also quite some taste variation exists. The reason for this seems to be unclear since a price of €0 is expected to be favored by all respondents.

Tab. 4.2.6 Mean parameters and standard deviations Random Parameter ML model

Attributes	Coefficient	Sign.	Std. dev.	Sign.
Constant Car + Bus	-2.00286	***	3.93268	***
Constant Car + Bike	-3.32113	***	4.49085	***
Constant Public Transport + Walk	0.07669		6.09501	***
Constant Public Transport + Bike	-5.68554	***	6.58687	***
Constant Bike	1.34723	**	11.2054	***
Car + Bus TT Reduction car: -4	0.36043	**	0.4689	**
Car + Bus TT Reduction car: -2	0.15589		0.44561	*
Car + Bike TT Reduction car: -4	0.15605		0.18064	
Car + Bike TT Reduction car: -2	-0.17339		0.33029	
Car + Bus PC Car at Hub: 0	1.61168	***	1.10131	***
Car + Bus PC Car at Hub: 4	0.05575		0.74889	***
Car + Bike PC Car at Hub: 0	2.00787	***	1.31924	***
Car + Bike PC Car at Hub: 4	-0.30594	*	0.10187	
Car PC Center: 3	1.3457	***	1.45569	***
Car PC Center: 5	-0.21215	*	0.13424	
Car + Bus TT Bus: 6	0.7742	***	0.12186	
Car + Bus TT Bus: 9	-0.13272		0.02128	
Car + Bus WT Bus: 2	0.74053	***	0.49504	**
Car + Bus WT Bus: 6	-0.17913		0.32332	
Car + Bike TT Bike: 5	0.80587	***	1.19055	***
Car + Bike TT Bike: 10	0.1169		0.54461	**
PT + Bike TC Bike: 0	0.77088	***	0.57535	***
PT + Bike TC Bike: 0.5	-0.15938		0.85174	***

4.2.2.2. Error Components ML model

As elaborated in Section 3.3.2 the Error Components Mixed Logit model allows for similarities to exist between alternatives. Three random components have been added to the model. It is assumed that the alternatives Car + Bus and Car + Bike have the common component of driving by car towards Eindhoven and parking the car outside the city center. The second common component is the public transport component for the alternatives PT + Walk and PT + Bike. Lastly, one can consider the common component of the bike in the alternatives Car + Bike and PT + Bike.

The standard deviation σ is estimated for the error components, and this represents the common unobserved factors, so the similarity between the alternatives. When the standard deviation σ of the error component is high, the similarity between the alternatives also increases and therefore the probabilities that these alternatives will be chosen decrease. The error components are assumed to follow a normal distribution (approximated using 1000 Halton draws). Note that the coefficients have been manually set to zero, in order to prevent identification problems. Since the common components are correlated with the respective alternatives. The ρ^2 of the model is 0.465, which means that a relatively large part of the variance seems to be explained by the model. The AIC is 6507.7, so the performance of this model seems to be less good than the Random Parameter model. The complete output can be found in Table E.2 in Appendix E.

Table 4.2.7 shows the standard deviations of the Error Components ML model, and as can be seen, all three error components seem to exist, meaning that for all assumed error components similarities exist. The standard deviation for the public transport component is the highest, so within these alternatives some strong common component is present. This might for example be the factor of traveling with other passengers, or being dependent on the transport mode. The other two standard deviations are less high, so the common component appears to be present to a lesser extent for the car + hub component and the 'last mile' bike component.

Tab. 4.2.7 Standard deviations Error Components ML model

Attributes	Coefficient	Std. dev.	Sign.
Car + Hub component	0	4.13327	***
Public transport component	0	6.21599	***
'Last mile' bike component	0	3.61986	***

4.2.2.3. Random Parameter + Error Components ML model

Sections 4.2.2.1 and 4.2.2.2 respectively discussed the Random Parameter Mixed Logit model and Error Component model. This section combines these two models and estimates the random parameters and error components in one model. As NLogit can only handle less than 25 random parameters, the least significant random parameters from the Random Parameter model have been removed from this model (the TT reduction by car to the hub). Again, the parameters are assumed to follow a normal distribution (approximated using 1000 Halton draws). The ρ^2 of the model is 0.566, and the AIC is 5331.8, so compared to the other two ML models, this model seems to have the better performance. Table E.3 in Appendix E shows the complete output of the model.

Table 4.2.8 shows the mean parameters and the standard deviations for the Random Parameter + Error Components ML model. When comparing this model to the EC model it can be noticed that the standard deviations of the common components remained more or less the same as for the EC model. The standard deviations of the constants on the other hand all decreased quite drastically, except for the bike alternative, which has been reduced only a little. This is an indication that part of the taste variation identified by the Random Parameter model is explained by the common components. So, for example, people that are willing to use the hub and take the bus, are also willing to use the hub and take the bike after. Similarly, the other way around, that they are not willing to use either one of these alternatives. Especially for the bike as 'last mile' transport mode this relation seems to exist. Regarding the high taste variation for the bike alternative, this might be caused by the fact if people have an e-bike or not. Since these can travel faster, it makes it a more interesting alternative. Moreover, when people already invested in an e-bike, they are probably more eager to use it.

Tab. 4.2.8 Mean parameters and std. dev. Random Parameter + Error Components ML model

Attributes	Coefficient	Sign.	Std. Dev.	Sign.
Car + Hub component	0		4.26475	***
Public transport component	0		5.96749	***
'Last mile' bike component	0		3.91081	***
Constant Car + Bus	-1.06201	***	0.97735	***
Constant Car + Bike	-2.13361	***	0.42454	
Constant Public Transport + Walk	-0.90171	***	4.06979	***
Constant Public Transport + Bike	-3.50375	***	0.28725	
Constant Bike	2.1146	***	10.9945	***
Car + Bus PC Car at Hub: 0	1.68043	***	0.58388	**
Car + Bus PC Car at Hub: 4	-0.01658		0.20448	
Car + Bike PC Car at Hub: 0	2.04951	***	0.92741	***
Car + Bike PC Car at Hub: 4	-0.4355	***	0.02331	
Car PC Center: 3	1.44103	***	1.57513	***
Car PC Center: 5	-0.14718		0.60912	*
Car + Bus TT Bus: 6	0.67704	***	0.22446	
Car + Bus TT Bus: 9	-0.05771		0.24202	
Car + Bus WT Bus: 2	0.70439	***	0.67807	***
Car + Bus WT Bus: 6	-0.15344		0.45617	*
Car + Bike TT Bike: 5	0.82341	***	0.89947	***
Car + Bike TT Bike: 10	0.12019		0.43485	
PT + Bike TC Bike: 0	0.53887	**	1.08643	***
PT + Bike TC Bike: 0.5	-0.11234		0.60453	*

4.2.3. LC models

The latent class model allocates individuals to a number of classes based on their choice behavior. Figure 4.2.30 shows an overview of the latent class models estimated in this study. First a general LC model is estimated and within the purpose categories and urbanization categories is checked if latent classes exist within these categories. For the purpose categories no latent classes have been identified within the categories. The LC model per urbanization category is discussed in Section 4.2.3.1.

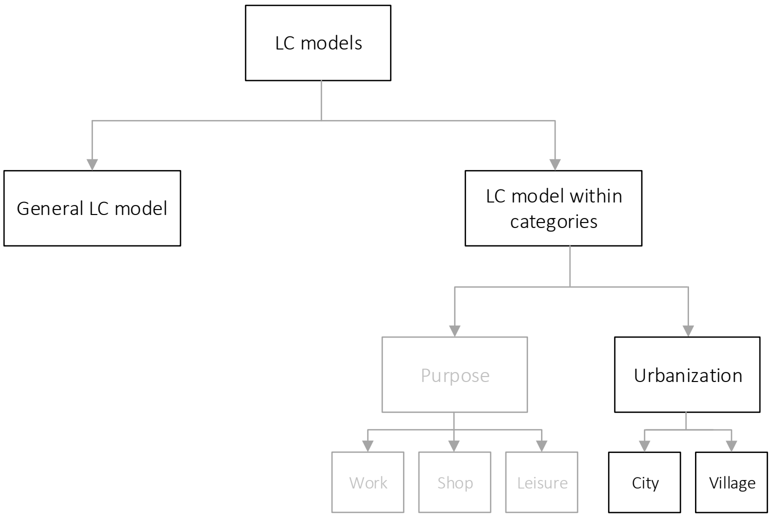

Fig. 4.2.30 Overview LC models

General LC model

Nlogit is again used to estimate the LC models, and by means of the AIC (Equation 7 in Section 3.3.1) the optimal number of classes is determined using the log likelihood LL and the number of parameters K. Table 4.2.9 shows the AIC for two, three and four classes for the general LC model.

Tab. 4.2.9 AIC values per number of classes general LC model

	2 Classes	3 Classes	4 Classes
LL	-4181.79889	-3580.04568	-3210.98788
K	63	95	127
AIC	8489.59778	7350.09136	6675.97576

As can be seen, the model with four classes seems to be the best model, as it has the lowest AIC value. However, when inspecting the output, this model showed extreme and insignificant coefficients. Therefore the model with three classes is selected and has a ρ^2 of 0.405, so the model seems to explain the data well and will be further elaborated in this section. Tables F.1.1 till F.1.3 in Appendix F.1 show the complete Nlogit output. The classes respectively contain 128, 153 and 94 respondents. Looking at the coefficients of the constants in Table 4.2.10, it can be seen that class 1 prefers the bike strongly over the car. This is also true for the alternative public transportation + walk, however, this effect seems to be less strong. Class 2 on the other hand seems to prefer the car over all alternatives. Class 3 seems to be keen on using public transportation.

Tab. 4.2.10 Constant coefficients classes general LC model

Alternatives	Constant Class 1	Sign.	Constant Class 2	Sign.	Constant Class 3	Sign.
Car + Bus	0.25812		-0.59042	***	-0.05335	
Car + Bike	-4.39673		-0.9146	***	0.56189	*
Public Transport + Walk	2.72821	***	-2.49652	***	2.57114	***
Public Transport + Bike	-4.21888		-9.56952		2.25698	***
Bike	5.79242	***	-1.61484	***	0.02666	

Figures 4.2.31 till 4.2.38 show the attributes with significant parameters. Comparing Figures 4.2.31 and 4.2.32 on the parking costs at the hub for respectively the car + bus and car+ bike alternative, shows the coefficients for the car + bike alternative are stronger than for the car + bus alternative. In both figures, class 1 seems to be most sensitive to the varying parking tariffs and class 2 the least sensitive. This makes sense, as class 2 seems not to be open to using other alternatives than the car.

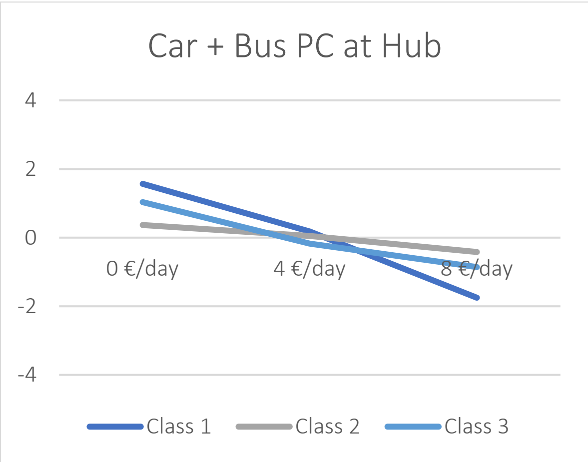

Fig. 4.2.31 PC Car at Hub (in Car + Bus) general LC model

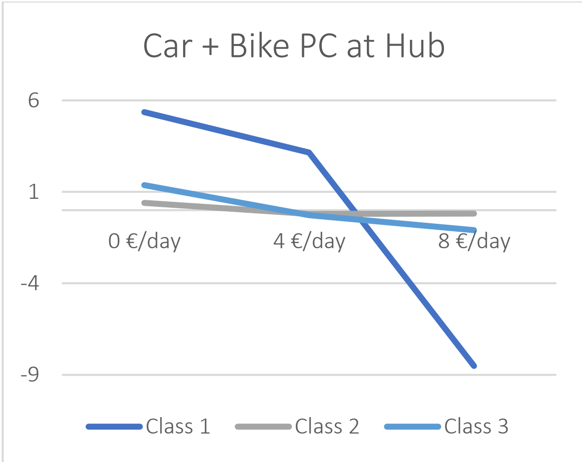

Fig. 4.2.32 PC Car at Hub (in Car + Bike) general LC model

Regarding the parking costs shown in Figure 4.2.33, class 1 again seems to be most sensitive to the changing parking tariffs and in the case class 2 seems to be least sensitive. Regarding the costs for the bike in the PT + bike alternative in Figure 4.2.34, class 3 seems to be insensitive to changing travel costs. For the other classes no unambiguous interpretation can be derived from the figure.

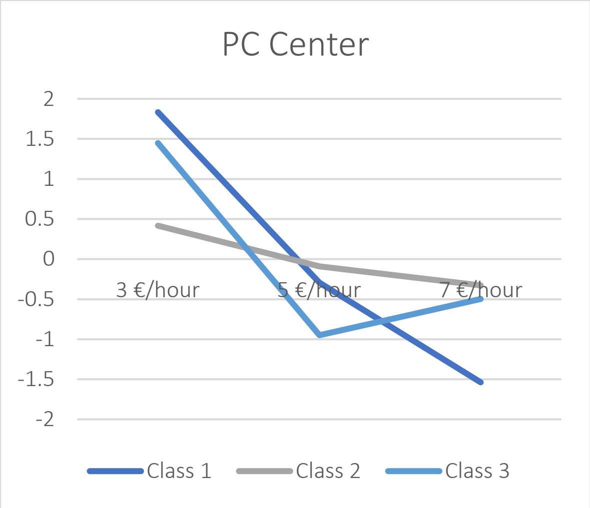

Fig. 4.2.33 PC Car City Center general LC model

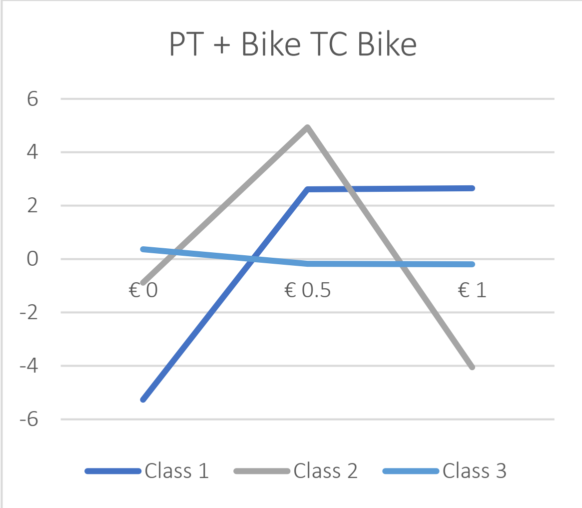

Fig. 4.2.34 TC Bike (in PT + Bike) general LC model

Considering Figures 4.2.35 and 4.2.36 on the travel time of respectively bus and bike from the hub. Class 2 seems to be most sensitive to the travel time of the bus and the bike from the hub. For class 1 and 3 the figures show non-interpretable behavior.

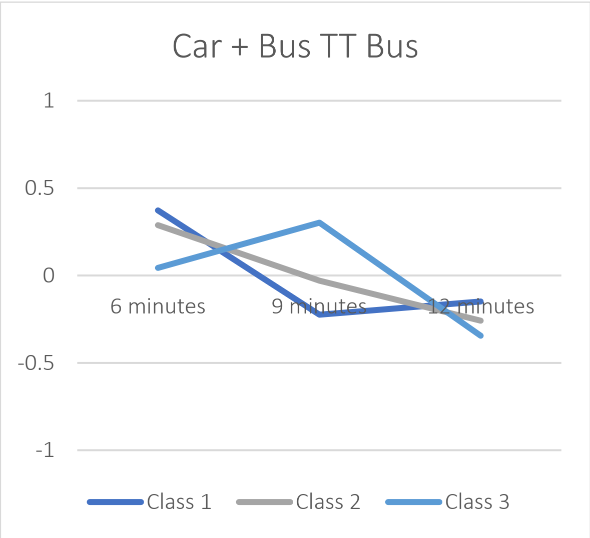

Fig. 4.2.35 TT Bus (in Car + Bus) general LC model

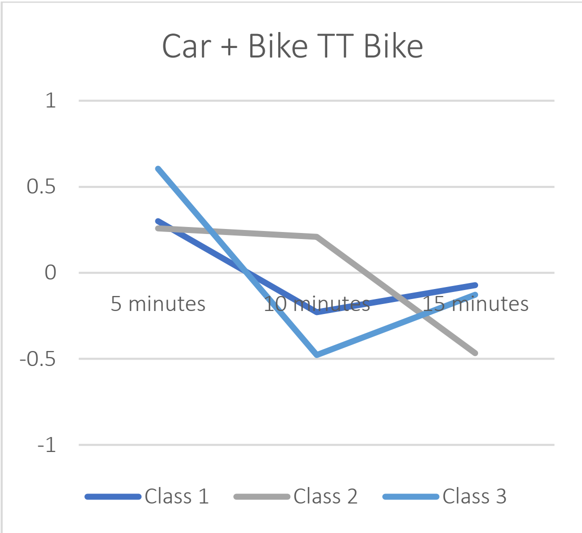

Fig. 4.2.36 TT Bike (in Car + Bike) general LC model

Figure 4.2.37 shows the waiting time for the bus and class 3 seems to be most sensitive to these waiting times. Looking at the reduction of travel time by car in Figure 4.2.38, class 1 shows quite remarkable results. Class 3 on the other hand seems to be most sensitive again.

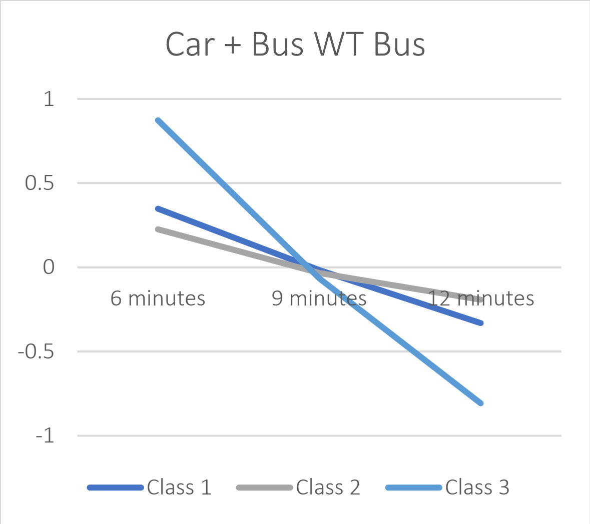

Fig. 4.2.37 WT Bus (in Car + Bus) general LC model

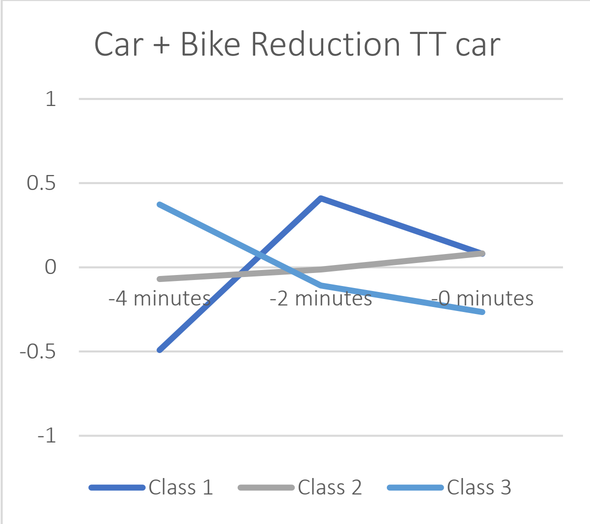

Fig. 4.2.38 TT Reduction Car (in Car + Bike) general LC model

Concluding, class 1 seems to be already preferring the alternatives public transportation + walk and bike over the car. Increased parking tariffs seem to have most effect on this class. Class 2 seems to be most sensitive to the travel time of both bus and bike from the hub, and looking at the constants of this class, they are not willing to switch from private car to another mode. Class 3 prefers using public transportation over the car. However, for this class an increase in waiting time seems to negatively contribute to their utility for this alternative.

Class characteristics

In order to be able to describe these classes in terms of personal characteristics, a multinomial logistic regression has been performed with the classes as dependent variable. The variables that possibly influence to which class the respondents belong have been entered as independent variables. These are the gender, age, education level, income level, work status, household size, living situation, distance to Eindhoven city center, urbanization, purpose of visit, duration of stay and public transport subscription. Using the backward stepwise method, the variables that have no influence on the classes are removed from the model. Appendix F.1.1 shows the complete SPSS output for this multinomial logistic regression. Table 4.2.11 provides the parameter estimates of the variables that seem to predict class membership.

As can be seen, the variables education level and urbanization seem to influence the class membership. Considering the significance of the variables in the model, there can be stated that people with a low or middle education level are less likely to belong to class 1 than to class 3 compared to people with a high education level. Moreover, people living in Eindhoven are less likely to belong to class 1 or 2 than class 3 compared to people living in another city. Additionally, people living in a village are more likely, compared to people living in another city than Eindhoven, to belong to class 1 and 2 than to class 3. Considering the behavior these classes perform, this does not immediately provide an explanation.

Tab. 4.2.11 Parameter estimates multinomial logistic regression classes general LC model

Class[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B) Lower Bound	95% Confidence Interval for Exp(B) Upper Bound
1	Intercept	.629	.364	2.994	1	.084			
	[Education_Low]	-1.192	.391	9.317	1	.002	.304	.141	.653
	[Education_Middle]	-.747	.335	4.962	1	.026	.474	.246	.914
	[Education_High]	0[b]	.	.	0	.	.	.	.
	[Urbanization_Eindhoven]	-.246	.423	.339	1	.561	.782	.341	1.791
	[Urbanization_Village]	.562	.392	2.053	1	.152	1.754	.813	3.784
	[Urbanization_OtherCity]	0[b]	.	.	0	.	.	.	.
2	Intercept	.978	.340	8.302	1	.004			
	[Education_Low]	-.751	.371	4.095	1	.043	.472	.228	.977
	[Education_Middle]	-.458	.330	1.927	1	.165	.632	.331	1.208
	[Education_High]	0[b]	.	.	0	.	.	.	.
	[Urbanization_Eindhoven]	-1.142	.418	7.451	1	.006	.319	.141	.725
	[Urbanization_Village]	.238	.359	.440	1	.507	1.269	.628	2.565
	[Urbanization_OtherCity]	0[b]	.	.	0	.	.	.	.

a. The reference category is: 3.

b. This parameter is set to zero because it is redundant.

4.2.3.1. Latent class model per urbanization category

Within the urbanization categories of people's home location, city and village, has been checked if latent classes exist within these two categories. First the latent classes within the city category will be discussed, followed by the village category.

City

For the people living in a city (154 respondents), a model with two and three latent classes have been estimated. The AIC values shown in Table 4.2.12 indicate that the model with three latent classes is better than with two. However, when inspecting the results, this model contained a low number of respondents in two of the classes, and showed insignificant results. Therefore eventually the model with two latent classes has been selected, with 88 and 66 in class 1 and 2 respectively. The ρ^2 of this model is 0.430, so the model seems to explain the data quite well. The complete output of these latent classes is shown in Tables F.2.1 till F.2.3 in Appendix F.2.

Tab. 4.2.12 AIC values per number of classes LC model within city category

	2 Classes	3 Classes
LL	-1408.438	-1271.94
K	63	95
AIC	2942.8767	2733.87

Table 4.2.13 shows the constant coefficients of the classes within the people living in a city. Class 1 seems to prefer all alternatives over the car except for the public transportation + bike alternative. This class is especially keen on using transport modes that do not require a transfer. Class 2 seems to prefer car over all other modes and has the strongest negative coefficient for the bike alternative.

Tab. 4.2.13 Constants classes within city category

Alternatives	Constant Class 1	Sign.	Constant Class 2	Sign.
Car + Bus	0.20332		-1.22864	***
Car + Bike	-0.33254		-1.13913	***
Public Transport + Walk	2.98351	***	-0.53413	***
Public Transport + Bike	0.16512		-1.08905	***
Bike	5.87082	***	-1.74291	***

Figures 4.2.39 till 4.2.49 show the attributes that have been found significant at a 5% level for at least one of the classes. Looking at Figures 4.2.39 and 4.2.40, the parking costs at the hub for both the bus and bike alternative seem most important to class 1, but affect both classes.

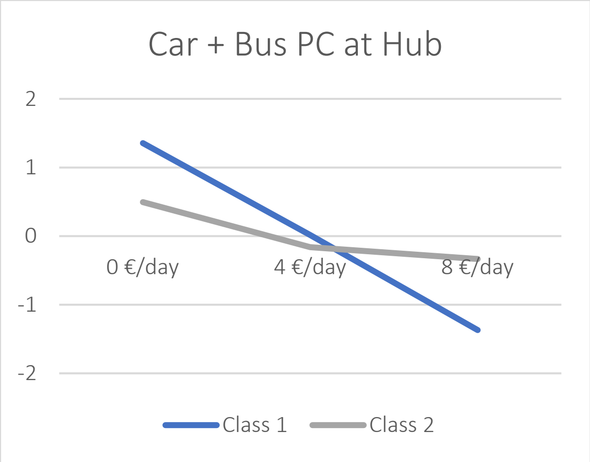

Fig. 4.2.39 PC Car at Hub (in Car + Bus) LC model within city category

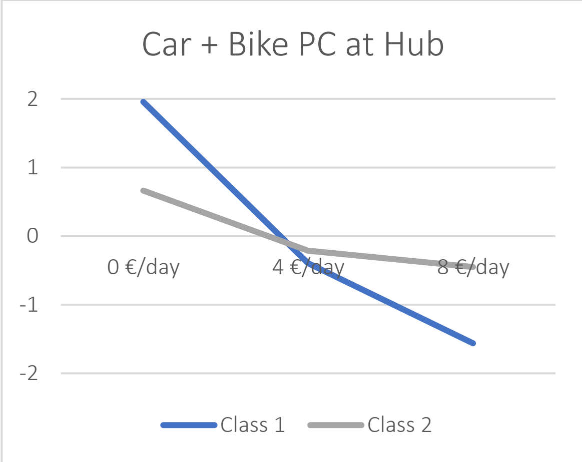

Fig. 4.2.40 PC Car at Hub (in Car + Bike) LC model within city category

Figure 4.2.41 shows the parking costs at the city center and again class 1 seems most sensitive to these changes. Figure 4.2.42 shows the travel costs of the bike in the public transportation + bike alternative, and again class 1 is most sensitive to the costs.

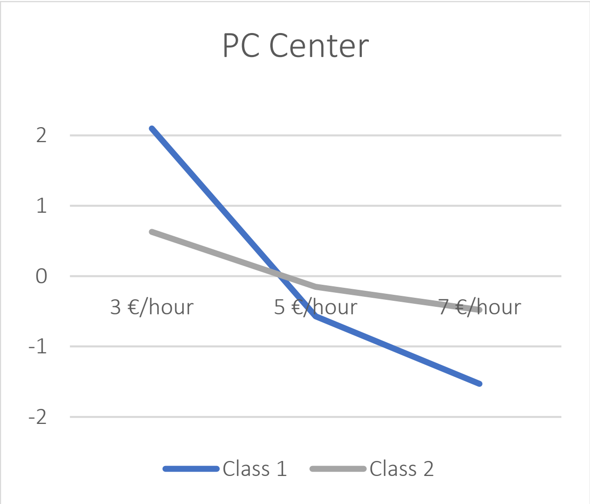

Fig. 4.2.41 PC Car City Center LC model within city category

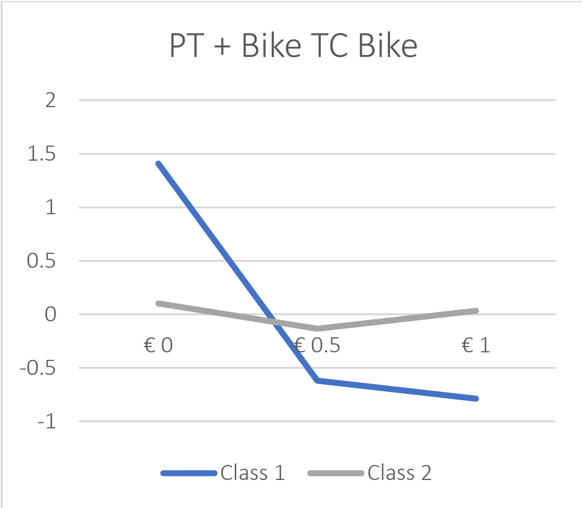

Fig. 4.2.42 TC Bike (in PT + Bike) LC model within city category

For Figures 4.2.43 and 4.2.44; the travel time reduction of the car in respectively the car + bus and car + bike alternative. As can be seen, class 2 is quite sensitive to the travel time reduction in both alternatives. Regarding class 1, they seem to be sensitive to the travel time reduction in the car + bike alternative, for the other figure, no univocal interpretation can be given.

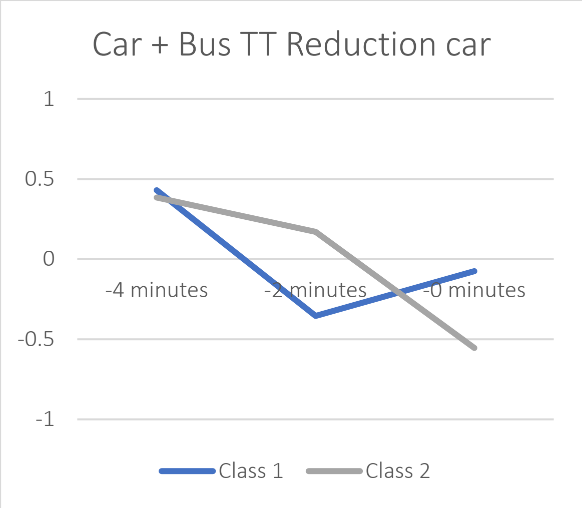

Fig. 4.2.43 TT Reduction Car (in Car + Bus) LC model within city category

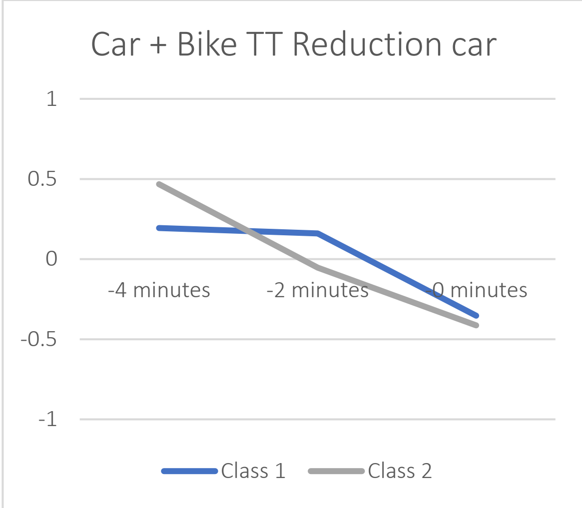

Fig. 4.2.44 TT Reduction Car (in Car + Bike) LC model within city category

In Figures 4.2.45 and 4.2.46 are respectively the travel times by bus and bike shown from the hub. As can be seen, for class 1 no univocal interpretation can be given, but regarding the travel time by bike, class 2 seems slightly sensitive to this attribute. The waiting time for the bus in the car + bus alternative is shown in Figure 4.2.47, and again class 2 seems to be sensitive to this attribute.

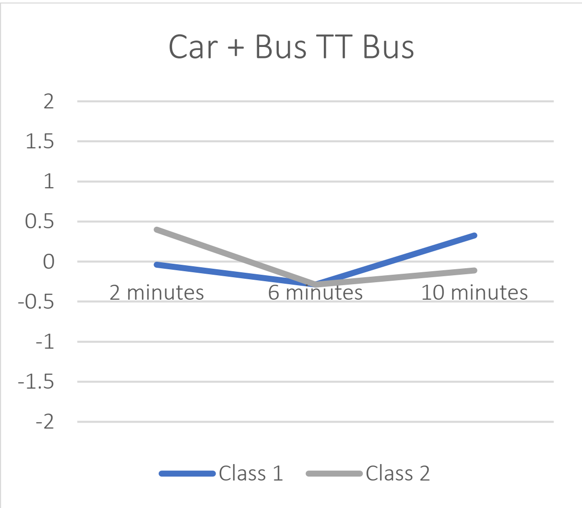

Fig. 4.2.45 TT Bus (in Car + Bus) LC model within city category

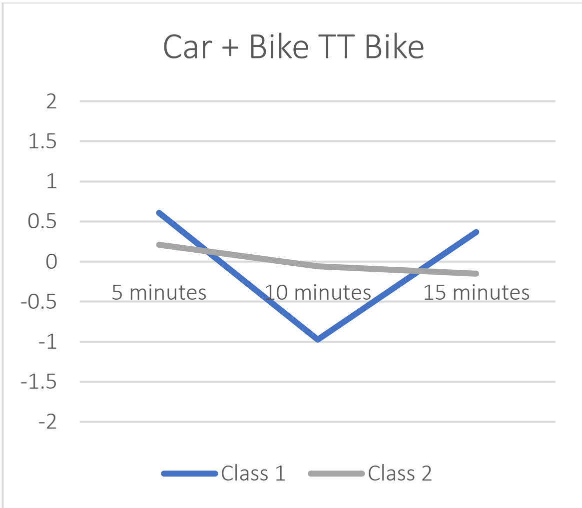

Fig. 4.2.46 TT Bike (in Car + Bike) LC model within city category

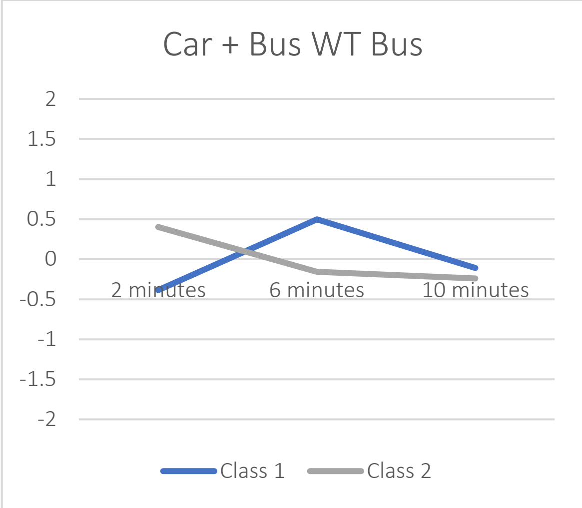

Fig. 4.2.47 WT Bus (in Car + Bus) LC model within city category

All in all, within the group of respondents living in a city, two classes have been distinguished. Class 1 has quite a strong intrinsic preference for the bike. This class overall has a preference for all alternatives over the car, except for the public transportation + bike alternative. Costs seem to affect this class most, both the parking costs at the hub and in the city center, as well as the costs for the bike after public transportation. Class 1 therefore seems to have potential for switching. Class 2 prefers the car alternative over all other alternatives and is sensitive to the increased waiting time for the bus from the hub, and slightly sensitive to an increased travel time by bike from the hub. Although this class has a preference for car, they seem to be somewhat sensitive to increased parking costs as well.

Class characteristics

Backward stepwise binary logistic regression is used to identify certain characteristics of the classes identified in this latent class model, as this model only has two levels in the dependent variable. The independent variables entered were gender, age, education level, income level, work status, household size, living situation, distance to Eindhoven city center, purpose of visit, duration of stay and public transport subscription. However, as can be seen in Appendix F.2.1, no significant variables have been found to influence class membership since all variables were removed from the model.

Village

Within the group living in a village (221 respondents), three classes have been identified. The AIC values in Table 4.2.14 show that the model containing four classes actually seems better, however, this model showed some extreme and insignificant results. Hence, the model containing three classes has been selected. The ρ^2 of the model is 0.381, so the model seems to explain the data quite well. The complete Nlogit output for these latent classes is shown in Tables F.3.1 till F.3.4 in Appendix F.3. The three classes respectively contain 76, 88 and 57 respondents.

Tab. 4.2.14 AIC values per number of classes LC model within village

	2 Classes	3 Classes	4 Classes
LL	-2630.44	-2193.86	-1946.08
K	63	95	127
AIC	5386.88	4577.724	4146.159

Table 4.2.15 shows the constant coefficients for these latent classes. As can be seen in the Table, class 1 only has a negative coefficient for the alternatives that contain public transportation. This class has positive constants for the hub alternatives, and also quite a strong positive constant for the bike. Class 2 has an intrinsic preference for the car over all alternatives. Class 3 only has a negative constant for the public transportation + bike alternative, and quite a strong positive constant for the public transportation + walk alternative.

Tab. 4.2.15 Constant coefficients classes within village category

Alternatives	Constant Class 1	Sign.	Constant Class 2	Sign.	Constant Class 3	Sign.
Car + Bus	1.5717	***	-1.85923	***	1.25264	**
Car + Bike	1.23682	***	-2.18001	***	0.1586	
PT + Walk	-1.56664	***	-1.9946	***	3.68813	***
PT +Bike	-4.93712		-0.8426	***	-2.36549	
Bike	4.89257	***	-2.8781	***	1.47649	**

Figures 4.2.48 till 4.2.53 show the significant attributes (for at least one class at a 5% level). Looking at Figure 4.2.48 class 3 is most sensitive to the increased parking costs at the hub for the car + bus alternative. Figure 4.2.49 shows class 3 is also most sensitive, followed by class 2, to the same costs but then for the car + bike alternative.

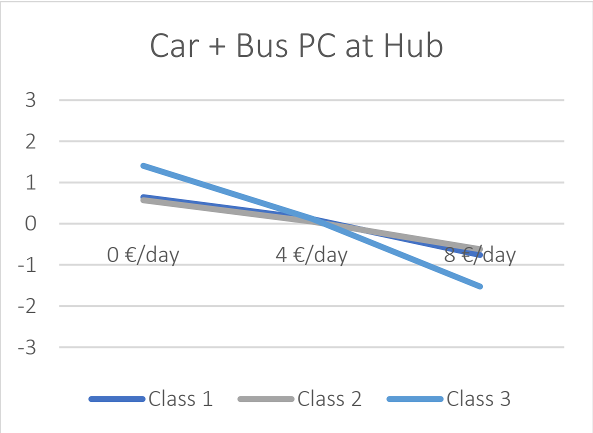

Fig. 4.2.48 PC Car at Hub (in Car + Bus) LC model within village category

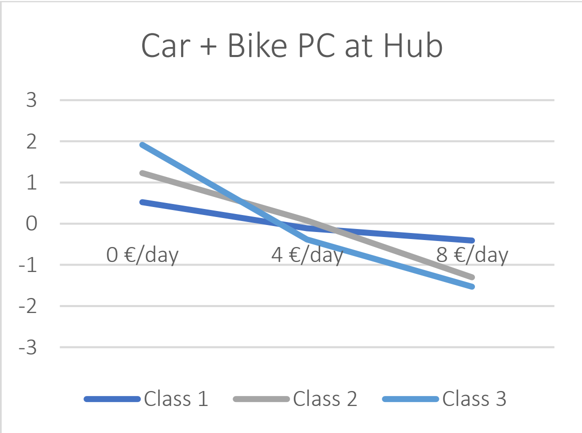

Fig. 4.2.49 PC Car at Hub (in Car + Bike) LC model within village category

Considering the parking costs in the center shown in Figure 4.2.50, class 3 seems again to be most sensitive to these costs, however the difference between €5 per hour and €7 per hour does not make sense. The waiting time for the bus in the car + bus alternative is plotted in Figure 4.2.51 and shows again class 3 is most sensitive to the waiting time.

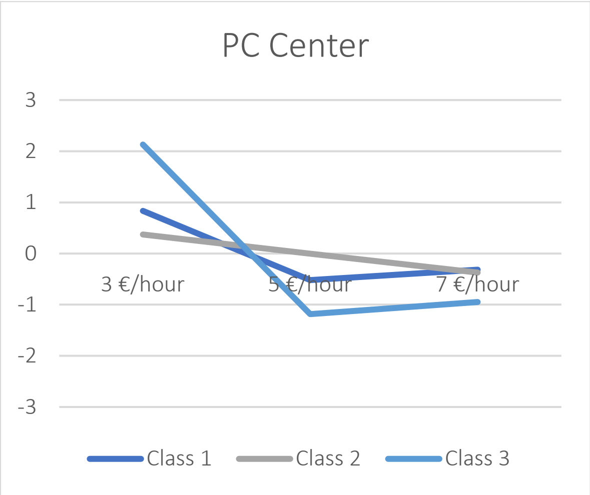

Fig. 4.2.50 PC Car City Center LC model village category

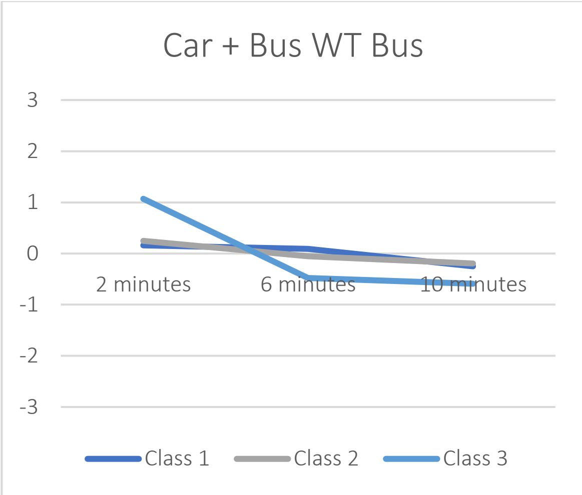

Fig. 4.2.51 WT Bus (in Car + Bus) LC model village category

Figure 4.2.52 and 4.2.53 show the travel time by respectively bus and bike from the hub. Class 1 and 3 seem almost equally sensitive to this travel time. Six and nine minutes both still seem to positively contribute to the overall utility for the alternative car + bus. Considering the travel time by bike, class 2 is most sensitive to a longer cycling time. For classes 1 and 2, five and ten minutes of cycling is fine, but for class 3 only five minutes of cycling contributes positively to their utility for this alternative.

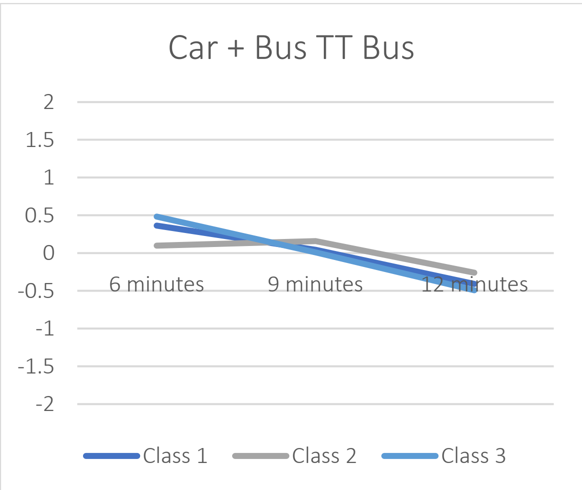

Fig. 4.2.52 TT Bus (in Car + Bus) LC model village category

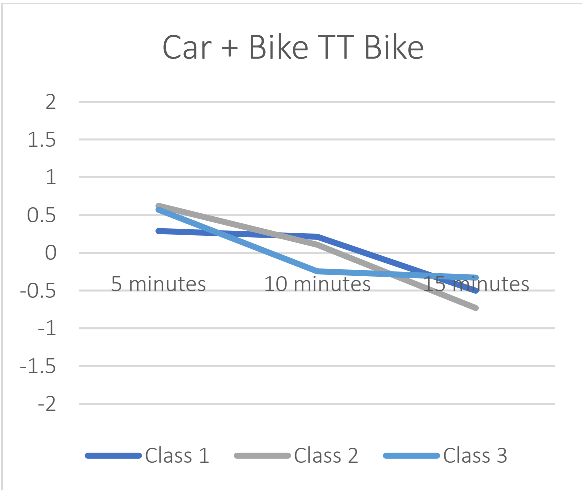

Fig. 4.2.53 TT Bike (in Car + Bike) LC model village category

Regarding the hub facilities in Figure 4.2.54, for class 3 the parcel pick-up facility negatively affects their utility for the car + bus alternative, they seem to rather prefer no facility, which does not directly makes sense.

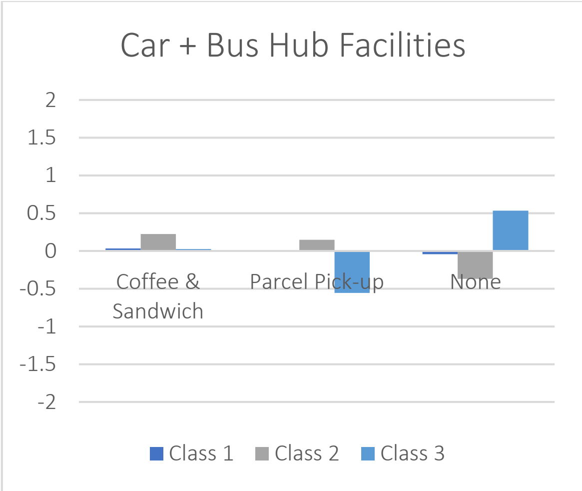

Fig. 4.2.54 Hub Facilities (in Car + Bus) LC model village category

Concluding, class 1 seems to have negative intrinsic coefficients for the alternatives that include public transportation. Class 2 shows negative constants for all alternatives, so this class has a strong intrinsic preference for car. They are quite insensitive to the parking costs in the city center. Moreover, the travel time by bike from a hub also seems to be a determinant for this class. Class 3 prefers all alternatives over the car except for the public transportation + bike alternative. The class is sensitive to parking prices at both the hub and city center, so this class seems to have potential for switching. However, attention should be paid to the waiting time for the bus and travel time by bike from the hub as this class is quite sensitive to these variables.

Class characteristics

For this latent class model, a multinomial logistic regression has been performed, as the dependent variable has three classes. The independent variables entered to the model were gender, age, education level, income level, work status, household size, living situation, distance to Eindhoven city center, purpose of visit, duration of stay and public transport subscription. The complete output can be found in Appendix F.3.1, and Table 4.2.16 shows the parameter estimates. As can be seen, two variables have been found that seem to influence class membership: distance to Eindhoven and public transport subscription. Comparing people living closer than fifty kilometers to people living further than fifty kilometers, the first group seems less likely to belong to class 1 and 2, than to class 3. Moreover, people in these classes also seem to be less likely to have a public transport subscription. This might explain why people in class 3 are more sensitive to the parking tariffs and already have a strong preference for the public transportation + walk alternative.

Tab. 4.2.16 Parameter estimates multinomial logistic regression classes village category

Parameter Estimates

Class[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
1	Intercept	2.752	.842	10.688	1	.001			
	[Distance_1-10km]	-1.808	.935	3.739	1	.053	.164	.026	1.025
	[Distance_11-30km]	-2.205	.852	6.694	1	.010	.110	.021	.586
	[Distance_31-50km]	-1.737	.895	3.770	1	.052	.176	.030	1.016
	[Distance_>50km]	0[b]	.	.	0	.	.	.	.
	[PT subscription]	-1.870	.427	19.215	1	.000	.154	.067	.356
	[No PT subscription]	0[b]	.	.	0	.	.	.	.
2	Intercept	1.709	.933	3.356	1	.067			
	[Distance_1-10km]	-.653	1.022	.409	1	.523	.520	.070	3.855
	[Distance_11-30km]	-.525	.940	.313	1	.576	.591	.094	3.730
	[Distance_31-50km]	-.991	.995	.992	1	.319	.371	.053	2.609
	[Distance_>50km]	0[b]	.	.	0	.	.	.	.
	[PT subscription]	-2.072	.414	25.099	1	.000	.126	.056	.283
	[No PT subscription]	0[b]	.	.	0	.	.	.	.

a. The reference category is: 3.

b. This parameter is set to zero because it is redundant.

4.2.3.2. Conclusion

This section considered three LC models: one general model and two for the urbanization categories city and village. The general model showed three classes, of which the first class seems to already preferring public transportation + walk and the bike alternative over the car. This group already is in favor of the most sustainable transportation alternatives. Their utility seems to be influenced most by the parking costs in the city and at the hub. The second class is not willing to switch to other alternatives, and are most triggered by the travel times from the hub by both bus and bike, these seem to be the real car lovers. Class 3 has an intrinsic preference for public transportation over the car, but waiting time for the bus seems to negatively affect this class.

Regarding the people living in a city, two latent classes have been distinguished from the data. The first class seems to have a strong intrinsic preference for the bike, which might be explained by the fact that the majority of the people in this class live within 10 kilometers from Eindhoven city center. Increased parking costs at the hub and city center, as well as the costs for the bike after using public transportation have most effect on this class. The second class is keen on using the car over the other alternatives, and is especially sensitive to the increased waiting time for the bus from hub and slightly sensitive to the travel time by bike from the hub. Moreover, parking costs also affect this class.

The last LC model, regarding the people living in villages, within this group three latent classes have been identified. The first class prefers all alternatives over the car, except for the public transport alternatives. As this class is also less likely to have a public transport subscription, this makes sense. The second class prefers the car over all alternatives and is also less likely to have a public transport subscription and is quite insensitive to parking tariffs in the city center. Class 3 has most potential for switching to more sustainable modes as this class is likely to already have a public transport subscription and living in a village within 50 kilometers of Eindhoven. They are sensitive to increased parking tariffs in the city center. Despite the fact that this class seems to be willing to use public transportation, there should be noted that this class is sensitive to increased waiting and travel times. They are only willing to cycle for a short period of time.

4.3. Implications

In order to provide a better understanding of what these results indicate, an attempt has been made to visualize them. For this purpose, various scenarios have been devised to reflect the effects of the measures investigated in this research. As already mentioned in Section 4.2.1.1, the MNL model per distance category has been estimated for this purpose. Section 4.3.1 introduces the 'mijn040routes' data and the possibility to compare it to the SC data. Section 4.3.2 provides the scenarios. Section 4.3.3 concludes this section by providing recommendations for the implementation of hubs in Eindhoven.

4.3.1. Data 'mijn040routes'

In 2017, the municipality started a study on the traffic flows in the city of Eindhoven. The study has been performed, because a knowledge gap existed on the travel behavior, modal split and route choice of the road users in Eindhoven. The data has been used to investigate the usage of the traffic network per modality, as well as to identify popular locations and patterns in origins and destinations, and as a base for the implementation for smart policy measures that fit the travel demand best (van Hal, 2018).

The data for this study has been collected by means of the Sesamo app, which was voluntarily installed on participants' smartphones and which automatically collected their movements, and the routes they took (Studio Bereikbaar, n.d.). The data collection was anonymous and no socio-demographic information was collected of the respondents. Participants gained insight in their travel behavior and their favorite locations, and they were contributing to making the city better accessible. As a reward, they received a €5 voucher of the Eindhoven Brandstore.

There was aimed for 2000 participants, however, eventually the study had 1,861 participants of which 1,619 had trip data of three days or more. Figure 4.3.1 shows the background of recruiting these participants.

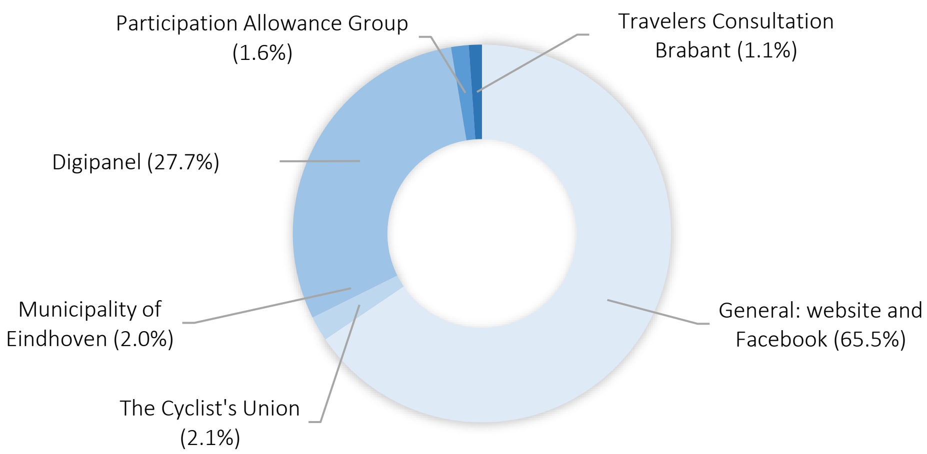

Fig. 4.3.1 Background recruitment participants, adapted from van Hal (2018)

In total 146,295 trips have been recorded, of which 17,218 trips (11.7%) spread over 1,305 participants (70.2%) were conducted from the home location towards Eindhoven with a final destination in the postal code area 5611; the city center. The home locations in 5611 have been removed from the data, as this group is living in the city center and this group has also been removed from the SC data. The sample of the 'mijn040routes' study and the study of the SC experiment could not be compared on socio-demographics, as no information is available on the 'mijn040routes' data; this study was completely anonymous. The only known variable is the home location of the respondents. These have been categorized as: within 10 kilometers of the central train station or more than 10 kilometers in the 'mijn040routes' data. Within 10 kilometers of Eindhoven has been categorized by the municipality of Eindhoven as 'people from Eindhoven'. This category of people living within 10 kilometers are 1106 people (97%) and 34 people (3%) are living outside of Eindhoven, indicating that the first category is highly overrepresented. Whereas, in the SC experiment, 116 (30.9%) people are living within 10 kilometers of the city center and 259 (69.1%) are living further than 10 kilometers. The data does therefore not match completely, and especially the sample could not be compared to people living further than 10 kilometers. Figures 4.53 and 4.54 show the model split identified in the 'mijn040 routes' for respectively the trips of both groups making a trip from their home location towards Eindhoven which ends in the postal code area 5611. Table 4.3.1 provides the data preparation of the 'mijn040routes' categories. The data has been prepared in a way that includes the same modes as the SC experiment data. There should be noted here, that only the 'main' transport mode of the trip and the 'last mile' transport mode have been included and not the 'first mile' transport mode.

Tab. 4.3.1 Data preparation 'mijn040routes'

Prepared category	Original 'mijn040routes' categories
Walk	Walk
Cycle	Cycle, Cycle + Walk
Car	Car, Car + Walk
Car + Cycle	Car + Cycle
PT + Walk	Bus, Bus + Walk, Train, Train + Walk
PT + Cycle	Bus + Cycle, Train + Cycle
PT + Car	Bus + Car

As can be seen in Figure 4.3.2, people living within 10 kilometers (3087 trips), mostly use their bicycle (61%) for their trip with a destination in the center area. Followed by walking (16%). The car is used for 15% of the trips and public transportation (both bus and train) in 7% of the trips. Regarding people living further than 10 kilometers away, less observations are collected (316). Again most of these participants cycle (57%), but now followed by the car (17%). Walking is performed in 14% of the trips, however, it is not expected that these people walk from their home towards Eindhoven city center. Since it was not possible to prepare the data personally, the reason that these trips are included in the selection is unknown. As can be seen in Figure 4.3.3, regarding public transportation, the alternative PT + walking is performed most often (10%) by this group. Using public transportation and taking the bike after has been performed in 2% of the trips.

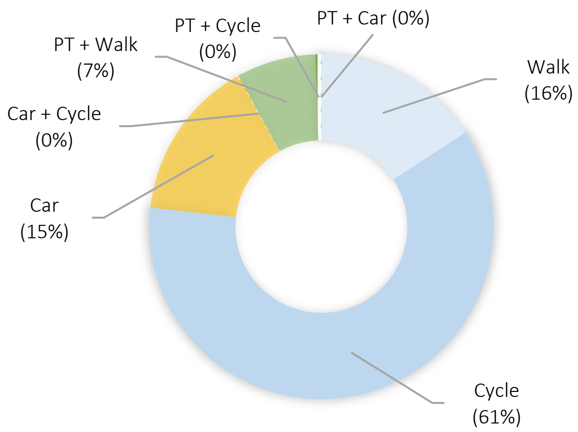

Fig. 4.3.2 Modal split ≤ 10 km 'mijn040routes'

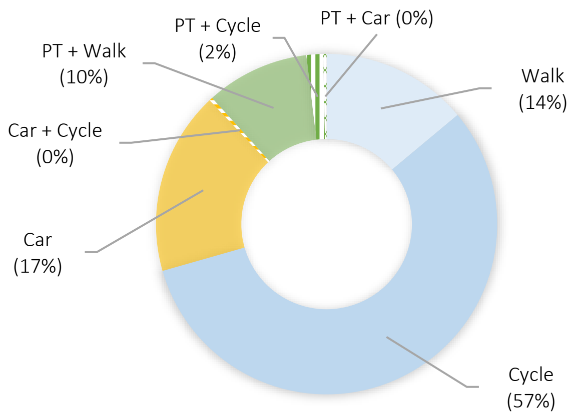

Fig. 4.3.3 Modal split > 10 km 'mijn040routes'

4.3.2. Scenarios

In order to show the implications of the results reported in this thesis, this section discusses several scenarios indicating the effects of various measures that could be implemented by the municipality. The MNL model per distance category discussed in Section 4.2.1.1 has been used for these scenarios, the output of this model can be seen in Appendix D.4. The structural utilities V for the both groups (≤10 km and > 10 km) have been calculated using the following equations:

$$V_{car} = \beta_{car\ PCcenter} * X_{car\ PCcenter}$$

$$V_{car+bus} = \beta_{car+bus\ TT\ Reduction\ Car} * X_{car+bus\ TT\ Reduction\ Car} + \beta_{car+bus\ PC\ Hub} * X_{car+bus\ PC\ Hub} + \beta_{car+bus\ Hub\ Facilities} * X_{car+bus\ Hub\ Facilities} + \beta_{car+bus\ TT\ Bus} * X_{car+bus\ TT\ Bus} + \beta_{car+bus\ WT\ Bus} * X_{car+bus\ WT\ Bus} + \beta_{car+bus\ TC\ Bus} * X_{car+bus\ TC\ Bus} + c_{car+bus}$$

$$V_{car+bike} = \beta_{car+bike\ TT\ Reduction\ Car} * X_{car+bike\ TT\ Reduction\ Car} + \beta_{car+bike\ PC\ Hub} * X_{car+bike\ PC\ Hub} + \beta_{car+bike\ Hub\ Facilities} * X_{car+bike\ Hub\ Facilities} + \beta_{car+bike\ TT\ Bike} * X_{car+bike\ TT\ Bike} + \beta_{car+bike\ TC\ Bike} * X_{car+bike\ TC\ Bike} + c_{car+bike}$$

$$V_{pt+walk} = c_{pt+walk}$$

$$V_{pt+bike} = \beta_{pt+bike\ TC\ Bike} * X_{car+bike\ TC\ Bike} + c_{pt+bike}$$

$$V_{bike} = c_{bike}$$

The probabilities of choosing an alternative have been calculated using Equation 4 in Section 3.3.1. Eleven scenarios have been composed in order to illustrate the differences regarding the different measures possibly implemented. The base scenario illustrates P+R Meerhoven in the West of Eindhoven (see Figure 4.3.4), which already exists and will probably be one of the first locations of a mobility hub. The first scenario illustrates the situation in which P+R Meerhoven facilitates shared-bicycles. The second scenario shows the situation when P+R Meerhoven would be free of charge. The third scenario increases the parking tariffs in the city center to €5 per hour, and shows the effect on the usage of P+R Meerhoven. The fourth scenario shows the planned hub at Genneper Parken in the South of Eindhoven (see Figure 4.3.4). Scenario five increases the bus frequency at Genneper Parken. The sixth scenario has the opposite scenario as it has a long waiting time at Genneper Parken. The seventh scenario again makes the Genneper Parken hub free of charge. Scenario eight indicates the effects of increasing the parking tariffs in the city center to €5 per hour on this hub and scenario nine the effect of parking tariffs of €7. Scenario ten shows the effect of having a free hub at Genneper Parken and increasing the parking tariffs in the city center to €5 per hour. The last scenario shows the effect of locating the hub near the ring road of Eindhoven, which could be location A or B, since in these direction no P+R is planned and they are connected to the HOV lines.

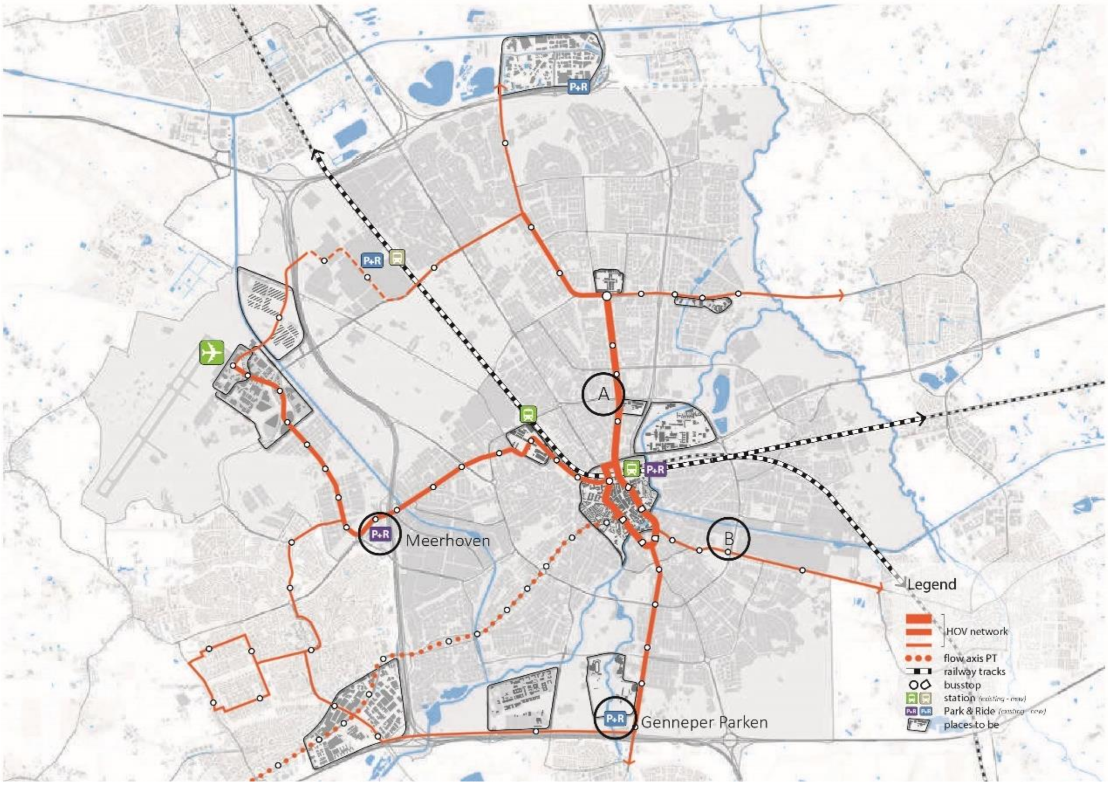

Fig. 4.3.4 Existing, planned and potential P+R locations; adapted from Gemeente Eindhoven (2013)

Scenario 0 – base scenario – P+R Meerhoven

Figure 4.3.5 shows the attribute levels included in the base scenario of P+R Meerhoven. As it illustrates the 'current' situation, the parking costs in the center have been set to €3 per hour and at the hub €4 per day. The location of P+R Meerhoven is approximately 12 minutes by bus, with a waiting time of approximately 6 minutes. Shared-bikes are not yet available at P+R Meerhoven, so these have not yet been added to the scenario. The costs for using a bike after public transportation are € 1. For this attribute the highest price is chosen, as the OV-bicycles now cost €3.25 per day.

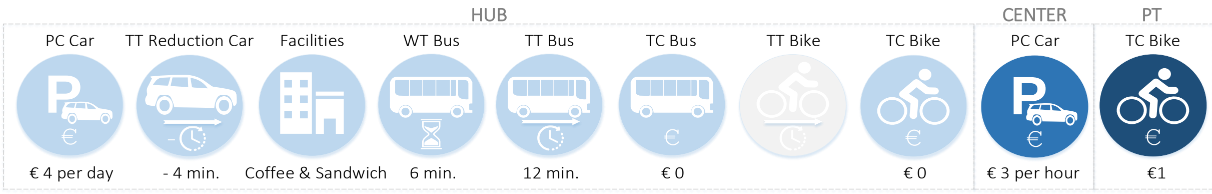

Fig. 4.3.5 Attribute levels base scenario

Considering Figure 4.3.6, there can be seen that almost half of the people living within 10 kilometers of the city center have the probability of choosing the bike for their trip. 30% will choose the car. As can be seen the alternatives that require a transfer are least interesting for this group. Looking at Figure 4.3.7, there can be seen that the hub has a higher probability of being chosen by people living further than 10 kilometers. Of these people 15% would choose the hub with a transfer to the bus (despite the waiting time of 6 minutes). The private bike on the other hand is less interesting, which makes sense as these people live at a longer distance. Looking at the public transportation alternatives, transferring to a bike does not seem so interesting for this price, people rather walk after using public transportation.

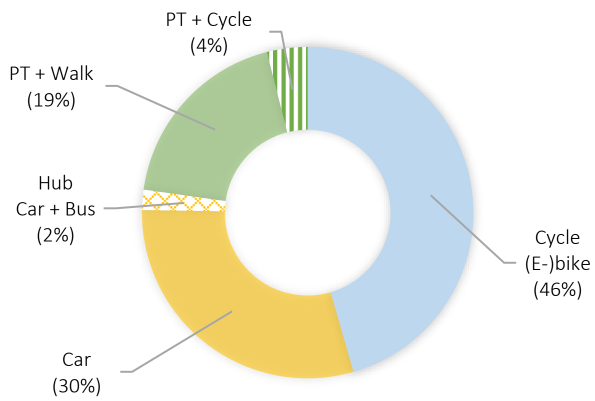

Fig. 4.3.6 Modal split base scenario ≤ 10 km

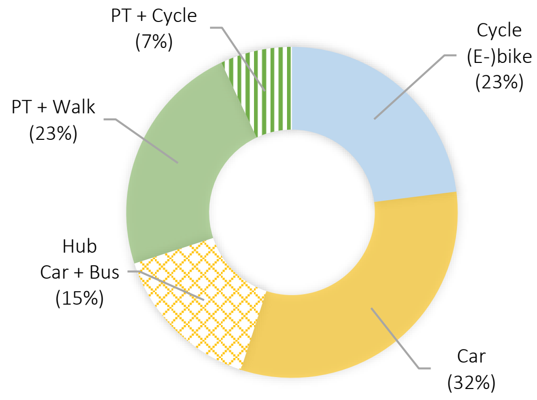

Fig. 4.3.7 Modal split base scenario > 10 km

Comparing the group living within 10 kilometers in the base scenario to this group in the 'mijn040routes' data, one of the main differences is the fact that the SC data does not include walking, which the 'mijn040routes' data does. Looking at the group living within 10 kilometers, in both the SC data and the 'mijn040routes' data, the majority of the trips is performed by bike (respectively 46% and 61%). In the SC data, the second most used transport mode is the car with 30%, in the 'mijn040routes' data this is only 15%. Comparing the use of public transportation, the SC data shows that 19% would use public transportation and walks towards the final destination and 4% would take the bike for the 'last mile'. In the 'mijn040routes' only 7% would use public transportation and walks to the final destination.

The 'mijn040routes' data seems to differ quite significantly from the SC data, which might be caused by the fact that the SC data considers an equal amount of trips per person and in the 'mijn040routes' this is not the case. Every trip made from someone's home location with a final destination in the city center is present within the 'mijn040routes' sample. An overrepresentation of people that often visit the city center by foot or bike might cause this difference. Therefore the scenarios that are elaborated in the next paragraphs have been compared to the base scenario (P+R Meerhoven) based on the SC data.

Scenario 1 – P+R Meerhoven + shared-bikes

Scenario 1 is the current situation of P+R Meerhoven, and at the moment no shared-bikes are available at that P+R, therefore this scenario includes those shared-bikes to see the effect. The rest of the attribute levels are the same as for the base scenario, as can be seen in Figure 4.3.8.

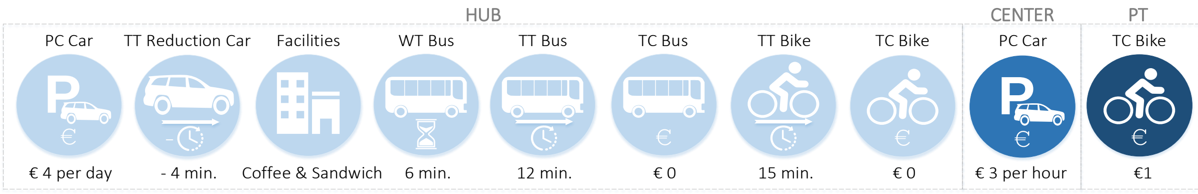

Fig. 4.3.8 Attribute levels scenario 1 – P+R Meerhoven + shared-bikes

The calculated probabilities are shown in Figures 4.3.9 and 4.3.10 for this scenario. As can be seen, adding shared-bikes at the P+R does not make a large difference. 30% will still choose the car for their trip (both ≤10 km and > 10 km). For people living within 10 kilometers, the (e-)bike is also still likely to be chosen. The hubs on the other hand are still not preferred by this group. The hub + bike option seems somewhat interesting for people living further than 10 kilometers. Only 6% will probably choose it, which might be due to the 15 minutes of cycling.

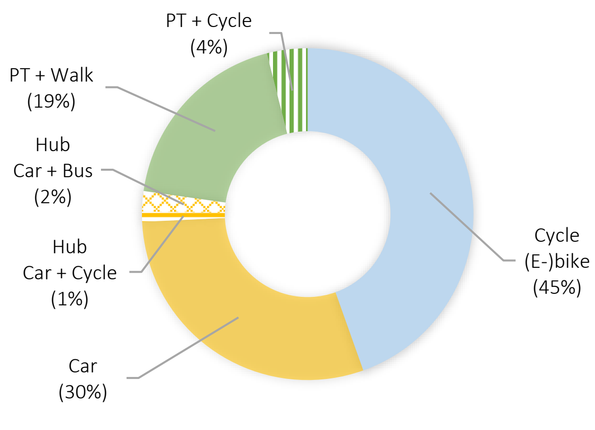

Fig. 4.3.9 Modal split scenario 1 ≤ 10 km

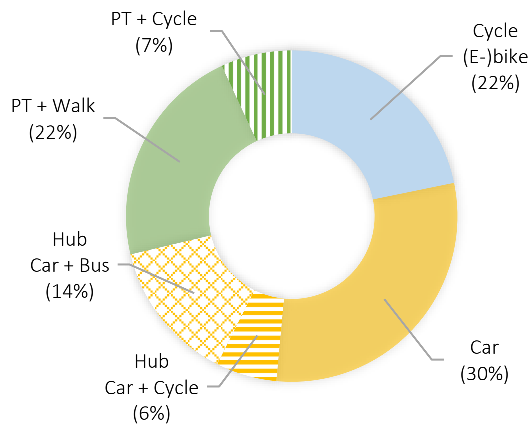

Fig. 4.3.10 Modal split scenario 1 > 10 km

Scenario 2 – Free P+R Meerhoven

Figure 4.3.11 shows the input for the second scenario, as can be seen it shows the same situation as the first scenario, but now the hub is free. Moreover, the transport modes from the hub to the city center are also free, and the price for using a shared-bike after public transport is reduced to €0.5. The travel time by bus from the hub Is still 12 minutes and by bike 15 minutes. The waiting time for the bus is still 6 minutes.

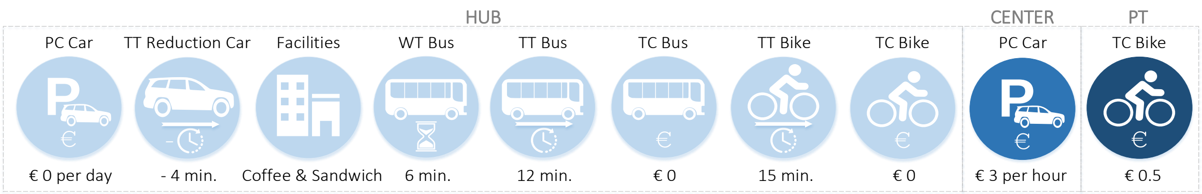

Fig. 4.3.11 Attribute levels scenario 2 – Free P+R Meerhoven

As can be seen in Figures 4.3.12 and 4.3.13, using stimulating measures to let people use the hub by making it free, shows that people living further than 10 kilometers away have a higher probability of using the hub compared to the base scenario. Part of the increase in hub users comes from people that would otherwise park their car in the center. However, also people that would otherwise use their (e-)bike or public transport would switch to using the hub, which are undesired effects.

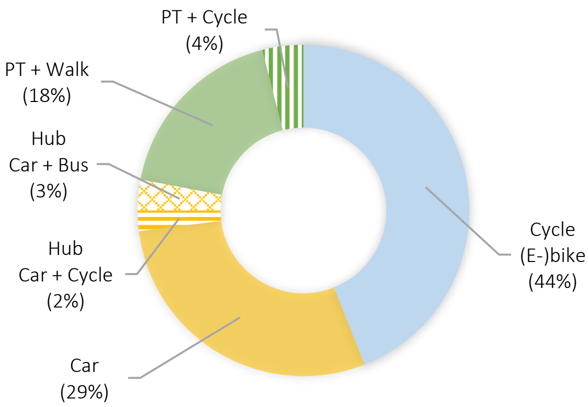

Fig. 4.3.12 Modal split scenario 2 ≤ 10 km

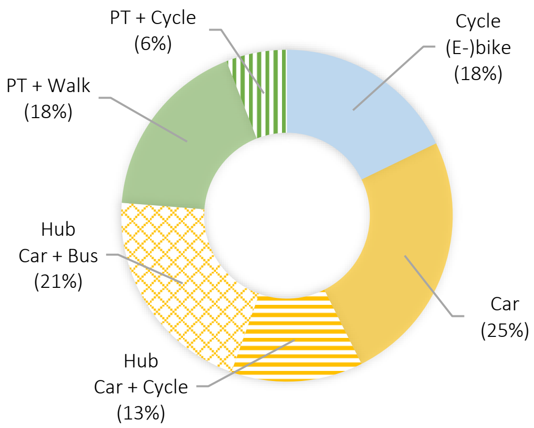

Fig. 4.3.13 Modal split scenario 2 > 10 km

Scenario 3 – P+R Meerhoven and €5 per hour PC city center

The third scenario is similar to the first scenario, but now the parking tariffs in the city center are increased to €5 per hour, the hub is again €4 per hour and using a bike after public transport is still €0.5. The rest of the conditions are the same as shown in Figure 4.3.14.

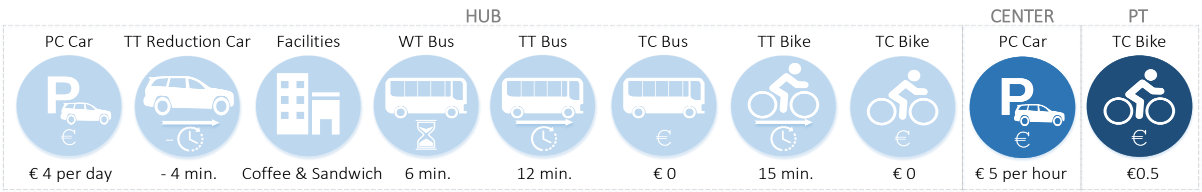

Fig. 4.3.14 Attribute levels scenario 3 – P+R Meerhoven and PC city center €5 per hour

The calculated probabilities are shown in Figures 4.3.15 and 4.3.16 for this scenario, and as can be seen, the increased parking tariffs result in less people taking the car to the city center. For both groups, people will switch to the bike or travel by public transport, and people living further away have a higher probability of using the hubs. Taking the bike from the hub still seems to be less interesting than taking the bus. Comparing this scenario to the previous one, the effect of increased parking tariffs seems to result in more desired behavior, as in this scenario the overall share of sustainable transport modes is higher.

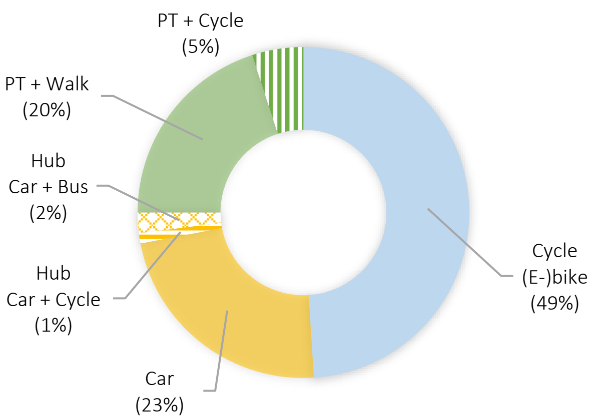

Fig. 4.3.15 Modal split scenario 3 ≤ 10 km

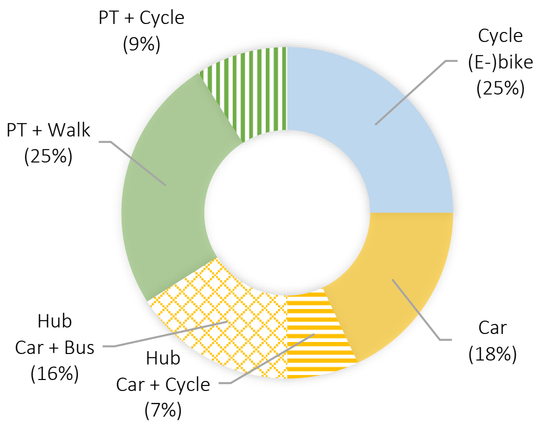

Fig. 4.3.16 Modal split scenario 3 > 10 km

Scenario 4 – Planned Hub Genneper Parken

The input for the scenario of the P+R at Genneper Parken is shown in Figure 4.3.17. This hub is also expected to have a price of approximately €4 per day, and is approximately 9 minutes by bus, with a waiting time of 6 minutes. By bike it will take approximately 10 minutes, and this bike will not cost extra money. The parking costs in the center are €3 per hour, and the bike after public transportation costs €1.

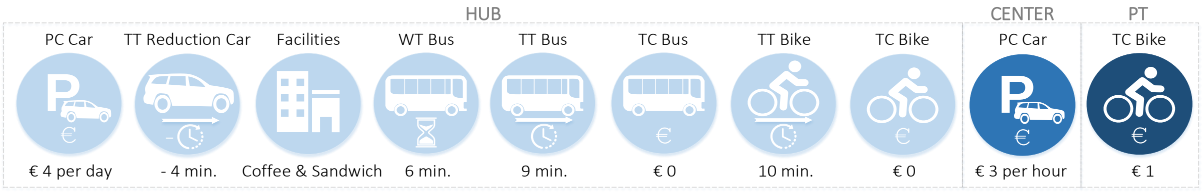

Fig. 4.3.17 Attribute levels scenario 4 – Planned Hub Genneper Parken

As can be seen in Figures 4.3.18 and 4.3.19, the option of parking the car in a hub and transfer to a bike has become more popular for people living further than 10 kilometers from Eindhoven, probably due to shorter cycling time. The car seems to be preferred somewhat less by this group in this scenario. For the other group of people living within 10 kilometers, this scenario does not seem to influence their preferences. From this scenario can be concluded that solely adding a hub with normal tariffs does not really seem to influence the mode choice towards Eindhoven drastically when compared to scenario 1 of P+R Meerhoven + shared-bikes.

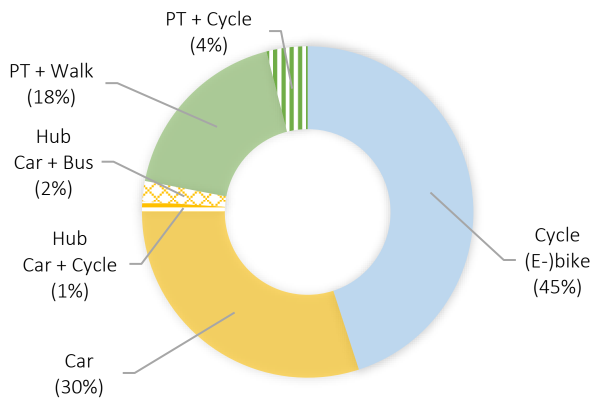

Fig. 4.3.18 Modal split scenario 4 ≤ 10 km

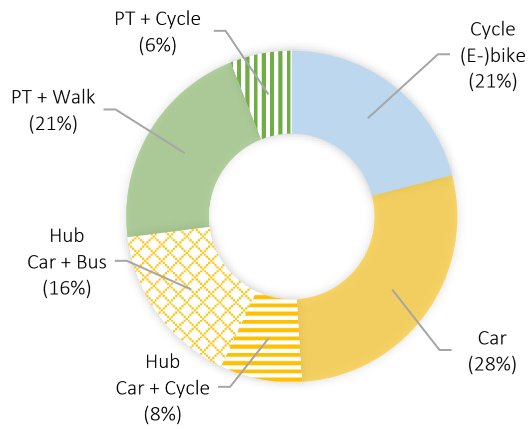

Fig. 4.3.19 Modal split scenario 4 > 10 km

Scenario 5 – Hub Genneper Parken with frequent bus service

Figure 4.3.20 shows the input for the fifth scenario which shows the situation of Genneper Parken having a frequent bus service, which results in a maximum waiting time of two minutes. The travel time by bus is still 9 minutes, and the travel time by bike 10 minutes. The parking costs in the city center are again €3 per hour.

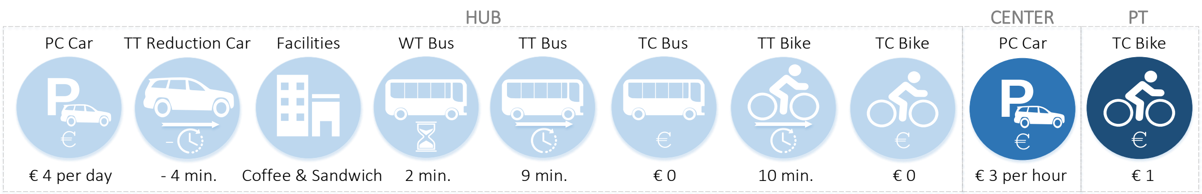

Fig. 4.3.20 Attribute levels scenario 5 – Hub Genneper Parken + frequent bus service

The probabilities of choosing the alternatives are shown in Figures 4.3.21 and 4.3.22. As can be seen, having a frequent bus service increases the probability the hub is being chosen, especially for people living further than 10 kilometers from the city center. Only few people that now travel by car will start using the hub, however, people that would take the bike and public transport in the previous scenario would start using the hub, which are undesired effects, as the share of sustainable transportation only decreases.

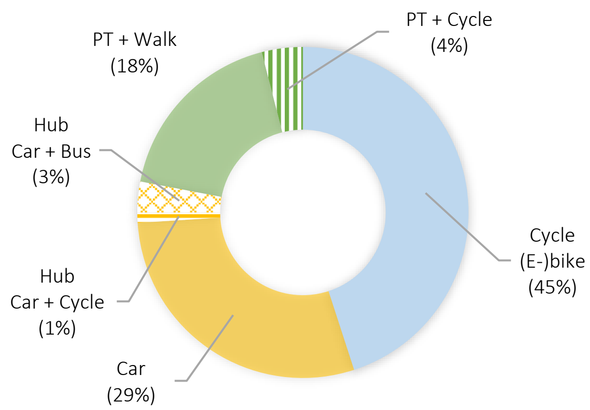

Fig. 4.3.21 Modal split scenario 5 ≤ 10 km

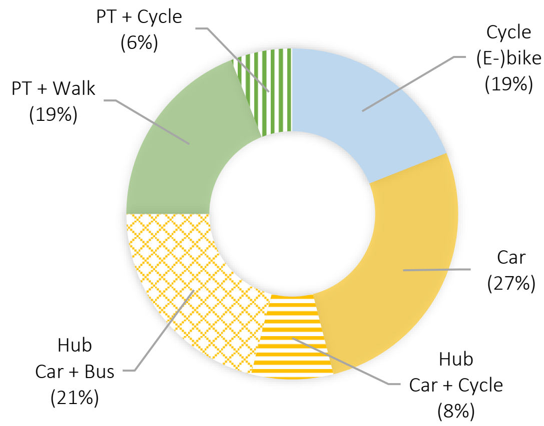

Fig. 4.3.22 Modal split scenario 5 > 10 km

Scenario 6 – Hub Genneper Parken with infrequent bus service

Figure 4.3.23 shows the input for the sixth scenario which shows the effect of an infrequent bus service at Genneper Parken, resulting in a waiting time of 10 minutes. The rest of the input is still the same as the previous scenario.

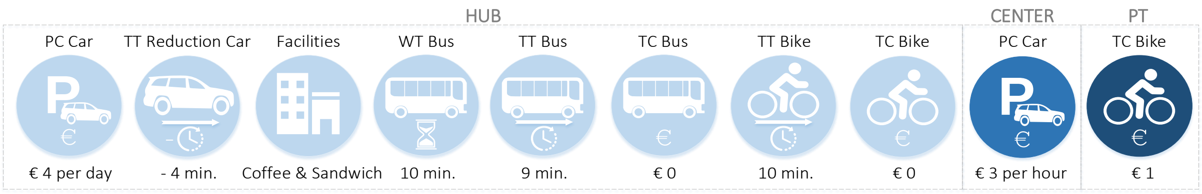

Fig. 4.3.23 Attribute levels scenario 6 – Hub Genneper Parken + infrequent bus service

The probabilities of choosing the alternatives are shown in Figures 4.3.24 and 4.3.25. As can be seen, a waiting time of 10 minutes reduces the probability of the hub being chosen. An increase of all other transport modes can be noticed. Moreover, note that taking the bus from the hub is still favored over taking the bike from the hub.

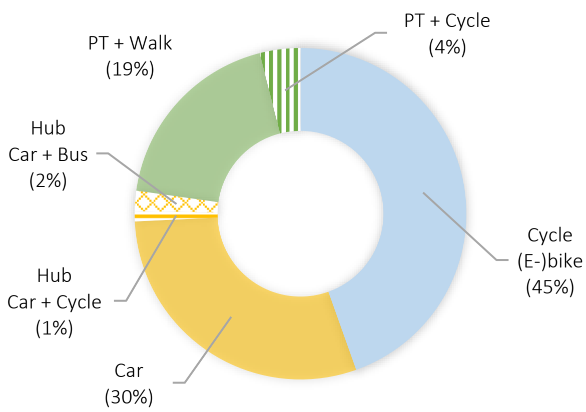

Fig. 4.3.24 Modal split scenario 6 ≤ 10 km

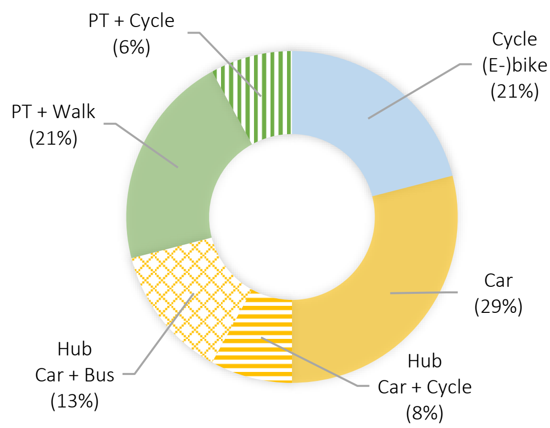

Fig. 4.3.25 Modal split scenario 6 > 10 km

Scenario 7 – Free hub Genneper Parken

Figure 4.3.26 shows the input for the seventh scenario which shows the situation of Genneper Parken as a free hub. Also the shared-bike after using public transport is free in this scenario. The waiting time for the bus is still 6 minutes, the travel time by bus 9 minutes, and the travel time by bike 10 minutes. The parking costs in the city center are again €3 per hour.

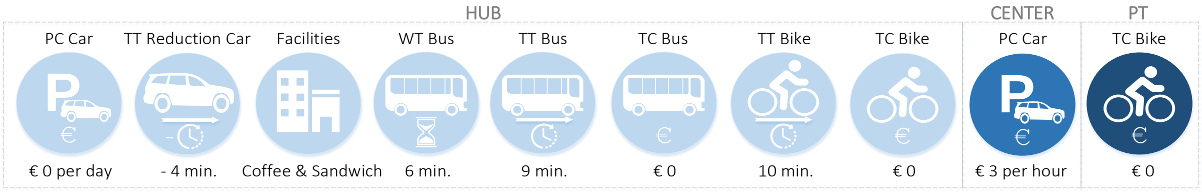

Fig. 4.3.26 Attribute levels scenario 7 – Free Hub Genneper Parken

Figures 4.3.27 and 4.3.28 show the probabilities for the alternatives regarding this scenario. As can be seen, making the hub free will significantly increase its use by people living further than ten kilometers from the city center. As can be seen, taking the bus from the hub is still a more preferred alternative than taking a bike. From this group, less people will travel by car to the city center, but also less people have the probability to travel by bike and public transport, which are unintended effects. Comparing this scenario to scenario 5, making the hub free has more effect than having a more frequent bus service at the hub to get people out of their car. However, the total share of sustainable transportation decreases when the hub free.

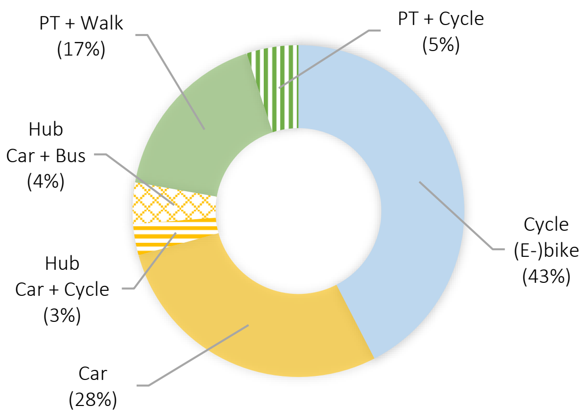

Fig. 4.3.27 Modal split scenario 7 ≤ 10 km

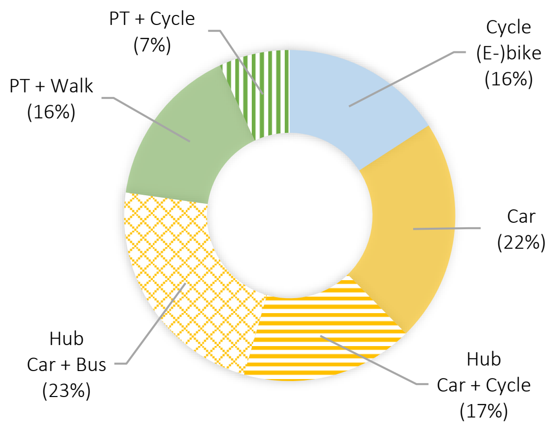

Fig. 4.3.28 Modal split scenario 7 > 10 km

Scenario 8 – Hub Genneper Parken and €5 per hour city center

Figure 4.3.29 shows the input for the eight scenario which shows the situation of increasing the parking tariffs to €5 per hour. The waiting time for the bus is still 6 minutes, the travel time by bus 9 minutes, and the travel time by bike 10 minutes. The costs for using a bike after public transportation are €0.5.

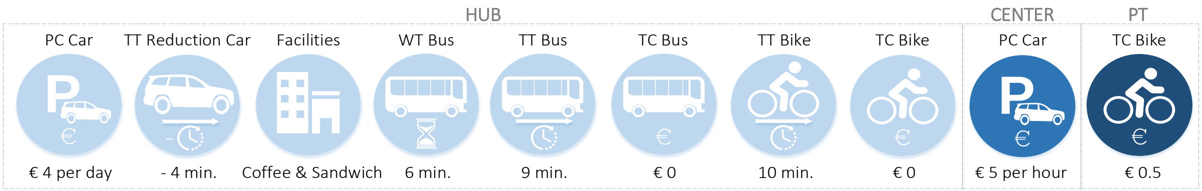

Fig. 4.3.29 Attribute levels scenario 8 – Hub Genneper Parken and PC city center €5 per hour

Figures 4.3.30 and 4.3.31 show that increasing the parking tariffs in the city center is again effective in getting people out of the car, especially in the group further than 10 kilometers from the city center. Overall the share of sustainable transportation is increased and not only the usage of the hubs. Compared to scenario 3 of P+R Meerhoven, which also increased the parking costs in the city center, positioning the hub closer to the city center seems to affect its usage and reduces the car usage a little further.

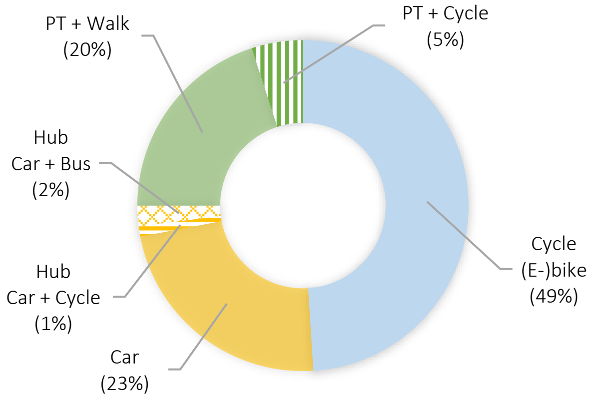

Fig. 4.3.30 Modal split scenario 8 ≤ 10 km

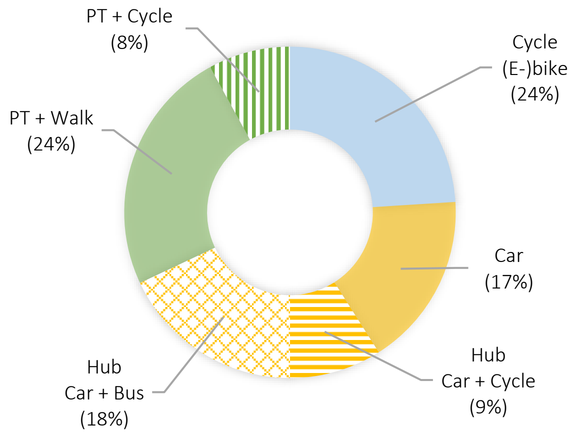

Fig. 4.3.31 Modal split scenario 8 > 10 km

Scenario 9 – Hub Genneper Parken and €7 per hour city center

Figure 4.3.32 shows the input for the ninth scenario which shows the situation of increasing the parking tariffs to €7 per hour. The rest of the input is similar to the previous scenario.

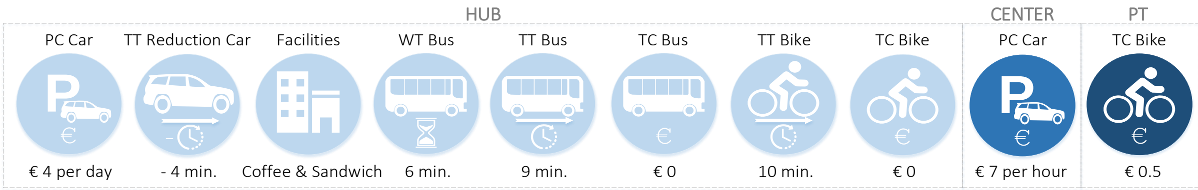

Fig. 4.3.32 Attribute levels scenario 9 – Hub Genneper Parken and PC city center €7 per hour

Figures 4.3.33 and 4.3.34 show that using discouraging measures, such as drastically increasing the parking costs in the city center especially affects people that live further than 10 kilometers from Eindhoven. As can be seen, the probability that they will use the car decreased even further than the previous scenario and the probability of using the hub, public transport or the bike increases. What is striking to note, is that people living within 10 kilometers are less keen on switching, as still 22% has the probability of traveling by car.

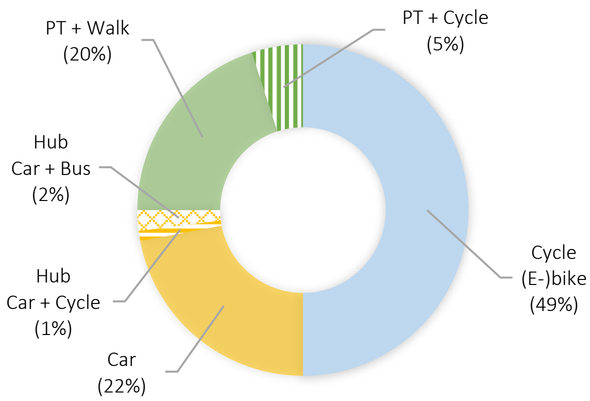

Fig. 4.3.33 Modal split scenario 9 ≤ 10 km

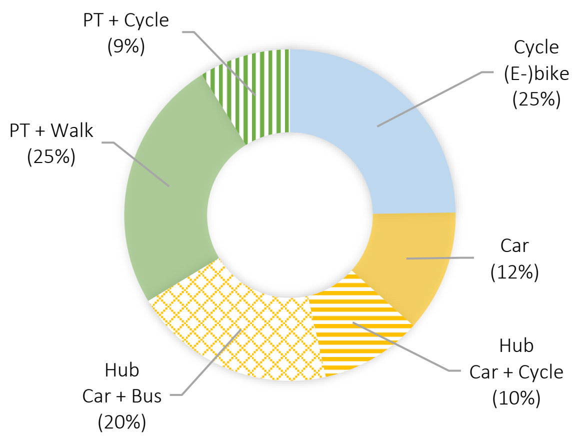

Fig. 4.3.34 Modal split scenario 9 > 10 km

Scenario 10 – Free Hub Genneper Parken and €5 per hour city center

Figure 4.3.35 shows the attribute levels of scenario ten, which are the same as for scenario six, except the parking tariffs in the city have been increased to the average PC of € 5 per hour. Resulting in both a stimulating and discouraging measure in this scenario.

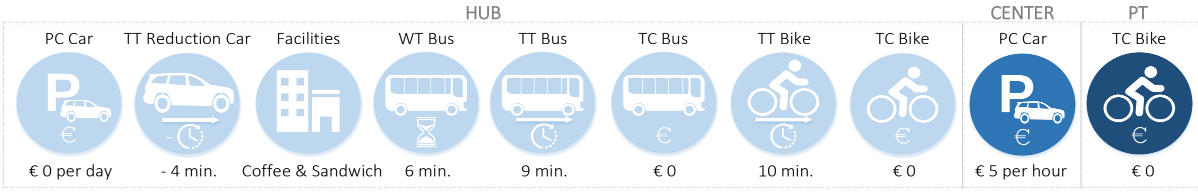

Fig. 4.3.35 Attribute levels scenario 10 – Free Hub Genneper Parken and PC city center € 5 per hour

Figures 4.3.36 and 4.3.37 show the probabilities for this scenario. As can be seen, increasing the parking tariffs in the city center in addition to the free hub, result in a further decrease of the probability of taking the car towards the city for the group living more than 10 kilometers away. Again, people living within 10 kilometers are less keen on switching. When they would switch, they will either travel by bike or use public transport. The hub is not interesting for them, which makes sense. Considering the people living further than 10 kilometers from the city center, a strong decrease of people traveling by car can be noticed. Using the hub seems to be a popular option for this group, taking the bus from the hub is still the most preferred option. However, considering the share of sustainable transportation, scenario 5 (no free hub) is more desired as in this scenario the usage of the hubs increases also by people that would otherwise take public transportation or the bike.

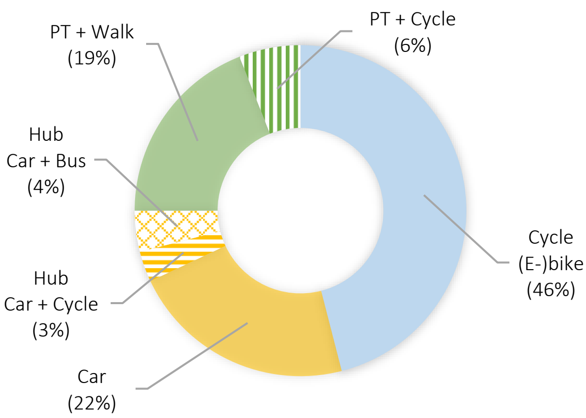

Fig. 4.3.36 Modal split scenario 10 ≤ 10 km

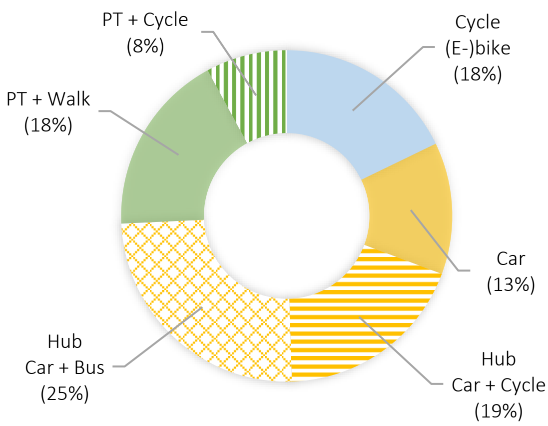

Fig. 4.3.37 Modal split scenario 10 > 10 km

Scenario 11 – Hub near ring road – location A or B

This scenario shows the situation in which a hub would be located near the ring road along one of the HOV lines at location A or B in Figure 4.3.4. Figure 4.3.38 shows the input for this scenario, and as can be seen the travel times by both bus and bike from the hub have been decreased to 6 and 5 minutes respectively. The waiting time for the bus is an average of 6 minutes, and the hub is priced at € 4 per day.

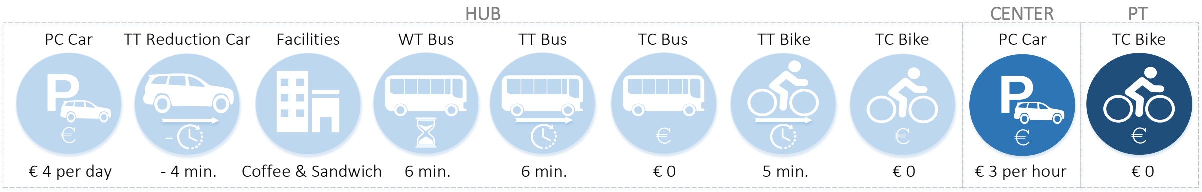

Fig. 4.3.38 Attribute levels scenario 11 – locating Hub near ring road - Location A or B

As can be seen in Figures 4.3.39 and 4.3.40, locating the hub near the ring road has somewhat effect on its usage compared to scenario 4 (location Genneper Parken). Both taking the bus and bike from the hub seems to be more interesting when the hub is located closer to the city center. However, the effect is limited, when comparing it to the measures discussed in the other scenarios. Especially when looking at the car usage, which is still 29% and 27%. Positioning a hub near the ring road is quite challenging, due to the limited space and it might only increase the pressure on the ring road. It is therefore not recommended to plan one there as it will not have a significant increase in usage.

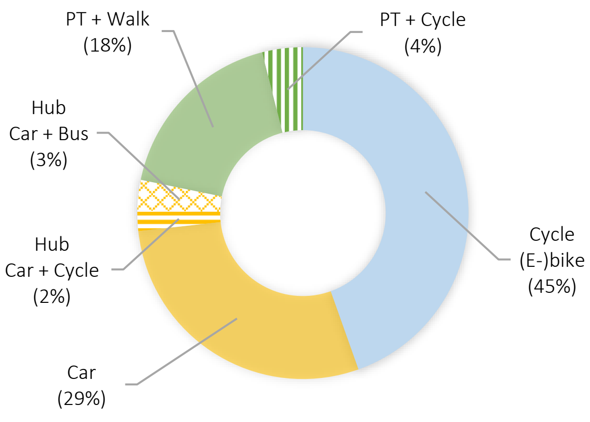

Fig. 4.3.39 Modal split scenario 11 ≤ 10 km

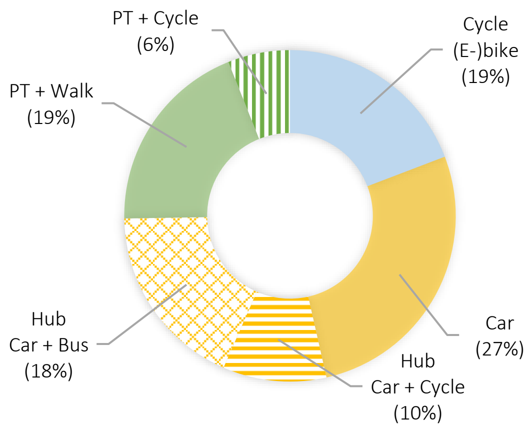

Fig. 4.3.40 Modal split scenario 11 > 10 km

4.3.3. Conclusion

The scenarios presented in this section show the effects of the investigated measures. Figures 4.3.41 and 4.3.42 show an overview of the implications of the various scenarios. Figure 4.3.41 shows the modal split per scenario for the people living closer than 10 kilometers to the city center. As can be seen, the bike is most preferred for this group, which makes sense. As well as the fact that the hubs are not favored by this group. Getting this group out of their car is difficult as can be seen, their sensitivity to increased parking tariffs (scenario 3, 8, 9 and 10) is only limited. Making the hub free of charge also can have the effect of this group using the hubs instead of cycling or traveling by public transport (scenario 2, 7 and 10). Other measures should be taken to stimulate this group using another transport mode than car towards the city center.

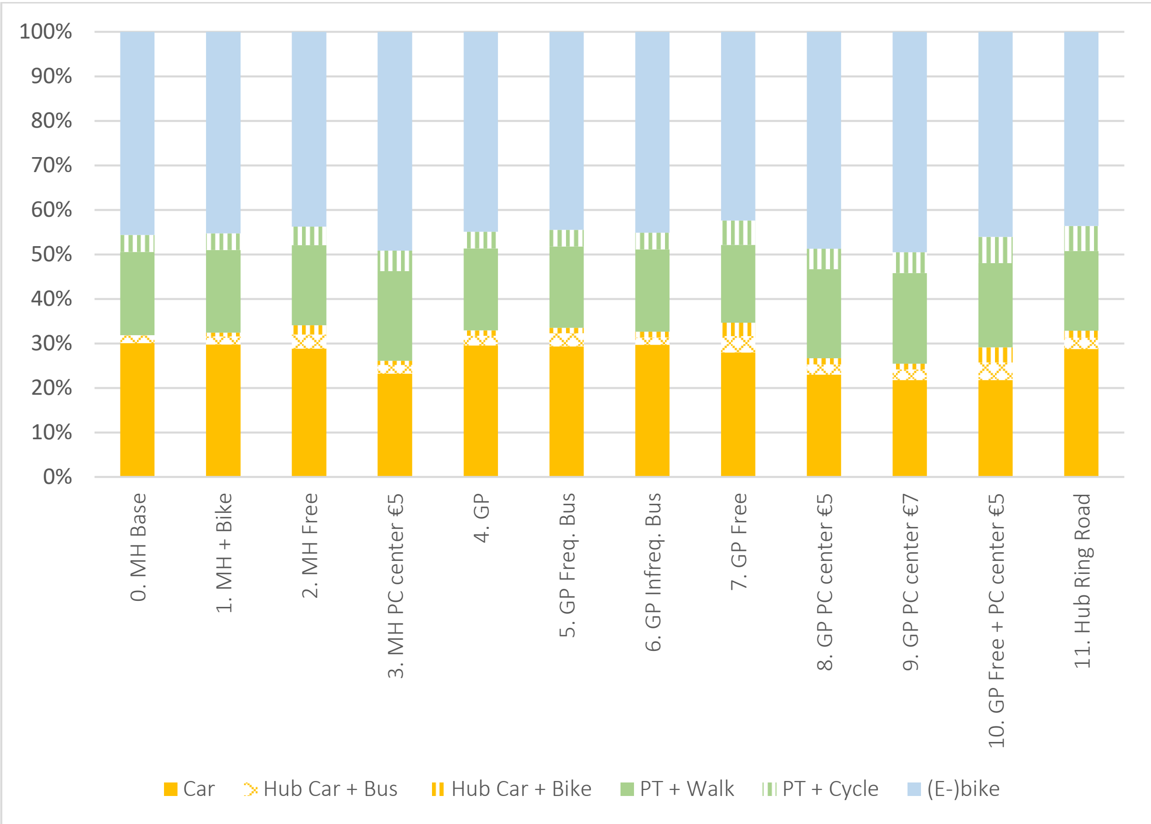

Fig. 4.3.41 Overview scenarios ≤ 10 km

Figure 4.3.42 shows the implications of the various scenarios for people living further than 10 kilometers from the city center. As can be seen, in general the hub is more preferred by this group than the other group, and especially taking the bus from the hub instead of a shared-bike. As can be seen, this group is also more sensitive to increased parking costs in the city center (scenario 3, 8, 9 and 10). Making the hub free also increases its usage, but also a reduces the usage of the sustainable modes (e-)bike and public transportation (scenarios 2, 7 and 10). The travel time from the hubs to the center especially affects the bike use from the hub, as this gets more interesting when the hub is located closer. When looking at scenarios 4 and 11 compared to the base scenario can also be concluded that solely realizing a hub does not immediately mean car users will start using the hub. However, here should be noted that in these scenarios, only one hub is present at the time and in reality multiple hubs are expected to be available in the future. Since a hub from every direction to Eindhoven is desired, the reduction in travel time by car to the hub will probably increase, making the hubs an even more interesting option.

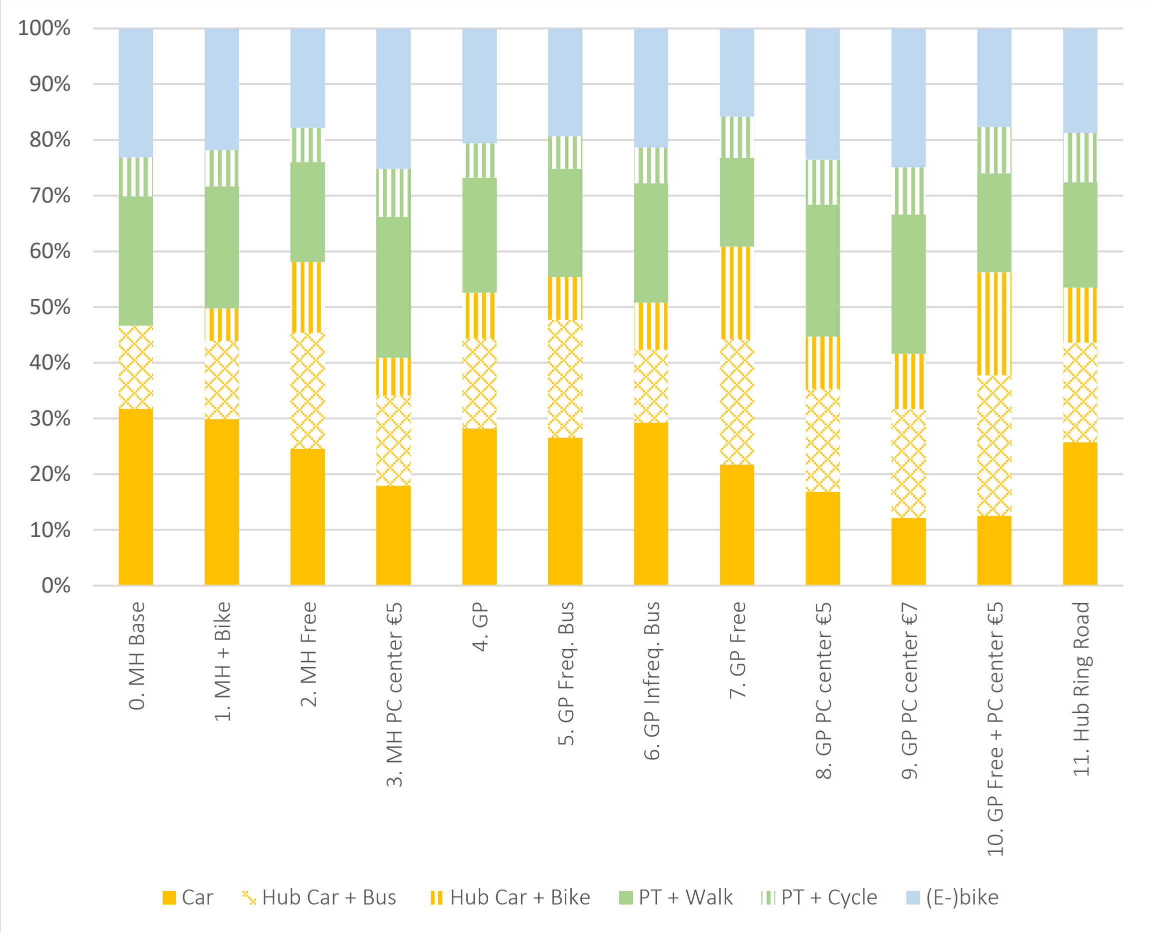

Fig. 4.3.42 Overview scenarios > 10 km

In general, it is recommended to the municipality to continue planning the hub at Genneper Parken, as this seems to be a good location regarding the travel times. Considering the hub at the ring road, that location only seems to have limited effect on hub usage, and since it will be complicated to realize a hub there, the pros do not seem to outweigh the cons. Genneper Parken seems to have an acceptable cycling distance, so it is recommended to offer shared-bikes. However, the bus stays important as transport mode from the hub to the city center. This service should therefore be as seamless as possible, having a frequent service resulting in a low waiting time. Regarding the hub, it is recommended to charge a fee and not make it free, as also undesired effects can occur, such as people who would usually bike or use public transportation would then start using the hubs as well. Therefore, it is recommended to increase the parking tariffs in the city center, since this seems to have most effect on increasing the share of sustainable transport mode usage towards Eindhoven city center.

4.4. Conclusion

This chapter discussed the results from the SC experiment. Data has been collected for a month between the 12th of February and 11th of March, resulting in 389 completed questionnaires, of which 375 could be used for the analyses. The descriptives of the data show that the sample is representing the visitors of Eindhoven well in terms of home location and purpose for their trip towards the city center. However, in the sample an overrepresentation of people with a high level of education and high level of income exists.

Several discrete choice models have been estimated to analyze the results. The MNL model showed that overall the respondents have an intrinsic preference for the alternatives that do not require a transfer, and especially for the (e-)bike alternative. The alternatives without a transfer were expected to be preferred as these transfers are often considered cumbersome (Chowdhury & Ceder, 2016; OECD/ITF, 2014). However, when looking at the MNL models per category, more taste variation seems to exist within these preferences. The MNL model per purpose category shows for example that people visiting Eindhoven for shopping do not want to switch to a bike as 'last mile' transport mode. This effect of a common component between these 'last mile' bike alternatives has also been confirmed by the ML models. Considering the LC models, many of the classes identified, distinguish themselves by either having a strong preference for car or not willing to switch to public transportation alternatives. Or the opposite, people having a preference for public transportation over car, or having a strong intrinsic preference for bike. This taste variation for the common component within the public transportation alternatives has also been identified by the ML models, just like the common component for the hub alternatives.

Regarding the attributes, the parking costs in the city center seem to affect the mode choice. The parking costs of €3 per hour have positive effect on the utility for the car alternative, however, when these costs are increased the opposite is true; however, a less strong effect can be distinguished. When looking at the various groups identified, this attribute has little effect on people with a working purpose for visiting Eindhoven. This might be explained by the fact that their parking costs might be paid by their employer. The attribute also has less effect on people living in villages and people older than fifty years. However, on people younger than thirty years, the increase of these costs seems to have effect. There needs to be taken into account here, that people with a higher income are overrepresented in the sample, which might influence these results.

The parking costs at the hub also seem to have an effect on the overall mode choice, however, they show similar coefficients as for the parking costs in the center, but these two have different units (for the hub these are per day and for the center these are per hour). Therefore is checked with a ML model, if high variances exist for these attributes, which was the case. This indicates that some respondents might have interpreted these attributes wrongly as they thought the attributes had the same units, resulting in a measurement error in the data.

Travel time seems to be important for people visiting Eindhoven with a working purpose, as they might have a time constraint. Overall, the travel time by bike from the hub seems to have a stronger effect than the travel time by bus, which might be explained by people having to put effort in cycling and in the bus they can simply take a seat. Looking at the scenarios, this could be confirmed. When the hub was located further away, using the bike from the hub became less popular. This effect seems stronger for people living in villages. People older than fifty years on the other hand seem to be less sensitive to increasing travel times. People between thirty and fifty years old seem to be most affected by increasing travel times by bus from the hub. Waiting time is related to these travel time attributes, and seems to have a slightly stronger effect than the travel time by bus. This was expected by literature as the waiting time is often considered rather annoying.

Regarding the travel costs for the bus or bike from the hubs, the effects of these attribute levels do not seem to differ significantly, making these prices not an important determinant for mode choice. Only in the public transportation + bike alternative the price seemed to have an effect on the choices as only the price of €0 seemed to positively contribute to the utility for that alternative. The facilities available at the hub have not been found to have a significant effect on the mode choice. In this study, it might not have the most important determinants for mode choice. However, it can be the case that people will appreciate it at the hubs, therefore it is recommended to perform additional studies on this topic.

Overall, considering all effects, it is recommended construct the hub at the planned hub Genneper Parken as locating it closer to the ring road does not significantly increase its usage, and will probably have consequences for its accessibility and the pressure on the ring road. The bus from the hub is recommended to operate at a frequent schedule, reducing the waiting time. The shared-bike from the hub is less preferred, but it is still recommended to offer it at the hub, as it is a feasible alternative at this distance and there are some people that would use it. As there is aimed to increase the share of sustainable transport modes used for visiting Eindhoven, it is recommended to increase the parking tariffs in the city center. This encourages people to change to public transportation or (e-)bike for their visit. Making the hub and its 'last mile' transport free, also encourages people that would otherwise use sustainable transportation to use take their car and use the hubs.

CHAPTER 5

CONCLUSION

The aim of this research was to obtain more insights in the determinants that influence travelers' decisions to switch to more sustainable (shared-mobility) alternatives. Resulting in the main research question: '*Which factors can influence visitors' inclination to switch to sustainable (shared) mobility for their visit of Eindhoven city center (in transition towards MaaS)?'* This research question is focused on the city of Eindhoven, as this subject is especially relevant for the city, since it is facing a challenging task. Due to increased business settling in the region, the population of the city is growing as well. As the vision for the city is to densify, new residential buildings are mainly being constructed and planned within the ring road. Parallel to these developments, the city needs to stay accessible and attractive for its (future) residents, visitors and businesses to settle. In order to make Eindhoven a healthy and inviting place to be, the pressure on the infrastructure needs to be reduced, as well as the emission levels. This leads to the first sub question of this research: '*What are the current developments and vision of the municipality of Eindhoven regarding emission-free mobility?'* The ambition of the city is to create a multimodal traffic network in order to keep the city and its economic high priority locations well-accessible. The focus is therefore on well-connecting the various modalities and making the switch from private car towards sustainable and shared-mobility as convenient as possible.

Mobility as a Service (MaaS) seems promising in being part of the solution, as it aims to reduce the private car use, and with that, the pressure on the traffic network. Therefore, MaaS was the base of this study, and regarding this new transportation service still much can be learned. Answering the second sub-question: '*What is the state-of-the-art concerning MaaS?*'; the service can be described as a new mobility concept, which offers users a tailormade, demand-responsive and sustainable mobility package all arranged via one platform. Mobility is considered as a service product, in which the users are the central point of focus. Hence, all features in the service are designed to make the trip of the user as seamless as possible. Within the MaaS platform a (co-modal) trip can be planned, booked and paid based on the users' preferences. Moreover, during the trip, the user is provided with the appropriate travel tickets and support on-demand. Focusing on the trip, it is believed that the current public transportation infrastructure is the basis for a well-working MaaS system, which is already available in Eindhoven. Moreover, it is only possible to successfully launch the service when travelers are ensured with convenient and seamless transfer possibilities at strategic locations; the mobility hubs. Since the hubs, which are to be realized in the built environment, are crucial for the convenience of MaaS, these have to be considered when studying and developing the adoption of MaaS. Here, a research gap exists, as insights in the preferences regarding these mobility hubs is limited. Moreover, other 'push' measures, such as differentiating parking tariffs, might be necessary to stimulate sustainable behavior using MaaS, as the service may not always provide the most sustainable option. Moreover, solely providing MaaS and hubs will not mean travelers will start using the service. Therefore, in order to determine the best strategy and provide the most appropriate transport modes, this research aimed to provide insights in the factors influencing mode choice behavior in the Eindhoven context towards the implementation of MaaS. In order to answer the main research question, two additional sub-questions have been formulated, of which the first reads: '*What could be the influence of travel costs and travel time on the inclination of visitors to switch from private car to sustainable (shared) mobility?'* A Stated Choice Experiment has been constructed to answer this question. In line with a MaaS platform, respondents were provided with an overview of their (potential) travel alternatives towards Eindhoven city center, which varied from i) car, ii) car to hub and transfer to bus iii) car to hub and transfer to bike iv) public transportation and walk v) public transportation and transfer to bike, and when applicable, vi) (e-)bike. The results of 375 respondents have been analyzed using the following discrete choice models: Multinomial Logit models, Mixed Logit models and Latent Class models. The results indicate that respondents prefer alternatives that do not require a transfer, such as the private car, the private (e-)bike, use the train or bus and walk towards the final destination. When a transfer to the bus is necessary, only a waiting time of two minutes seems to be contributing positively to the utility for the hub and bus alternative. This result is in line with previous literature, which already identified the waiting time to be perceived as unpleasant. For people with working purposes this effect seems stronger, which is also the case for travel time of the bus. In literature, the travel time was also already identified to have a negative effect on mode choice, and this is confirmed by this study. The travel time by bike from the hub seems to have an even stronger negative effect than by bus. The reason why these travel times are more important for people with a working purpose might be explained by the fact that these people have a certain time limitation during their workday. On the other hand, these working people are less sensitive to increased parking costs in the city center. This would indicate that for this group, the alternatives should be as seamless as possible to make them switch. The working people are not the only group of people that seem to be less sensitive to the costs, people over fifty years also seem to be less affected by this measure. Moreover, they are also less affected by the increased travel time by bus in the alternative of transferring at a hub to the bus. The age category of thirty till fifty years on the other hand, seems quite sensitive to this travel time, which might be explained by the fact that the majority of this group belongs to the people with a working purpose as well. These people might have complex daily routines influencing their mode choice. People living in villages also seem sensitive to the increase in travel time for both bus and bike from the hub. This indicates that when the travel time from the hub is too long, the working people and visitors of Eindhoven living in villages will have a considerably lower probability of using the hubs. Which provides a first answer to the fourth sub-question: *What criteria should the mobility hubs meet in terms of location, tariffs, modalities and facilities?* Regarding the facilities, no indication has been found that these affect the mode choice behavior in this sample. This is also the case for the travel costs of the bus or bike from the hub. These costs differed between €0, €0.5 and €1 per trip and it seems that this variation does not matter for the mode choice. However, other financial incentives appeared to have an effect on people's willingness to use the hubs. Regarding the public transportation and transferring to bike, the price of the bike seemed to matter. The parking costs at the hub seemed to affect the mode choice behavior in a way that only free parking at the hub seemed to positively contribute to the utility for the use of the hub.

The last sub question reads: *What is the effect of the investigated measures on the current travel behavior towards the city?*. To answer this sub question a base scenario has been identified using the current situation in Eindhoven. In order to illustrate the effect of the investigated measures, several scenarios have been constructed (both planned and hypothetical) and these have been compared to the base scenario. The results show that the planned hub at Genneper Parken seems to be a good location in terms of travel time. The location at the ring road seems only to have limited effect on its usage, and as these locations would also result in more traffic near the ring road, this is not desired. For the use of the bike from the hub, the location at the ring road would be better as this has a shorter cycling time, but possibly other measures such as making the cycling routes convenient or providing shared e-bikes would have the preferred effect as well. In general, also a strong preference is found for using the private (e-)bike for trips towards Eindhoven city center as well. Therefore the strategy of the municipality of focusing on making the infrastructure more friendly for slow traffic is positive. The bus remains the most preferred 'last mile' transport mode from the hub, so this service should be as seamless as possible, having a frequent service, reducing its waiting time.

The parking tariffs at the hub seem to influence its usage as well, and can even create unintended effects. A free hub also attracts people living within 10 kilometers of the city center that would otherwise possibly use the bike or public transportation, and are therefore not the target group for the hub. As the aim for Eindhoven is to increase the share of sustainable transportation (public transportation and private (e-)bike) towards the city center, it is recommended to increase the parking costs in the city center. This 'push' measure results in the highest share of sustainable transportation. In order to have the most effective deployment of available resources to create hubs in the future, a working combination of measures is important to have the intended effects.

5.1. Scientific relevance

This study enhances academic understanding of mode choice behavior, with a focus on mobility hubs as transfer locations in the context of Mobility as a Service. The study provides more evidence (Hounsell et al., 2011; Molin et al., 2014) that increased parking costs in the city center might be effective as 'push' factor to the switch to more sustainable transport modes. The results also indicate unintended effects can occur when the hub is free of charge, as people living in Eindhoven might also use the hubs instead of going by bike or use public transportation. Other factors such as the location of the hub and the operating scheme of the bus service are determinant for this choice as well. Travel time (Yang et al., 2018) and waiting time were already identified in literature (Chowdhury & Ceder, 2016; OECD/ITF, 2014) as a determinants for mode choice, and this study confirms these effects. Especially people with a working purpose seem to be sensitive to the waiting time and travel time in general. This was identified using a Multinomial Logit model per purpose to identify differences between people with different purpose categories, and also confirms the study of (Yang et al., 2018). Other Multinomial Logit models per age group, distance and urbanization type have been estimated, giving more depth to the data and identifying different groups for the strategy of the municipality. By means of Mixed Logit models, the taste variation and common components between alternatives have been identified which influence the mode choice.

Moreover, this study contributes to the knowledge on the demand side of Mobility as a Service in the built environment. The experiment conducted for this research provided the respondent with a complete overview of its available modalities for the trip to Eindhoven city center. This has been performed for the current context of Eindhoven, as it is believed that MaaS should start with the current modalities available in a city. Other Stated Preference experiments have been conducted to obtain more insights in the adoption of MaaS and the MaaS subscriptions. One in Sydney (Ho et al., 2018) and one in London (Matyas & Kamargianni, 2018a) on people's preferred Maas bundles. Instead of focusing on the bundles, this study focused on the demand for modalities. Since it is believed that people should have convenient travel possibilities according to their preferences in order to be willing to adopt MaaS. Moreover, the complete overview of transport modes provided respondents with a broader view on their choices, and therefore might have remediated habitual behavior. However, additional research should be performed to confirm this.

5.2. Societal relevance

On societal level, this research is relevant in terms of providing the municipality of Eindhoven with insights in the determinants of mode choice behavior in relation to the implementation of hubs in the city center. The municipality of Eindhoven has the ambition to have its city multimodally accessible, while reducing the pressure on the infrastructure and decreasing the emission levels. Mobility hubs in the context of MaaS are proposed, but these will only be used when it is a feasible alternative for the visitors. Since the data and models generated for this research have been directly applied to the situation in Eindhoven, it provides a clear image of the consequences of certain measures for the city. The visitors of a city center are usually a group which is unknown to a municipality and therefore it is difficult to discover feasible measures for these visitors. These visitors have been identified and the sample especially contains visitors from the province Noord-Brabant. As this group of people usually seems to be quite keen on using the car, they were especially targeted for this study. The study was focused on the preferences of these users, in order to provide the municipality with knowledge on how to design the appropriate measures for their specific visitors in order to reach their goals. For example differences between age groups and people with a different purpose in the city center have been identified, as well as on the specifications of respondents' home location. These insights can be used for specific strategy purposes.

In other words, the municipality can use the knowledge identified in this thesis as underpinning for their considerations of the realization of hubs. And, even more importantly, this study provides insights on how to influence the share of sustainable transportation modes towards Eindhoven city center. Making the hub free of charge for example has a very positive influence on its usage, however, the total share of sustainable transport mode usage will be smaller. Since making the hub free, will also attract unintended visitors. Therefore the focus of this study on the combination of all available transportation modes in a MaaS context was important in discovering all effects on influencing the share of sustainable transportation.

5.3. Limitations and recommendations

During the research several limitations of the study have been identified that are mentioned in this section, as well as, an evaluation of the method and recommendations for future studies.

When the method is critically reflected upon, this SC design was more difficult for the respondents to evaluate than usual SC experiments. Firstly, as discussed in Section 3.4, usually respondents are faced two (or more) alternatives with varying attribute levels. This choice task would then be repeated a number of times and in each choice task the attribute levels differ per alternative. However, in this study respondents were given five or six transportation alternatives, each having certain attributes specifically related to one or two of the alternatives, which is quite some information to process. Secondly when respondents preferred the alternative "public transportation + walking" or "(e-)bike", they sometimes perceived it as if nothing changed during the evaluation of the nine choice tasks as their preferred choice had no changing attributes. Some respondents provided the feedback that they had the feeling that the questionnaire was malfunctioning as they thought they were getting the same choice task over and over again. Moreover, when people dropped out in the questionnaire, they had often already repeatedly provided their preference for the "public transportation + walking" or "(e-)bike". It is therefore recommended to take this into consideration when designing a SC experiment similar to this one. What could possibly help in reducing this problem, is adding a counter that provides people with the feedback of how many choice tasks they still need to evaluate. Another solution would be the reduce to amount of choice tasks per respondent, as the respondents that dropped out during the questionnaire mainly dropped out in the last couple of choice tasks (after choosing the same alternative multiple times).

Focusing on the attributes included in the Stated Choice experiment, possibly other factors, than those included in the experiment, influenced the user's decision as well. For example the congestion time, time to find a parking spot, 'first mile' transport to the public transportation were all excluded from the eventual experiment to reduce the number of 'time attributes' in the experiment. Other factors such as comfort and convenience, time of day, (perceived) safety, weather and image are also influencing the decision-making, but have not been included in the study. In the feedback provided by the respondents, the 'first mile' transport to the public transportation was mentioned a number of times. Moreover, some respondents indicated that when they go shopping they would not go by themselves, but go with their family for example. The price levels in the study were constructed from the perspective that the respondents would travel by themselves towards Eindhoven. However, when going shopping with a family of four, the public transportation would be four times as expensive, whereas the car costs will remain (almost) equal.

By means of the ML model has been indicated that quite some taste variation existed for the attributes of the parking costs in the city center and the parking costs at the hub. However, this was not expected, and can be a sign that some respondents did not observe the difference between the parking costs per hour in the city center and the parking costs per day at the hub. This would mean that a measurement error exists in the data.

Moreover, as was already indicated in Section 4.1.2, the sample is overrepresented by highly educated people and respondents with a high income level. This might have influenced the results as these people might be less sensitive to increasing parking costs. Moreover, it should be noted that the majority of the people living in a city is actually living in Eindhoven, probably resulting in different results than when the sample would have come from other cities (or villages). In general it also needs to be taken into account, that the choices the respondents made, were presented in a clear overview, providing all their possible travel alternatives. However, in real-life this is not the case yet, as MaaS is not operational yet. And when it will be realized, human beings are creatures of habit, so this mode choice behavior should not be expected too soon. Therefore, it is recommended to pay close attention the planned MaaS pilots, as these will provide the best insights in the adoption process. Another, more general limitation of the method is the uncertainty of people answering the stated choice scenarios with socially desirable behavior instead of their actual choice behavior. It might for example be the case that people would use their car for the trip, but now say they would bike. Maybe they would actually want to bike, but in real-life their decision-making can be different.

Recommendations for further research are to focus on the specific directions the visitors originate from. The sample of this research contains people from villages surrounding Eindhoven at various distances, and maybe a certain pattern can be distinguished on mode choice behavior, based on facilities (hubs) that are currently available at each direction and where potential exists for implementing certain measures. Moreover, the spatial consequences for the hub locations are also an important area of research. Since the hubs will attract quite some traffic towards that location, this has its implications for the surrounding built environment as well.

CHAPTER 6

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APPENDIX

APPENDIX A – Experimental Design

A.1 Experimental design

Profile	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	2	2	2	2	2
3	1	1	1	1	1	3	3	3	3	3
4	1	1	3	2	3	1	1	3	2	3
5	1	1	3	2	3	2	2	1	3	1
6	1	1	3	2	3	3	3	2	1	2
7	1	2	2	3	3	1	2	2	3	3
8	1	2	2	3	3	2	3	3	1	1
9	1	2	2	3	3	3	1	1	2	2
10	1	2	3	1	2	1	2	3	1	2
11	1	2	3	1	2	2	3	1	2	3
12	1	2	3	1	2	3	1	2	3	1
13	1	3	1	3	2	1	3	1	3	2
14	1	3	1	3	2	2	1	2	1	3
15	1	3	1	3	2	3	2	3	2	1
16	1	3	2	2	1	1	3	2	2	1
17	1	3	2	2	1	2	1	3	3	2
18	1	3	2	2	1	3	2	1	1	3
19	2	1	2	1	3	1	3	1	3	2
20	2	1	2	1	3	2	1	2	1	3
21	2	1	2	1	3	3	2	3	2	1
22	2	1	3	3	2	1	3	2	2	1
23	2	1	3	3	2	2	1	3	3	2
24	2	1	3	3	2	3	2	1	1	3
25	2	2	1	3	1	1	1	3	2	3
26	2	2	1	3	1	2	2	1	3	1
27	2	2	1	3	1	3	3	2	1	2
28	2	2	2	2	2	1	1	1	1	1
29	2	2	2	2	2	2	2	2	2	2
30	2	2	2	2	2	3	3	3	3	3
31	2	3	1	2	3	1	2	3	1	2
32	2	3	1	2	3	2	3	1	2	3
33	2	3	1	2	3	3	1	2	3	1
34	2	3	3	1	1	1	2	2	3	3
35	2	3	3	1	1	2	3	3	1	1
36	2	3	3	1	1	3	1	1	2	2
37	3	1	1	2	2	1	2	2	3	3
38	3	1	1	2	2	2	3	3	1	1
39	3	1	1	2	2	3	1	1	2	2
40	3	1	2	3	1	1	2	3	1	2
41	3	1	2	3	1	2	3	1	2	3
42	3	1	2	3	1	3	1	2	3	1
43	3	2	1	1	3	1	3	2	2	1
44	3	2	1	1	3	2	1	3	3	2
45	3	2	1	1	3	3	2	1	1	3
46	3	2	3	2	1	1	3	1	3	2
47	3	2	3	2	1	2	1	2	1	3
48	3	2	3	2	1	3	2	3	2	1
49	3	3	2	1	2	1	1	3	2	3
50	3	3	2	1	2	2	2	1	3	1
51	3	3	2	1	2	3	3	2	1	2
52	3	3	3	3	3	1	1	1	1	1
53	3	3	3	3	3	2	2	2	2	2
54	3	3	3	3	3	3	3	3	3	3

A.2 Experimental design input Berg system

Profile	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
1	4	0	Coffee & Sandwich	3	6	2	0	5	0	0
2	4	0	Coffee & Sandwich	3	6	6	0.5	10	0.5	0.5
3	4	0	Coffee & Sandwich	3	6	10	1	15	1	1
4	4	0	No facilities	5	12	2	0	15	0.5	1
5	4	0	No facilities	5	12	6	0.5	5	1	0
6	4	0	No facilities	5	12	10	1	10	0	0.5
7	4	4	Parcel Pick-up	7	12	2	0.5	10	1	1
8	4	4	Parcel Pick-up	7	12	6	1	15	0	0
9	4	4	Parcel Pick-up	7	12	10	0	5	0.5	0.5
10	4	4	No facilities	3	9	2	0.5	15	0	0.5
11	4	4	No facilities	3	9	6	1	5	0.5	1
12	4	4	No facilities	3	9	10	0	10	1	0
13	4	8	Coffee & Sandwich	7	9	2	1	5	1	0.5
14	4	8	Coffee & Sandwich	7	9	6	0	10	0	1
15	4	8	Coffee & Sandwich	7	9	10	0.5	15	0.5	0
16	4	8	Parcel Pick-up	5	6	2	1	10	0.5	0
17	4	8	Parcel Pick-up	5	6	6	0	15	1	0.5
18	4	8	Parcel Pick-up	5	6	10	0.5	5	0	1
19	2	0	Parcel Pick-up	3	12	2	1	5	1	0.5
20	2	0	Parcel Pick-up	3	12	6	0	10	0	1
21	2	0	Parcel Pick-up	3	12	10	0.5	15	0.5	0
22	2	0	No facilities	7	9	2	1	10	0.5	0
23	2	0	No facilities	7	9	6	0	15	1	0.5
24	2	0	No facilities	7	9	10	0.5	5	0	1
25	2	4	Coffee & Sandwich	7	6	2	0	15	0.5	1
26	2	4	Coffee & Sandwich	7	6	6	0.5	5	1	0
27	2	4	Coffee & Sandwich	7	6	10	1	10	0	0.5
28	2	4	Parcel Pick-up	5	9	2	0	5	0	0
29	2	4	Parcel Pick-up	5	9	6	0.5	10	0.5	0.5
30	2	4	Parcel Pick-up	5	9	10	1	15	1	1
31	2	8	Coffee & Sandwich	5	12	2	0.5	15	0	0.5
32	2	8	Coffee & Sandwich	5	12	6	1	5	0.5	1
33	2	8	Coffee & Sandwich	5	12	10	0	10	1	0
34	2	8	No facilities	3	6	2	0.5	10	1	1
35	2	8	No facilities	3	6	6	1	15	0	0
36	2	8	No facilities	3	6	10	0	5	0.5	0.5
37	0	0	Coffee & Sandwich	5	9	2	0.5	10	1	1
38	0	0	Coffee & Sandwich	5	9	6	1	15	0	0
39	0	0	Coffee & Sandwich	5	9	10	0	5	0.5	0.5
40	0	0	Parcel Pick-up	7	6	2	0.5	15	0	0.5
41	0	0	Parcel Pick-up	7	6	6	1	5	0.5	1
42	0	0	Parcel Pick-up	7	6	10	0	10	1	0
43	0	4	Coffee & Sandwich	3	12	2	1	10	0.5	0
44	0	4	Coffee & Sandwich	3	12	6	0	15	1	0.5
45	0	4	Coffee & Sandwich	3	12	10	0.5	5	0	1
46	0	4	No facilities	5	6	2	1	5	1	0.5
47	0	4	No facilities	5	6	6	0	10	0	1
48	0	4	No facilities	5	6	10	0.5	15	0.5	0
49	0	8	Parcel Pick-up	3	9	2	0	15	0.5	1
50	0	8	Parcel Pick-up	3	9	6	0.5	5	1	0
51	0	8	Parcel Pick-up	3	9	10	1	10	0	0.5
52	0	8	No facilities	7	12	2	0	5	0	0
53	0	8	No facilities	7	12	6	0.5	10	0.5	0.5
54	0	8	No facilities	7	12	10	1	15	1	1

APPENDIX B – Questionnaire

B.1 Page 1 - Introduction

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Your trip to Eindhoven city center

Page: Introductie

How will you travel to the city center of Eindhoven in the future?

Do you sometimes bring a visit by car to the city center of Eindhoven, for example for shopping, your job or a visiting friends or family?

Then we need your opinion!

This questionnaire has been composed for a graduation research at Eindhoven University of Technology, in which is studied how the city center of Eindhoven can stay accessible in the future. Therefore, we are interested in your travel behavior and your preferences regarding traveling to the Eindhoven city center in the future.

Filling out the questionnaire takes approximately 15 minutes, and among the respondents that fill out the questionnaire completely, the following prices are raffled:

1 Voucher for Escape Room Videolab in Eindhoven (one room for minimal 2 persons, maximal 7 persons)

20 Koffiekaartjes Eindhoven, with 1 card you get 2 cups of coffee or tea at 5 coffee stores in Eindhoven (this means 10 cups per card!)

Your answers to this questionnaire will be handled confidential and anonymous.

NOTE: if you are filling out this questionnaire on your phone, please tilt your phone.

B.2 Page 2 – Target group selection

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Your trip to Eindhoven city center

Page: Doelgroep

Do you sometimes visit the center of Eindhoven

The center of Eindhoven is shown by the red framed area in the image below.

- (●) Yes
- ( ) No

How often do you visit the city center of Eindhoven by car?

This can be both as driver or passenger.

Weekly ▾

Do you possess a car driving license?

- (●) Yes
- ( ) No

What car do you use for this trip to Eindhoven city center?

- (●) Private (lease) car
- ( ) Company (lease) car
- ( ) I borrow a car from family/friends
- ( ) Shared-car (such as Greenwheels)
- ( ) Rental car
- ( ) Other, namely:

Is this an electric car?

- ( ) Yes
- (●) No
- ( ) I don't know

To what extent do you consider switching to an electric car in the near future (within 2 years)?

Very unlikely — Very likely

Do you have physical constraints that limit you in the use of public transport (train/bus)?

- Yes
- No

Do you have physical constraints that limit you to cycle?

- Yes
- No

What kind of bicycles do you have at your disposal?

- A regular bicycle
- An electric bicycle
- Both a regular and an electric bicycle
- None

B.3 Page 2.1 – Out of target group

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Your trip to Eindhoven city center

Page: FinalDoelgroep

Unfortunately, you are not the target group of this study.

Thank you for your interest and participation!

If you have any questions or suggestions regarding the survey, please enter them below:

Please press the button "Submit" to submit your answers.

B.4 Page 3 – Car trip to Eindhoven

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Your trip to Eindhoven city center

Page: Bezoek Eindhoven Auto

For what purpose do you visit the city center of Eindhoven by car?
When more than one answer is applicable, please take the purpose which you have most often.

Work ▾

Do you need your car during your workday to do your job?
This means you can't do your job without a car (for example due to materials you have to take; due to physical constraints; or appointments at locations that are inaccessible by public transport/bicycle etc.)

- (•) Yes
- ( ) No

When you visit the city center for this purpose by car, how long does your visit on average take?

2 - 4 hours ▾

When you visit the city center of Eindhoven for this purpose by car, where do you usually park your car?

- ( ) In an area with free parking
- (•) In an area with paid parking (on the streets)
- ( ) In a parking garage or in an open-air parking facility
- ( ) At a P+R location

What are your parking costs in Eindhoven for this visit?
Please estimate when you don't know this precisely.

€ 5 . 00 per visit

- [ ] I don't know

What are the 4 digits of your postal code *(1234)*?

5388

How far is your home location from the city center of Eindhoven? *(Round-off to whole kilometers)*
Please estimate when you don't know this precisely.

40 kilometer

- [ ] I don't know

How long does it usually take you to make this trip by car?
Please estimate when you don't know this precisely.

30 minutes

- [ ] I don't know

What are your fuel costs for this one-way trip? (parking and maintenance costs excluded)
Please estimate when you don't know this precisely.

€ .

- [x] I don't know

B.5 Page 4 – Public transportation trip to Eindhoven

Your trip to Eindhoven city center

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Page: Bezoek Eindhoven OV

Suppose you have to visit Eindhoven city center by public transport (PT), which transport mode would you use?
When you use both bus and train for your trip, choose the transport mode you spend most of your time in during your trip.

- (●) Bus
- ( ) Train
- ( ) I don't know

How far is this public transport stop (bus stop/train station) away from your home?
When you use both bus and train for this trip, answer this question for the first stop you use.

- ( ) < 500 m
- (●) 500 m - 1 km
- ( ) 1 - 2 km
- ( ) 2 - 5 km
- ( ) > 5 km
- ( ) I don't know

What do you think this one-way trip will cost from this bus stop/train station to the bus stop/train station in Eindhoven?
Please estimate when you don't know this precisely.

€ [3] , [5]

- [ ] I don't know

How many minutes does this trip take you from bus stop/train station to the bus stop/train station in Eindhoven?
Please estimate when you don't know this precisely.

[50] **minutes**

- [ ] I don't know

How often do you travel by public transport (bus/train)?

- ( ) Every day
- ( ) A couple of times per week
- ( ) Weekly
- (●) A couple of times per month
- ( ) Monthly
- ( ) A couple of times per year
- ( ) Never

Do you possess an 'OV-chipkaart'?

- (●) Yes
- ( ) No

What subscription(s) do you have on your 'OV-chipkaart'? *(multiple answers can be selected)*

- [ ] I don't know
- [ ] I don't have a subscription
- [ ] I use a NS Businesscard
- [x] Student travel product
- [ ] NS Off-Peak Discount (40% Off-peak)
- [ ] NS Weekend Free
- [ ] NS Off-peak Free
- [ ] NS Always Free
- [ ] Bus Region Discount
- [ ] Bus Region Free
- [ ] Other, namely:

B.6 Page 5 – Introduction hubs and shared mobility

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Your trip to Eindhoven city center

Page: Introductie Concepten

As a preparation to the choice tasks that are going to follow, the concepts '**mobility-hubs**' and '**shared mobility**' are introduced.

Mobility hubs are locations where you can transfer to various (sustainable) transport modes. You can compare them with a **transferium/P+R** at the edge of a city where you park your car and you travel by bus or bike to the center. At these mobility hubs other facilities such as a coffee- & sandwich store, supermarket, or parcel pick-up point can be present as well.

Shared mobility are transport modes that you do not own personally, but that can be used by everyone against payment. This can be the train or bus, but also shared bicycles and shared cars.

When you need some more explanation to understand these concepts, watch the following movie before you continue.

(Source: Provincie Noord-Brabant, 2018)

B.7 Page 6 – Example page

Your trip to Eindhoven city center

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Page: 1_VOORBEELD_ENG_3BUSGEENFIETS

In this part of the questionnaire you will be given a number of **imaginary (not existing) situations**.

These situations are composed for research purposes of Eindhoven University of Technology and are not based on the policy of the municipality of Eindhoven.

In the next tasks, you will be given 5 **alternatives** for your future trip to Eindhoven city center, from your home location to Eindhoven city center ("Your context" shows your current trip to Eindhoven by car). These alternatives vary from: **car, car + bus, car + shared bicycle, bus + walk** and **bus + shared bicycle**.

Explanation alternatives:

1 - You drive by **CAR** to the **CENTER** of Eindhoven and pay **€7.00 PER HOUR** to park within the ring road. 'Price trip' shows your costs for this trip (excl. parking costs).

2 - You drive by **CAR** to a **MOBILITY HUB** (with a **COFFEE & SANDWICH STORE**) located at the edge of Eindhoven (outside the ring road), where you park your car against a reduced tariff of **€0.00 PER DAY**. You have to wait ***2 MIN.*** for the bus and this trip takes **6 MIN.** to the center. 'Price trip' shows your costs for the car trip (excl. parking costs) + bus trip.

3 - You drive by **CAR** to a **MOBILITY HUB** (with a **COFFEE & SANDWICH STORE**) located at the edge of Eindhoven (outside the ring road), where you park your car against a reduced tariff of **€0.00 PER DAY**. You change to a **SHARED BICYCLE** and you cycle **10 MIN.** to the center. 'Price trip' shows your costs for the car trip (excl. parking costs) + bike trip.

4 - You take the **BUS** to the center and **WALK** in **7 MIN.** from the bus stop to your destination in the center. 'Price trip' shows your costs for the bus trip.

5 - You take the **BUS** to the center, change to a **SHARED BICYCLE** and cycle in **2 MIN.** from the bus stop to your destination. 'Price trip' shows your costs for the bus trip + bike trip.

What alternative would you prefer in the future to travel to Eindhoven city center?

Your trip	Your context
A Your home location B Eindhoven city center	**Purpose of visit:** Work **Duration of stay:** 2 - 4 hours **Travel time:** 30 min **Travel distance:** 40 km

	car	car + bus	car + shared bicycle	bus + walking	bus + shared bicycle
Alternatives	A – 30 min – B	A – 26 min – HUB – *2 min* – 6 min – B	A – 26 min – HUB – 10 min – B	A – 50 min – BUS STOP – 7 min – B	A – 50 min – BUS STOP – 2 min – B
Total travel time	30 min	34 min	36 min	57 min	52 min
Price trip	€ 4.40	€ 5.40	€ 4.90	€ 3.05	€ 3.55
Parking tariff	€7.00 per hour	€0.00 per day	€0.00 per day	-	-
Facilities hub	-	Coffee & Sandwich	Coffee & Sandwich	-	-
Your choice	○	○	○	○	○

This is an example question, you can choose any answer.

B.8 Page 7 – Preparation for tasks

Your trip to Eindhoven city center

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Page: 1_VOORBEELDTUSSEN_ENG_3BUSGEENFIETS

This was the example task, 9 choice tasks will follow now.

Note: the tasks look similar, but the travel times, waiting time for bus, costs, parking tariffs and facilities are different per task and are therefore underlined.

B.9 Page 8 – Choice task (will be repeated 9 times)

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Your trip to Eindhoven city center

Page: Eindhoven_ENG_1_3BUSGEENFIETS

What alternative would you prefer in the future to travel to Eindhoven city center?

Your trip	Your context
A Your home location B Eindhoven city center	**Purpose of visit:** Work **Duration of stay:** 2 - 4 hours **Travel time:** 30 min **Travel distance:** 40 km

	car	car + bus	car + shared bicycle	bus + walking	bus + shared bicycle
Alternatives	A – car 30 min – B	A – car 30 min – HUB 6 min – bus 9 min – B	A – car 30 min – HUB – shared bicycle 5 min – B	A – bus 50 min – BUS STOP – walking 7 min – B	A – bus 50 min – BUS STOP – shared bicycle 2 min – B
Total travel time	30 min	45 min	35 min	57 min	52 min
Price trip	€4.40	€4.90	€5.40	€3.05	€3.05
Parking tariff	€3.00 per hour	€8.00 per day	€8.00 per day	-	-
Facilities hub	-	Parcel Pick-up	Parcel Pick-up	-	-
Your choice	○	○	○	○	○

B.10 Page 9 – Innovative transport modes

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Your trip to Eindhoven city center

Page: Vervoersmiddelen

When for your trip to Eindhoven city center also the following transport modes are available *in addition to bus and bike* at the mobility hub, which one(s) would you consider using?

					
Electric 2 person car (max. 45 km/hour)	Electric car	Electric step	Electric skateboard	Electric scooter	Electric bicycle
☐	☐	☐	☐	☐	☐

None of these

☐

B.11 Page 10 – Socio-demographics

Your trip to Eindhoven city center

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Page: Socio-demografisch

What is your gender?

- [x] Male
- (•) Female
- ( ) Neutral

What is the highest level of education you enjoyed?

- ( ) None
- ( ) Primary school/special education
- (•) Secondary education
- ( ) Vocational education
- ( ) Undergraduate (University Bachelor level)
- ( ) University Master, PDEng or PhD
- ( ) Other, namely:

What is your year of birth?

1994

What is your yearly net income?

- (•) Not more than €10,000
- ( ) €10,001 till €20,000
- ( ) €20,001 till €30,000
- ( ) €30,001 till €40,000
- ( ) More than €40,000
- ( ) I'd rather not say

What is the size of your household?

4

What is your living situation?

- ( ) Single with child(ren) living with me
- ( ) Married/living together without child(ren) living with us
- ( ) Married/living together with child(ren) living with us
- (•) Living with (grand)parents/family
- ( ) Living with other people (no family)
- ( ) Other, namely:

How would you describe your living environment?

- ( ) City center
- ( ) Outer center (urban)
- (•) Outer center (green)
- ( ) Village
- ( ) Rural

What is your work situation? ***(multiple answers can be selected)***

- [ ] I work 12-30 hours per week (paid)
- [ ] I work more than 30 hours per week (paid)
- [ ] Student or intern
- [x] No job/job seeker
- [ ] Retired
- [ ] I'd rather not say
- [ ] Other, namely:

B.12 Page 11 – Thank page

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Your trip to Eindhoven city center

Page: Final

You have reached the end of the questionnaire.
Thank you for your interest and participation!

If you want to have a chance of winning the Escape Room voucher or one of the Koffiecaartjes Eindhoven, please fill-in your name and email address. (This information will only be used to let you know if you won one of the prices, and will be immediately removed afterwards).

First name:

Last name:

E-mail address:

If you have any questions or suggestions regarding the survey, please enter them below:

Please press the button "Submit" to submit your answers.

APPENDIX C – Data preparation

Modifications:

- 2 respondents filled in 'Other, namely: Private car' on the question about the type of car they drive. However, 'Private (lease) car' was one of the answer possibilities. These values have been changed from 'Other, namely:' to 'Private (lease) car'.
- 1 respondent filled in 'Other, namely: Student house' on the question on the type of living situation. However, 'Living with others (no family)' was one of the answer possibilities. This value has been changed from 'Other, namely:' to 'Living with others (no family)'.
- 1 respondent filled in 'Other, namely: Mobility card from employer' at the question about the type of subscription on the OV-chipkaart. However, 'NS Business' was one of the answer possibilities, so this answer has been changed from 'Other, namely:' to 'NS Businesscard'.
- 1 respondent filled in 'Other, namely: NS Fiets' at this question, this is not considered as a public transport subscription, so this value has been changed from 'Other, namely:' to 'No subscription'.
- 1 respondent filled in 'Other, namely: anonymous OV' at this question, this is considered no subscription, so this value has been changed from 'Other, namely:' to 'No subscription'.
- 1 respondent filled in 'Other, namely: normal OV' at the same question, however 'No subscription' was one of the answer possibilities, so this value has been changed from 'Other, namely:' to 'No subscription'.
- 1 respondent filled in 'Other, namely: LTS', which belongs to the category 'Secondary education' on the question about education. This value has been changed accordingly.
- 2 respondents filled in an odd number at the question on the amount of time it takes them to drive by car to Eindhoven city center:
    - 351 minutes → this respondent indicated in the feedback this value should be 35 instead of 351. When the sub-questionnaire was checked for this respondent, this did not seem to influence the results as the respondent still choose some alternatives that included the car time. Therefore, the 351 has been changed into 35 minutes.
    - 251 minutes → this respondent did not indicate anything on the high number of minutes. However, when the rest of the filled-in numbers were consulted, no strange records have been found. When checking the postal code 25 minutes seems to be a valid number and this might as well have been typing mistake. The sub-questionnaire was also checked for this respondent, and again the high number of minutes seems not to influence the results. Therefore, the 251 has been changed into 25 minutes.
- 3 respondents filled in a postal code which was not valid. However, they have all filled-in all necessary values for their trip towards Eindhoven city center themselves, so no problems occurred in the sub questionnaires.

Removed:

- 2 respondents state they do not use a car for their trip to the city center of Eindhoven (despite the question on how often they visit Eindhoven city center <u>by car</u>).
- Unrealistic values have been entered:

    - 1 respondent answered zero to every question on the amount of kilometers or time to Eindhoven by car and public transportation.
    - 1 respondent filled in 999 on the question about the travel time by public transportation to Eindhoven, as that respondent felt the public transportation was not applicable option for him/her.
- Travel time by car is a small number, making the travel time by car in the sub-questionnaires unrealistic due to the attribute levels -2 and -4 of the attribute ‘Reduction on car travel time to hub’:
    - 3 respondents filled in 0 minutes.
    - 1 respondent filled in 2 minutes.
    - 4 respondents filled in 3 minutes.
    - 2 respondents filled in 4 minutes.

APPENDIX D – Output MNL model estimations

D.1 General MNL

Attributes	Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	-0.50088	***	0.06367	-7.87	0	-0.62567	-0.37609
Constant Car + Bike	-0.73076	***	0.06862	-10.65	0	-0.86525	-0.59626
Constant Public Transport + Walk	0.11877	**	0.05242	2.27	0.0235	0.01604	0.22151
Constant Public Transport + Bike	-0.91088	***	0.07123	-12.79	0	-1.05049	-0.77126
Constant Bike	1.00024	***	0.05945	16.83	0	0.88373	1.11675
Car + Bus TT Reduction car: -4	0.15493	**	0.07275	2.13	0.0332	0.01233	0.29752
Car + Bus TT Reduction car: -2	-0.00314		0.07394	-0.04	0.9661	-0.14806	0.14178
Car + Bus TT Reduction car: 0	-0.15179	-					
Car + Bike TT Reduction car: -4	0.01233		0.08152	0.15	0.8798	-0.14744	0.17211
Car + Bike TT Reduction car: -2	-0.07911		0.082	-0.96	0.3347	-0.23983	0.08161
Car + Bike TT Reduction car: 0	0.06678	-					
Car + Bus PC Car at Hub: 0	0.53494	***	0.07082	7.55	0	0.39614	0.67375
Car + Bus PC Car at Hub: 4	-0.00238		0.07467	-0.03	0.9746	-0.14873	0.14397
Car + Bus PC Car at Hub: 8	-0.53256	-					
Car + Bike PC Car at Hub: 0	0.65338	***	0.07634	8.56	0	0.50377	0.803
Car + Bike PC Car at Hub: 4	-0.26586	***	0.08715	-3.05	0.0023	-0.43667	-0.09506
Car + Bike PC Car at Hub: 8	-0.38752	-					
Car + Bus Hub fac.: Coffee & Sandwich	0.12071	*	0.0726	1.66	0.0964	-0.02157	0.263
Car + Bus Hub fac.: Parcel Pick-up	-0.09266		0.07544	-1.23	0.2194	-0.24051	0.0552
Car + Bus Hub fac.: None	-0.02805	-					
Car + Bike Hub fac.: Coffee & Sandwich	-0.03918		0.08201	-0.48	0.6328	-0.19992	0.12156
Car + Bike Hub fac.: Parcel Pick-up	0.06243		0.07978	0.78	0.4339	-0.09394	0.21881
Car + Bike Hub fac.: None	-0.02325	-					
Car PC Center: 3	0.50649	***	0.05807	8.72	0	0.39268	0.62031
Car PC Center: 5	-0.11661	*	0.06219	-1.88	0.0608	-0.2385	0.00528
Car PC Center: 7	-0.38988	-					
Car + Bus TT Bus: 6	0.19796	***	0.07117	2.78	0.0054	0.05847	0.33745
Car + Bus TT Bus: 9	0.0013		0.07355	0.02	0.9859	-0.14285	0.14545
Car + Bus TT Bus: 12	-0.19926	-					
Car + Bus WT Bus: 2	0.28466	***	0.06985	4.08	0	0.14775	0.42156
Car + Bus WT Bus: 6	-0.03324		0.07332	-0.45	0.6503	-0.17695	0.11046
Car + Bus WT Bus: 10	-0.25142	-					
Car + Bus TC Bus: 0	-0.05029		0.07306	-0.69	0.4912	-0.19348	0.0929
Car + Bus TC Bus: 0.5	-0.01095		0.07263	-0.15	0.8801	-0.15331	0.1314
Car + Bus TC Bus: 1	0.06124	-					
Car + Bike TT Bike: 5	0.30949	***	0.07658	4.04	0.0001	0.1594	0.45958
Car + Bike TT Bike: 10	0.02084		0.07997	0.26	0.7944	-0.1359	0.17759
Car + Bike TT Bike: 15	-0.33033	-					
Car + Bike TC Bike: 0	0.00935		0.07937	0.12	0.9062	-0.1462	0.16491
Car + Bike TC Bike: 0.5	-0.0057		0.07964	-0.07	0.9429	-0.16179	0.15039
Car + Bike TC Bike: 1	-0.00365	-					
PT + Bike TC Bike: 0	0.25361	***	0.08413	3.01	0.0026	0.08872	0.4185
PT + Bike TC Bike: 0.5	-0.06377		0.09002	-0.71	0.4787	-0.2402	0.11266
PT + Bike TC Bike: 1	-0.18984	-					

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

AIC	10238.7
LL (β)	-5088.33494
LL (0)	-5714.65293
ρ2	0.110
K	31

D.2 MNL model per purpose category

P1 = Work & study   P2 = Shopping & Groceries   P3 = Leisure, Visiting friends/family, Event, Going out/going for dinner & *sports*

Tab. D.2.1 Effects purpose categories

Attributes	Effects Work (P1)	Effects Shopping (P2)	Effects Leisure (P3)
Constant Car + Bus	-1.03116	-0.30377	-0.62773
Constant Car + Bike	-0.16904	-1.08341	-0.86471
Constant Public Transport + Walk	0.34316	-0.18542	0.30096
Constant Public Transport + Bike	-0.35105	-1.49773	-0.76176
Constant Bike	1.77924	0.66327	0.85794
Car + Bus TT Reduction car: -4	0.17237	0.06734	0.2318
Car + Bus TT Reduction car: -2	-0.33886	0.17085	-0.13442
Car + Bus TT Reduction car: 0	0.16649	-0.23819	-0.09738
Car + Bike TT Reduction car: -4	0.19068	-0.28201	0.14542
Car + Bike TT Reduction car: -2	-0.35431	0.05589	0.01246
Car + Bike TT Reduction car: 0	0.16363	0.22612	-0.15788
Car + Bus PC Car at Hub: 0	0.63286	0.51979	0.57001
Car + Bus PC Car at Hub: 4	0.06805	0.00134	-0.05613
Car + Bus PC Car at Hub: 8	-0.70091	-0.52113	-0.51388
Car + Bike PC Car at Hub: 0	0.48697	0.60379	0.8731
Car + Bike PC Car at Hub: 4	-0.33662	-0.17354	-0.28673
Car + Bike PC Car at Hub: 8	-0.15035	-0.43025	-0.58637
Car + Bus Hub fac.: Coffee & Sandwich	0.05166	0.16394	0.06388
Car + Bus Hub fac.: Parcel Pick-up	-0.07798	-0.14691	-0.04385
Car + Bus Hub fac.: None	0.02632	-0.01703	-0.02003
Car + Bike Hub fac.: Coffee & Sandwich	0.1213	-0.21157	-0.07806
Car + Bike Hub fac.: Parcel Pick-up	-0.00466	0.09843	0.11176
Car + Bike Hub fac.: None	-0.11664	0.11314	-0.0337
Car PC Center: 3	0.23415	0.53313	0.62562
Car PC Center: 5	-0.08141	-0.08462	-0.1766
Car PC Center: 7	-0.15274	-0.44851	-0.44902
Car + Bus TT Bus: 6	0.49124	0.19495	0.04398
Car + Bus TT Bus: 9	-0.17364	0.05948	0.06121
Car + Bus TT Bus: 12	-0.3176	-0.25443	-0.10519
Car + Bus WT Bus: 2	0.80735	0.32266	0.02046
Car + Bus WT Bus: 6	-0.44325	-0.05784	0.14628
Car + Bus WT Bus: 10	-0.3641	-0.26482	-0.16674
Car + Bus TC Bus: 0	0.09119	-0.11628	-0.01571
Car + Bus TC Bus: 0.5	-0.10835	0.06479	-0.10884
Car + Bus TC Bus: 1	0.01716	0.05149	0.12455
Car + Bike TT Bike: 5	0.23555	0.27604	0.43677
Car + Bike TT Bike: 10	-0.00728	0.02973	0.05036
Car + Bike TT Bike: 15	-0.22827	-0.30577	-0.48713
Car + Bike TC Bike: 0	0.00844	0.00626	-0.16954
Car + Bike TC Bike: 0.5	0.02364	0.12605	-0.11693
Car + Bike TC Bike: 1	-0.03208	-0.13231	0.28647
PT + Bike TC Bike: 0	0.35973	0.22393	0.23234
PT + Bike TC Bike: 0.5	-0.0621	-0.06428	-0.07264
PT + Bike TC Bike: 1	-0.29763	-0.15965	-0.1597

AIC	10122.3
LL (β)	-4968.13487
LL (0)	-5714.65293
ρ2	0.131
K	93

Tab. D.2.2 Beta coefficients MNL purpose categories

Attributes		Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	β	-0.65422	***	0.07755	-8.44	0	-0.80621	-0.50223
Constant Car + Bike	β	-0.70572	***	0.07173	-9.84	0	-0.8463	-0.56513
Constant Public Transport + Walk	β	0.1529	***	0.05485	2.79	0.0053	0.04539	0.26041
Constant Public Transport + Bike	β	-0.87018	***	0.07373	-11.8	0	-1.01469	-0.72566
Constant Bike	β	1.10015	***	0.06226	17.67	0	0.97813	1.22217
Car + Bus TT Reduction car: -4	β	0.15717	*	0.0844	1.86	0.0626	-0.00825	0.32258
Car + Bus TT Reduction car: -2	β	-0.10081		0.08876	-1.14	0.2561	-0.27477	0.07316
Car + Bike TT Reduction car: -4	β	0.01803		0.08329	0.22	0.8286	-0.14521	0.18127
Car + Bike TT Reduction car: -2	β	-0.09532		0.08344	-1.14	0.2533	-0.25885	0.06821
Car + Bus PC Car at Hub: 0	β	0.57422	***	0.08214	6.99	0	0.41322	0.73522
Car + Bus PC Car at Hub: 4	β	0.00442		0.0879	0.05	0.9599	-0.16785	0.1767
Car + Bike PC Car at Hub: 0	β	0.65462	***	0.07777	8.42	0	0.5022	0.80704
Car + Bike PC Car at Hub: 4	β	-0.26563	***	0.08842	-3	0.0027	-0.43893	-0.09234
Car + Bus Hub fac.: Coffee & Sandwich	β	0.09316		0.08382	1.11	0.2664	-0.07112	0.25744
Car + Bus Hub fac.: Parcel Pick-up	β	-0.08958		0.08735	-1.03	0.3051	-0.26078	0.08162
Car + Bike Hub fac.: Coffee & Sandwich	β	-0.05611		0.08388	-0.67	0.5035	-0.22051	0.10828
Car + Bike Hub fac.: Parcel Pick-up	β	0.06851		0.08114	0.84	0.3985	-0.09052	0.22755
Car PC Center: 3	β	0.4643	***	0.06195	7.49	0	0.34288	0.58571
Car PC Center: 5	β	-0.11421	*	0.0656	-1.74	0.0817	-0.24277	0.01436
Car + Bus TT Bus: 6	β	0.24339	***	0.08168	2.98	0.0029	0.0833	0.40348
Car + Bus TT Bus: 9	β	-0.01765		0.08721	-0.2	0.8396	-0.18857	0.15327
Car + Bus WT Bus: 2	β	0.38349	***	0.08137	4.71	0	0.22399	0.54298
Car + Bus WT Bus: 6	β	-0.11827		0.09358	-1.26	0.2063	-0.30168	0.06514
Car + Bus TC Bus: 0	β	-0.0136		0.0829	-0.16	0.8697	-0.17608	0.14888
Car + Bus TC Bus: 0.5	β	-0.0508		0.08545	-0.59	0.5522	-0.21827	0.11668
Car + Bike TT Bike: 5	β	0.31612	***	0.07783	4.06	0	0.16358	0.46867
Car + Bike TT Bike: 10	β	0.02427		0.08104	0.3	0.7645	-0.13455	0.1831
Car + Bike TC Bike: 0	β	0.0042		0.08101	0.05	0.9586	-0.15458	0.16299
Car + Bike TC Bike: 0.5	β	0.01092		0.08097	0.13	0.8927	-0.14777	0.16961
PT + Bike TC Bike: 0	β	0.272	***	0.08613	3.16	0.0016	0.10319	0.44081
PT + Bike TC Bike: 0.5	β	-0.06634		0.09221	-0.72	0.4719	-0.24708	0.1144

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

Tab. D.2.3 Gamma coefficients MNL purpose categories

Attributes		Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	γ	-0.37694	***	0.13135	-2.87	0.0041	-0.63438	-0.1195
Constant Car + Bike	γ	0.53668	***	0.10405	5.16	0	0.33275	0.7406
Constant Public Transport + Walk	γ	0.19026	**	0.08521	2.23	0.0256	0.02325	0.35727
Constant Public Transport + Bike	γ	0.51913	***	0.1074	4.83	0	0.30863	0.72962
Constant Bike	γ	0.67909	***	0.09532	7.12	0	0.49226	0.86592
Car + Bus TT Reduction car: -4	γ	0.0152		0.13979	0.11	0.9134	-0.25878	0.28918
Car + Bus TT Reduction car: -2	γ	-0.23805		0.14789	-1.61	0.1075	-0.52791	0.05181
Car + Bike TT Reduction car: -4	γ	0.17265		0.11778	1.47	0.1427	-0.05818	0.40349
Car + Bike TT Reduction car: -2	γ	-0.25899	**	0.12164	-2.13	0.0332	-0.49741	-0.02057
Car + Bus PC Car at Hub: 0	γ	0.05864		0.13562	0.43	0.6655	-0.20718	0.32445
Car + Bus PC Car at Hub: 4	γ	0.06363		0.14609	0.44	0.6632	-0.2227	0.34996
Car + Bike PC Car at Hub: 0	γ	-0.16765		0.11151	-1.5	0.1327	-0.38621	0.05091
Car + Bike PC Car at Hub: 4	γ	-0.07099		0.12644	-0.56	0.5745	-0.3188	0.17683
Car + Bus Hub fac.: Coffee & Sandwich	γ	-0.0415		0.13754	-0.3	0.7628	-0.31108	0.22807
Car + Bus Hub fac.: Parcel Pick-up	γ	0.0116		0.14442	0.08	0.936	-0.27146	0.29467
Car + Bike Hub fac.: Coffee & Sandwich	γ	0.17741		0.1172	1.51	0.1301	-0.0523	0.40713
Car + Bike Hub fac.: Parcel Pick-up	γ	-0.07317		0.11757	-0.62	0.5337	-0.30361	0.15726
Car PC Center: 3	γ	-0.23015	**	0.09801	-2.35	0.0189	-0.42225	-0.03806
Car PC Center: 5	γ	0.0328		0.10266	0.32	0.7493	-0.1684	0.23401
Car + Bus TT Bus: 6	γ	0.24785	*	0.13326	1.86	0.0629	-0.01333	0.50903
Car + Bus TT Bus: 9	γ	-0.15599		0.14551	-1.07	0.2837	-0.44117	0.1292
Car + Bus WT Bus: 2	γ	0.42386	***	0.13269	3.19	0.0014	0.16378	0.68393
Car + Bus WT Bus: 6	γ	-0.32498	**	0.16204	-2.01	0.0449	-0.64258	-0.00739
Car + Bus TC Bus: 0	γ	0.10479		0.13528	0.77	0.4386	-0.16035	0.36993
Car + Bus TC Bus: 0.5	γ	-0.05755		0.14118	-0.41	0.6835	-0.33425	0.21916
Car + Bike TT Bike: 5	γ	-0.08057		0.11217	-0.72	0.4726	-0.30042	0.13927
Car + Bike TT Bike: 10	γ	-0.03155		0.11547	-0.27	0.7847	-0.25785	0.19476
Car + Bike TC Bike: 0	γ	0.08471		0.11399	0.74	0.4574	-0.13871	0.30812
Car + Bike TC Bike: 0.5	γ	0.01272		0.11646	0.11	0.913	-0.21552	0.24097
PT + Bike TC Bike: 0	γ	0.08773		0.12167	0.72	0.4709	-0.15074	0.3262
PT + Bike TC Bike: 0.5	γ	0.00424		0.13004	0.03	0.974	-0.25064	0.25912

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

Tab. D.2.4 Delta coefficients MNL purpose categories

Attributes		Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	δ	0.35045	***	0.09342	3.75	0.0002	0.16736	0.53354
Constant Car + Bike	δ	-0.37769	***	0.09879	-3.82	0.0001	-0.57132	-0.18406
Constant Public Transport + Walk	δ	-0.33832	***	0.07348	-4.6	0	-0.48235	-0.1943
Constant Public Transport + Bike	δ	-0.62755	***	0.10669	-5.88	0	-0.83667	-0.41844
Constant Bike	δ	-0.43688	***	0.08175	-5.34	0	-0.5971	-0.27666
Car + Bus TT Reduction car: -4	δ	-0.08983		0.10347	-0.87	0.3853	-0.29264	0.11297
Car + Bus TT Reduction car: -2	δ	0.27166	**	0.10689	2.54	0.011	0.06216	0.48116
Car + Bike TT Reduction car: -4	δ	-0.30004	**	0.1207	-2.49	0.0129	-0.53659	-0.06348
Car + Bike TT Reduction car: -2	δ	0.15121		0.11698	1.29	0.1961	-0.07806	0.38048
Car + Bus PC Car at Hub: 0	δ	-0.05443		0.10084	-0.54	0.5894	-0.25208	0.14321
Car + Bus PC Car at Hub: 4	δ	-0.00308		0.10695	-0.03	0.977	-0.21269	0.20653
Car + Bike PC Car at Hub: 0	δ	-0.05083		0.10979	-0.46	0.6434	-0.26601	0.16435
Car + Bike PC Car at Hub: 4	δ	0.09209		0.12421	0.74	0.4585	-0.15136	0.33554
Car + Bus Hub fac.: Coffee & Sandwich	δ	0.07078		0.10274	0.69	0.4909	-0.13059	0.27215
Car + Bus Hub fac.: Parcel Pick-up	δ	-0.05733		0.10702	-0.54	0.5922	-0.26708	0.15242
Car + Bike Hub fac.: Coffee & Sandwich	δ	-0.15546		0.12144	-1.28	0.2005	-0.39348	0.08255
Car + Bike Hub fac.: Parcel Pick-up	δ	0.02992		0.11408	0.26	0.7931	-0.19368	0.25351
Car PC Center: 3	δ	0.06883		0.08048	0.86	0.3924	-0.08891	0.22656
Car PC Center: 5	δ	0.02959		0.0854	0.35	0.729	-0.13779	0.19697
Car + Bus TT Bus: 6	δ	-0.04844		0.10047	-0.48	0.6297	-0.24535	0.14848
Car + Bus TT Bus: 9	δ	0.07713		0.10567	0.73	0.4655	-0.12999	0.28425
Car + Bus WT Bus: 2	δ	-0.06083		0.09962	-0.61	0.5415	-0.25608	0.13443
Car + Bus WT Bus: 6	δ	0.06043		0.11101	0.54	0.5862	-0.15715	0.278
Car + Bus TC Bus: 0	δ	-0.10268		0.10287	-1	0.3182	-0.3043	0.09894
Car + Bus TC Bus: 0.5	δ	0.11559		0.10371	1.11	0.265	-0.08767	0.31885
Car + Bike TT Bike: 5	δ	-0.04008		0.10988	-0.36	0.7153	-0.25545	0.17529
Car + Bike TT Bike: 10	δ	0.00546		0.11425	0.05	0.9619	-0.21847	0.22938
Car + Bike TC Bike: 0	δ	0.08903		0.11323	0.79	0.4317	-0.13289	0.31095
Car + Bike TC Bike: 0.5	δ	0.11513		0.11323	1.02	0.3092	-0.10679	0.33705
PT + Bike TC Bike: 0	δ	-0.04807		0.12816	-0.38	0.7076	-0.29925	0.20312
PT + Bike TC Bike: 0.5	δ	0.00206		0.13779	0.01	0.9881	-0.26799	0.27212

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

D.3 MNL model per urbanization category

Tab. D.3.1 Effects urbanization categories

Attributes	Effects City	Effects Village
Constant Car + Bus	-1.00861	-0.33141
Constant Car + Bike	-1.03175	-0.65773
Constant Public Transport + Walk	0.44386	-0.09288
Constant Public Transport + Bike	-0.91875	-0.91283
Constant Bike	1.70404	0.32966
Car + Bus TT Reduction car: -4	0.33282	0.077
Car + Bus TT Reduction car: -2	0.02742	0.00562
Car + Bus TT Reduction car: 0	-0.36024	-0.08262
Car + Bike TT Reduction car: -4	0.30307	-0.11891
Car + Bike TT Reduction car: -2	0.00972	-0.11038
Car + Bike TT Reduction car: 0	-0.31279	0.22929
Car + Bus PC Car at Hub: 0	0.61422	0.52966
Car + Bus PC Car at Hub: 4	-0.12625	0.02303
Car + Bus PC Car at Hub: 8	-0.48797	-0.55269
Car + Bike PC Car at Hub: 0	0.87681	0.60263
Car + Bike PC Car at Hub: 4	-0.27751	-0.26255
Car + Bike PC Car at Hub: 8	-0.5993	-0.34008
Car + Bus Hub fac.: Coffee & Sandwich	0.04999	0.14001
Car + Bus Hub fac.: Parcel Pick-up	-0.13803	-0.08451
Car + Bus Hub fac.: None	0.08804	-0.0555
Car + Bike Hub fac.: Coffee & Sandwich	0.04942	-0.0773
Car + Bike Hub fac.: Parcel Pick-up	0.05075	0.08933
Car + Bike Hub fac.: None	-0.10017	-0.01203
Car PC Center: 3	0.64552	0.44142
Car PC Center: 5	-0.09267	-0.14063
Car PC Center: 7	-0.55285	-0.30079
Car + Bus TT Bus: 6	0.33071	0.19885
Car + Bus TT Bus: 9	-0.35724	0.08908
Car + Bus TT Bus: 12	0.02653	-0.28793
Car + Bus WT Bus: 2	0.24436	0.30194
Car + Bus WT Bus: 6	-0.04761	-0.03499
Car + Bus WT Bus: 10	-0.19675	-0.26695
Car + Bus TC Bus: 0	-0.1194	-0.03184
Car + Bus TC Bus: 0.5	0.13753	-0.04893
Car + Bus TC Bus: 1	-0.01813	0.08077
Car + Bike TT Bike: 5	0.24712	0.36942
Car + Bike TT Bike: 10	-0.27726	0.13728
Car + Bike TT Bike: 15	0.03014	-0.5067
Car + Bike TC Bike: 0	-0.11422	0.0393
Car + Bike TC Bike: 0.5	0.25314	-0.09714
Car + Bike TC Bike: 1	-0.13892	0.05784
PT + Bike TC Bike: 0	0.40103	0.17925
PT + Bike TC Bike: 0.5	-0.27196	0.03344
PT + Bike TC Bike: 1	-0.12907	-0.21269

AIC	9990.5
LL (β)	-4933.22964
LL (0)	-5714.65293
ρ2	0.137
K	62

Tab. D.3.2 Beta coefficients MNL urbanization categories

Attributes		Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	β	-0.67001	***	0.07644	-8.77	0	-0.81983	-0.52019
Constant Car + Bike	β	-0.84474	***	0.07988	-10.58	0	-1.00129	-0.68818
Constant Public Transport + Walk	β	0.17549	***	0.0545	3.22	0.0013	0.06866	0.28231
Constant Public Transport + Bike	β	-0.91579	***	0.07631	-12	0	-1.06535	-0.76623
Constant Bike	β	1.01685	***	0.06307	16.12	0	0.89323	1.14046
Car + Bus TT Reduction car: -4	β	0.20491	**	0.08583	2.39	0.017	0.03668	0.37314
Car + Bus TT Reduction car: -2	β	0.01652		0.08916	0.19	0.853	-0.15824	0.19128
Car + Bike TT Reduction car: -4	β	0.09208		0.08965	1.03	0.3044	-0.08363	0.2678
Car + Bike TT Reduction car: -2	β	-0.05033		0.09135	-0.55	0.5817	-0.22937	0.12871
Car + Bus PC Car at Hub: 0	β	0.57194	***	0.08394	6.81	0	0.40743	0.73646
Car + Bus PC Car at Hub: 4	β	-0.05161		0.09141	-0.56	0.5724	-0.23077	0.12756
Car + Bike PC Car at Hub: 0	β	0.73972	***	0.08616	8.58	0	0.57084	0.90859
Car + Bike PC Car at Hub: 4	β	-0.27003	***	0.10046	-2.69	0.0072	-0.46693	-0.07313
Car + Bus Hub fac.: Coffee & Sandwich	β	0.095		0.08794	1.08	0.28	-0.07736	0.26736
Car + Bus Hub fac.: Parcel Pick-up	β	-0.11127		0.091	-1.22	0.2214	-0.28964	0.06709
Car + Bike Hub fac.: Coffee & Sandwich	β	-0.01394		0.09085	-0.15	0.878	-0.192	0.16411
Car + Bike Hub fac.: Parcel Pick-up	β	0.07004		0.09018	0.78	0.4374	-0.10672	0.2468
Car PC Center: 3	β	0.54347	***	0.0611	8.9	0	0.42372	0.66321
Car PC Center: 5	β	-0.11665	*	0.06592	-1.77	0.0768	-0.24585	0.01254
Car + Bus TT Bus: 6	β	0.26478	***	0.08551	3.1	0.002	0.09718	0.43239
Car + Bus TT Bus: 9	β	-0.13408		0.09499	-1.41	0.1581	-0.32025	0.05209
Car + Bus WT Bus: 2	β	0.27315	***	0.08383	3.26	0.0011	0.10885	0.43745
Car + Bus WT Bus: 6	β	-0.0413		0.08819	-0.47	0.6395	-0.21415	0.13154
Car + Bus TC Bus: 0	β	-0.07562		0.08954	-0.84	0.3984	-0.25112	0.09988
Car + Bus TC Bus: 0.5	β	0.0443		0.08545	0.52	0.6042	-0.12317	0.21177
Car + Bike TT Bike: 5	β	0.30827	***	0.08597	3.59	0.0003	0.13978	0.47676
Car + Bike TT Bike: 10	β	-0.06999		0.09409	-0.74	0.457	-0.2544	0.11443
Car + Bike TC Bike: 0	β	-0.03746		0.09177	-0.41	0.6831	-0.21732	0.1424
Car + Bike TC Bike: 0.5	β	0.078		0.08705	0.9	0.3703	-0.09262	0.24861
PT + Bike TC Bike: 0	β	0.29014	***	0.08841	3.28	0.001	0.11686	0.46341
PT + Bike TC Bike: 0.5	β	-0.11926		0.09841	-1.21	0.2256	-0.31214	0.07363

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

Tab. D.3.3 Gamma coefficients MNL urbanization categories

Attributes		Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	γ	-0.3386	***	0.07644	-4.43	0	-0.48842	-0.18878
Constant Car + Bike	γ	-0.18701	**	0.07988	-2.34	0.0192	-0.34357	-0.03046
Constant Public Transport + Walk	γ	0.26837	***	0.0545	4.92	0	0.16155	0.3752
Constant Public Transport + Bike	γ	-0.00296		0.07631	-0.04	0.9691	-0.15252	0.1466
Constant Bike	γ	0.68719	***	0.06307	10.9	0	0.56357	0.8108
Car + Bus TT Reduction car: -4	γ	0.12791		0.08583	1.49	0.1362	-0.04032	0.29614
Car + Bus TT Reduction car: -2	γ	0.0109		0.08916	0.12	0.9027	-0.16386	0.18566
Car + Bike TT Reduction car: -4	γ	0.21099	**	0.08965	2.35	0.0186	0.03527	0.38671
Car + Bike TT Reduction car: -2	γ	0.06005		0.09135	0.66	0.5109	-0.11899	0.23909
Car + Bus PC Car at Hub: 0	γ	0.04228		0.08394	0.5	0.6145	-0.12224	0.20679
Car + Bus PC Car at Hub: 4	γ	-0.07464		0.09141	-0.82	0.4142	-0.2538	0.10453
Car + Bike PC Car at Hub: 0	γ	0.13709		0.08616	1.59	0.1116	-0.03179	0.30597
Car + Bike PC Car at Hub: 4	γ	-0.00748		0.10046	-0.07	0.9407	-0.20438	0.18942
Car + Bus Hub fac.: Coffee & Sandwich	γ	-0.04501		0.08794	-0.51	0.6088	-0.21737	0.12735
Car + Bus Hub fac.: Parcel Pick-up	γ	-0.02676		0.091	-0.29	0.7687	-0.20513	0.15161
Car + Bike Hub fac.: Coffee & Sandwich	γ	0.06336		0.09085	0.7	0.4856	-0.1147	0.24141
Car + Bike Hub fac.: Parcel Pick-up	γ	-0.01929		0.09018	-0.21	0.8307	-0.19604	0.15747
Car PC Center: 3	γ	0.10205	*	0.0611	1.67	0.0949	-0.0177	0.22179
Car PC Center: 5	γ	0.02398		0.06592	0.36	0.716	-0.10521	0.15318
Car + Bus TT Bus: 6	γ	0.06593		0.08551	0.77	0.4407	-0.10167	0.23354
Car + Bus TT Bus: 9	γ	-0.22316	**	0.09499	-2.35	0.0188	-0.40934	-0.03699
Car + Bus WT Bus: 2	γ	-0.02879		0.08383	-0.34	0.7312	-0.19309	0.13551
Car + Bus WT Bus: 6	γ	-0.00631		0.08819	-0.07	0.943	-0.17915	0.16653
Car + Bus TC Bus: 0	γ	-0.04378		0.08954	-0.49	0.6249	-0.21928	0.13173
Car + Bus TC Bus: 0.5	γ	0.09323		0.08545	1.09	0.2752	-0.07424	0.2607
Car + Bike TT Bike: 5	γ	-0.06115		0.08597	-0.71	0.4768	-0.22964	0.10733
Car + Bike TT Bike: 10	γ	-0.20727	**	0.09409	-2.2	0.0276	-0.39168	-0.02286
Car + Bike TC Bike: 0	γ	-0.07676		0.09177	-0.84	0.4029	-0.25662	0.1031
Car + Bike TC Bike: 0.5	γ	0.17514	**	0.08705	2.01	0.0442	0.00453	0.34575
PT + Bike TC Bike: 0	γ	0.11089		0.08841	1.25	0.2098	-0.06239	0.28416
PT + Bike TC Bike: 0.5	γ	-0.1527		0.09841	-1.55	0.1208	-0.34558	0.04018

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

D.4 MNL model per distance category

Tab. D.4.1 Coefficients MNL distance categories

Attributes	Effects ≤ 10 km	Effects > 10 km
Constant Car + Bus	-2.56421	-0.18219
Constant Car + Bike	-2.66873	-0.41117
Constant Public Transport + Walk	-0.22597	0.25089
Constant Public Transport + Bike	-1.6369	-0.761
Constant Bike	0.66338	0.2472
Car + Bus TT Reduction car: -4	0.16186	0.16186
Car + Bus TT Reduction car: -2	-0.01432	-0.01432
Car + Bus TT Reduction car: 0	-0.14754	-0.14754
Car + Bike TT Reduction car: -4	0.01516	0.01516
Car + Bike TT Reduction car: -2	-0.08551	-0.08551
Car + Bike TT Reduction car: 0	0.07035	0.07035
Car + Bus PC Car at Hub: 0	0.58034	0.58034
Car + Bus PC Car at Hub: 4	-0.01688	-0.01688
Car + Bus PC Car at Hub: 8	-0.56346	-0.56346
Car + Bike PC Car at Hub: 0	0.6943	0.6943
Car + Bike PC Car at Hub: 4	-0.27589	-0.27589
Car + Bike PC Car at Hub: 8	-0.41841	-0.41841
Car + Bus Hub fac.: Coffee & Sandwich	0.11627	0.11627
Car + Bus Hub fac.: Parcel Pick-up	-0.09435	-0.09435
Car + Bus Hub fac.: None	-0.02192	-0.02192
Car + Bike Hub fac.: Coffee & Sandwich	-0.04051	-0.04051
Car + Bike Hub fac.: Parcel Pick-up	0.06654	0.06654
Car + Bike Hub fac.: None	-0.02603	-0.02603
Car PC Center: 3	0.24547	0.56385
Car PC Center: 5	-0.08947	-0.08947
Car PC Center: 7	-0.156	-0.47438
Car + Bus TT Bus: 6	0.19284	0.19284
Car + Bus TT Bus: 9	0.00271	0.00271
Car + Bus TT Bus: 12	-0.19555	-0.19555
Car + Bus WT Bus: 2	0.3034	0.3034
Car + Bus WT Bus: 6	-0.02685	-0.02685
Car + Bus WT Bus: 10	-0.27655	-0.27655
Car + Bus TC Bus: 0	-0.05035	-0.05035
Car + Bus TC Bus: 0.5	-0.01214	-0.01214
Car + Bus TC Bus: 1	0.06249	0.06249
Car + Bike TT Bike: 5	0.32029	0.32029
Car + Bike TT Bike: 10	0.03543	0.03543
Car + Bike TT Bike: 15	-0.35572	-0.35572
Car + Bike TC Bike: 0	0.00036	0.00036
Car + Bike TC Bike: 0.5	-0.00609	-0.00609
Car + Bike TC Bike: 1	0.00573	0.00573
PT + Bike TC Bike: 0	0.25402	0.25402
PT + Bike TC Bike: 0.5	-0.06622	-0.06622
PT + Bike TC Bike: 1	-0.1878	-0.1878

Tab. D.4.2 Beta coefficients MNL distance categories (step 0)

Attributes		Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	β	-1.3653	***	0.13132	-10.4	0	-1.62268	-1.10793
Constant Car + Bike	β	-1.55929	***	0.14706	-10.6	0	-1.84753	-1.27106
Constant Public Transport + Walk	β	0.01227		0.05648	0.22	0.8281	-0.09843	0.12297
Constant Public Transport + Bike	β	-1.19738	***	0.08859	-13.52	0	-1.37101	-1.02375
Constant Bike	β	0.45754	***	0.06419	7.13	0	0.33173	0.58334
Car + Bus TT Reduction car: -4	β	-0.01109		0.16474	-0.07	0.9463	-0.33398	0.3118
Car + Bus TT Reduction car: -2	β	-0.05242		0.16086	-0.33	0.7445	-0.36771	0.26286
Car + Bike TT Reduction car: -4	β	-0.07879		0.16704	-0.47	0.6372	-0.40618	0.2486
Car + Bike TT Reduction car: -2	β	0.0616		0.14869	0.41	0.6787	-0.22982	0.35302
Car + Bus PC Car at Hub: 0	β	0.50372	***	0.15231	3.31	0.0009	0.2052	0.80224
Car + Bus PC Car at Hub: 4	β	0.05957		0.15531	0.38	0.7013	-0.24482	0.36397
Car + Bike PC Car at Hub: 0	β	0.872	***	0.1539	5.67	0	0.57036	1.17365
Car + Bike PC Car at Hub: 4	β	-0.3113		0.19467	-1.6	0.1098	-0.69284	0.07025
Car + Bus Hub fac.: Coffee & Sandwich	β	0.1097		0.15168	0.72	0.4696	-0.18759	0.40699
Car + Bus Hub fac.: Parcel Pick-up	β	-0.20285		0.16854	-1.2	0.2287	-0.53318	0.12748
Car + Bike Hub fac.: Coffee & Sandwich	β	-0.1		0.16584	-0.6	0.5465	-0.42503	0.22504
Car + Bike Hub fac.: Parcel Pick-up	β	0.12862		0.14821	0.87	0.3855	-0.16188	0.41911
Car PC Center: 3	β	0.40342	***	0.06083	6.63	0	0.28418	0.52265
Car PC Center: 5	β	-0.08956		0.06406	-1.4	0.1621	-0.21511	0.036
Car + Bus TT Bus: 6	β	0.1755		0.14896	1.18	0.2387	-0.11644	0.46745
Car + Bus TT Bus: 9	β	-0.05439		0.16045	-0.34	0.7346	-0.36886	0.26008
Car + Bus WT Bus: 2	β	0.30028	**	0.14611	2.06	0.0399	0.01391	0.58665
Car + Bus WT Bus: 6	β	0.02893		0.15336	0.19	0.8504	-0.27164	0.3295
Car + Bus TC Bus: 0	β	-0.035		0.15492	-0.23	0.8213	-0.33865	0.26864
Car + Bus TC Bus: 0.5	β	-0.14584		0.1684	-0.87	0.3865	-0.4759	0.18422
Car + Bike TT Bike: 5	β	0.4462	***	0.14221	3.14	0.0017	0.16747	0.72492
Car + Bike TT Bike: 10	β	-0.08905		0.16443	-0.54	0.5881	-0.41133	0.23323
Car + Bike TC Bike: 0	β	0.00948		0.15155	0.06	0.9501	-0.28755	0.30652
Car + Bike TC Bike: 0.5	β	0.00716		0.14989	0.05	0.9619	-0.28662	0.30095
PT + Bike TC Bike: 0	β	0.2673	**	0.1094	2.44	0.0145	0.05289	0.48172
PT + Bike TC Bike: 0.5	β	-0.05073		0.11507	-0.44	0.6593	-0.27627	0.17481

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

Tab. D.4.3 Gamma coefficients MNL distance categories (step 0)

Attributes		Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	γ	-1.17543	***	0.13132	-8.95	0	-1.43281	-0.91805
Constant Car + Bike	γ	-1.15351	***	0.14706	-7.84	0	-1.44174	-0.86527
Constant Public Transport + Walk	γ	-0.23857	***	0.05648	-4.22	0	-0.34927	-0.12787
Constant Public Transport + Bike	γ	-0.43481	***	0.08859	-4.91	0	-0.60844	-0.26118
Constant Bike	γ	0.21096	***	0.06419	3.29	0.001	0.08515	0.33676
Car + Bus TT Reduction car: -4	γ	-0.21336		0.16474	-1.3	0.1953	-0.53625	0.10953
Car + Bus TT Reduction car: -2	γ	-0.04385		0.16086	-0.27	0.7852	-0.35913	0.27144
Car + Bike TT Reduction car: -4	γ	-0.12524		0.16704	-0.75	0.4534	-0.45264	0.20215
Car + Bike TT Reduction car: -2	γ	0.18262		0.14869	1.23	0.2194	-0.1088	0.47404
Car + Bus PC Car at Hub: 0	γ	-0.08034		0.15231	-0.53	0.5979	-0.37885	0.21818
Car + Bus PC Car at Hub: 4	γ	0.09035		0.15531	0.58	0.5607	-0.21405	0.39474
Car + Bike PC Car at Hub: 0	γ	0.22832		0.1539	1.48	0.1379	-0.07333	0.52996
Car + Bike PC Car at Hub: 4	γ	-0.04409		0.19467	-0.23	0.8208	-0.42564	0.33745
Car + Bus Hub fac.: Coffee & Sandwich	γ	-0.01185		0.15168	-0.08	0.9377	-0.30914	0.28544
Car + Bus Hub fac.: Parcel Pick-up	γ	-0.1322		0.16854	-0.78	0.4328	-0.46252	0.19813
Car + Bike Hub fac.: Coffee & Sandwich	γ	-0.07923		0.16584	-0.48	0.6328	-0.40427	0.24581
Car + Bike Hub fac.: Parcel Pick-up	γ	0.07916		0.14821	0.53	0.5933	-0.21133	0.36965
Car PC Center: 3	γ	-0.16023	***	0.06083	-2.63	0.0084	-0.27947	-0.041
Car PC Center: 5	γ	0.00425		0.06406	0.07	0.9471	-0.1213	0.1298
Car + Bus TT Bus: 6	γ	-0.01844		0.14896	-0.12	0.9015	-0.31039	0.27351
Car + Bus TT Bus: 9	γ	-0.0737		0.16045	-0.46	0.646	-0.38817	0.24077
Car + Bus WT Bus: 2	γ	0.00286		0.14611	0.02	0.9844	-0.28351	0.28923
Car + Bus WT Bus: 6	γ	0.0647		0.15336	0.42	0.6731	-0.23587	0.36528
Car + Bus TC Bus: 0	γ	0.01563		0.15492	0.1	0.9197	-0.28802	0.31927
Car + Bus TC Bus: 0.5	γ	-0.16161		0.1684	-0.96	0.3372	-0.49167	0.16845
Car + Bike TT Bike: 5	γ	0.16176		0.14221	1.14	0.2554	-0.11697	0.44048
Car + Bike TT Bike: 10	γ	-0.15254		0.16443	-0.93	0.3536	-0.47482	0.16974
Car + Bike TC Bike: 0	γ	0.00585		0.15155	0.04	0.9692	-0.29119	0.30288
Car + Bike TC Bike: 0.5	γ	0.02163		0.14989	0.14	0.8853	-0.27215	0.31541
PT + Bike TC Bike: 0	γ	0.01146		0.1094	0.1	0.9166	-0.20295	0.22587
PT + Bike TC Bike: 0.5	γ	0.02606		0.11507	0.23	0.8209	-0.19948	0.2516

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

AIC	9943.6
LL (β)	-4909.80169
LL (0)	-5714.65293
ρ2	0.141
K	62

Tab. D.4.4 Beta coefficients MNL distance categories (step 12)

Attributes		Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	β	-1.3732	***	0.11732	-11.7	0	-1.60315	-1.14325
Constant Car + Bike	β	-1.53995	***	0.12276	-12.54	0	-1.78054	-1.29935
Constant Public Transport + Walk	β	0.01246		0.05629	0.22	0.8248	-0.09787	0.12279
Constant Public Transport + Bike	β	-1.19895	***	0.08786	-13.65	0	-1.37116	-1.02675
Constant Bike	β	0.45529	***	0.06413	7.1	0	0.3296	0.58098
Car + Bus TT Reduction car: -4	β	0.16186	**	0.07545	2.15	0.0319	0.01398	0.30974
Car + Bus TT Reduction car: -2	β	-0.01432		0.07659	-0.19	0.8516	-0.16444	0.13579
Car + Bike TT Reduction car: -4	β	0.01516		0.08382	0.18	0.8565	-0.14913	0.17945
Car + Bike TT Reduction car: -2	β	-0.08551		0.08421	-1.02	0.3099	-0.25057	0.07954
Car + Bus PC Car at Hub: 0	β	0.58034	***	0.07389	7.85	0	0.43551	0.72516
Car + Bus PC Car at Hub: 4	β	-0.01688		0.07711	-0.22	0.8267	-0.16801	0.13425
Car + Bike PC Car at Hub: 0	β	0.6943	***	0.07898	8.79	0	0.53951	0.8491
Car + Bike PC Car at Hub: 4	β	-0.27589	***	0.0888	-3.11	0.0019	-0.44994	-0.10184
Car + Bus Hub fac.: Coffee & Sandwich	β	0.11627		0.07524	1.55	0.1223	-0.03121	0.26374
Car + Bus Hub fac.: Parcel Pick-up	β	-0.09435		0.07804	-1.21	0.2266	-0.2473	0.0586
Car + Bike Hub fac.: Coffee & Sandwich	β	-0.04051		0.0842	-0.48	0.6305	-0.20554	0.12452
Car + Bike Hub fac.: Parcel Pick-up	β	0.06654		0.08207	0.81	0.4175	-0.09431	0.22739
Car PC Center: 3	β	0.40466	***	0.06067	6.67	0	0.28576	0.52356
Car PC Center: 5	β	-0.08947		0.06389	-1.4	0.1614	-0.2147	0.03576
Car + Bus TT Bus: 6	β	0.19284	***	0.07318	2.64	0.0084	0.04942	0.33626
Car + Bus TT Bus: 9	β	0.00271		0.0755	0.04	0.9714	-0.14527	0.15069
Car + Bus WT Bus: 2	β	0.3034	***	0.07202	4.21	0	0.16223	0.44457
Car + Bus WT Bus: 6	β	-0.02685		0.07526	-0.36	0.7212	-0.17435	0.12065
Car + Bus TC Bus: 0	β	-0.05035		0.07514	-0.67	0.5028	-0.19762	0.09691
Car + Bus TC Bus: 0.5	β	-0.01214		0.07464	-0.16	0.8708	-0.15844	0.13416
Car + Bike TT Bike: 5	β	0.32029	***	0.07817	4.1	0	0.16708	0.47349
Car + Bike TT Bike: 10	β	0.03543		0.08144	0.44	0.6635	-0.12419	0.19506
Car + Bike TC Bike: 0	β	0.00036		0.08088	0	0.9965	-0.15817	0.15889
Car + Bike TC Bike: 0.5	β	-0.00609		0.08114	-0.08	0.9402	-0.16513	0.15294
PT + Bike TC Bike: 0	β	0.25402	***	0.0849	2.99	0.0028	0.08761	0.42043
PT + Bike TC Bike: 0.5	β	-0.06622		0.09092	-0.73	0.4664	-0.24443	0.11198

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

Tab. D.4.5 Gamma coefficients MNL distance categories (step 12)

Attributes		Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	γ	-1.19101	***	0.11549	-10.31	0	-1.41736	-0.96465
Constant Car + Bike	γ	-1.12878	***	0.12041	-9.37	0	-1.36479	-0.89278
Constant Public Transport + Walk	γ	-0.23843	***	0.05629	-4.24	0	-0.34876	-0.1281
Constant Public Transport + Bike	γ	-0.43795	***	0.08732	-5.02	0	-0.6091	-0.26681
Constant Bike	γ	0.20809	***	0.06413	3.24	0.0012	0.0824	0.33378
Car PC Center: 3	γ	-0.15919	***	0.06064	-2.63	0.0087	-0.27805	-0.04033
Car PC Center: 5	γ	0.00371		0.06387	0.06	0.9537	-0.12148	0.1289

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

AIC	9919.3
LL (β)	-4921.66330
LL (0)	-5714.65293
ρ2	0.139
K	38

D.5 MNL model per age category

Tab. D.5.1 Effects MNL age categories

Attributes	Effects A1 ≤ 30	Effects 30 – 50	Effects > 50 years
Constant Car + Bus	-0.43031	-1.3279	-0.13881
Constant Car + Bike	-0.52407	-1.15477	-0.60134
Constant Public Transport + Walk	0.43569	-0.2568	0.23205
Constant Public Transport + Bike	-0.73152	-1.12263	-0.86127
Constant Bike	1.78613	0.55376	0.85016
Car + Bus TT Reduction car: -4	0.27964	-0.03392	0.19687
Car + Bus TT Reduction car: -2	-0.15163	-0.10365	0.08764
Car + Bus TT Reduction car: 0	-0.12801	0.13757	-0.28451
Car + Bike TT Reduction car: -4	0.12921	0.09457	-0.08578
Car + Bike TT Reduction car: -2	-0.00219	-0.11421	-0.12456
Car + Bike TT Reduction car: 0	-0.12702	0.01964	0.21034
Car + Bus PC Car at Hub: 0	0.77738	0.51022	0.45183
Car + Bus PC Car at Hub: 4	-0.1824	0.23331	-0.02811
Car + Bus PC Car at Hub: 8	-0.59498	-0.74353	-0.42372
Car + Bike PC Car at Hub: 0	0.97341	0.64871	0.46741
Car + Bike PC Car at Hub: 4	-0.43462	-0.16001	-0.20394
Car + Bike PC Car at Hub: 8	-0.53879	-0.4887	-0.26347
Car + Bus Hub fac.: Coffee & Sandwich	0.11315	0.13233	0.15871
Car + Bus Hub fac.: Parcel Pick-up	-0.30376	-0.09972	-0.04961
Car + Bus Hub fac.: None	0.19061	-0.03261	-0.1091
Car + Bike Hub fac.: Coffee & Sandwich	-0.05579	0.05228	-0.09555
Car + Bike Hub fac.: Parcel Pick-up	0.05733	0.0344	0.09391
Car + Bike Hub fac.: None	-0.00154	-0.08668	0.00164
Car PC Center: 3	0.71698	0.58712	0.30663
Car PC Center: 5	-0.10938	-0.2474	-0.01084
Car PC Center: 7	-0.6076	-0.33972	-0.29579
Car + Bus TT Bus: 6	0.27322	0.29678	0.13758
Car + Bus TT Bus: 9	-0.19053	0.20838	0.02886
Car + Bus TT Bus: 12	-0.08269	-0.50516	-0.16644
Car + Bus WT Bus: 2	0.33622	0.53758	0.18889
Car + Bus WT Bus: 6	0.00061	-0.28649	0.01021
Car + Bus WT Bus: 10	-0.33683	-0.25109	-0.1991
Car + Bus TC Bus: 0	0.26963	-0.05548	-0.2371
Car + Bus TC Bus: 0.5	-0.18598	-0.06496	0.13703
Car + Bus TC Bus: 1	-0.08365	0.12044	0.10007
Car + Bike TT Bike: 5	0.51407	0.46605	0.09484
Car + Bike TT Bike: 10	-0.15592	0.04079	0.1148
Car + Bike TT Bike: 15	-0.35815	-0.50684	-0.20964
Car + Bike TC Bike: 0	-0.296	0.17881	0.11594
Car + Bike TC Bike: 0.5	0.2242	-0.02822	-0.1475
Car + Bike TC Bike: 1	0.0718	-0.15059	0.03156
PT + Bike TC Bike: 0	0.55437	0.25838	0.04753
PT + Bike TC Bike: 0.5	-0.38336	0.09145	0.00712
PT + Bike TC Bike: 1	-0.17101	-0.34983	-0.05465

AIC	10166.7
LL (β)	-4990.36204
LL (0)	-5714.65293
ρ2	0.127
K	93

Tab. D.5.2 Beta coefficients MNL age categories

Attributes		Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	β	-0.63234	***	0.0731	-8.65	0	-0.77561	-0.48907
Constant Car + Bike	β	-0.76006	***	0.07337	-10.36	0	-0.90386	-0.61626
Constant Public Transport + Walk	β	0.13698	**	0.05448	2.51	0.0119	0.0302	0.24375
Constant Public Transport + Bike	β	-0.90514	***	0.07444	-12.16	0	-1.05104	-0.75923
Constant Bike	β	1.06335	***	0.06193	17.17	0	0.94197	1.18472
Car + Bus TT Reduction car: -4	β	0.14753	*	0.08161	1.81	0.0706	-0.01241	0.30748
Car + Bus TT Reduction car: -2	β	-0.05588		0.08334	-0.67	0.5026	-0.21923	0.10747
Car + Bike TT Reduction car: -4	β	0.046		0.0836	0.55	0.5821	-0.11784	0.20985
Car + Bike TT Reduction car: -2	β	-0.08032		0.08456	-0.95	0.3422	-0.24607	0.08542
Car + Bus PC Car at Hub: 0	β	0.57981	***	0.07841	7.39	0	0.42613	0.73349
Car + Bus PC Car at Hub: 4	β	0.0076		0.0836	0.09	0.9276	-0.15625	0.17145
Car + Bike PC Car at Hub: 0	β	0.69651	***	0.07915	8.8	0	0.54137	0.85164
Car + Bike PC Car at Hub: 4	β	-0.26619	***	0.09103	-2.92	0.0035	-0.44459	-0.08778
Car + Bus Hub fac.: Coffee & Sandwich	β	0.13473	*	0.07954	1.69	0.0903	-0.02117	0.29062
Car + Bus Hub fac.: Parcel Pick-up	β	-0.15103	*	0.08501	-1.78	0.0756	-0.31765	0.01559
Car + Bike Hub fac.: Coffee & Sandwich	β	-0.03302		0.08409	-0.39	0.6945	-0.19784	0.13179
Car + Bike Hub fac.: Parcel Pick-up	β	0.06188		0.08315	0.74	0.4567	-0.10108	0.22484
Car PC Center: 3	β	0.53691	***	0.06025	8.91	0	0.41882	0.655
Car PC Center: 5	β	-0.12254	*	0.06493	-1.89	0.0591	-0.24979	0.00471
Car + Bus TT Bus: 6	β	0.23586	***	0.07812	3.02	0.0025	0.08275	0.38897
Car + Bus TT Bus: 9	β	0.01557		0.08145	0.19	0.8484	-0.14407	0.1752
Car + Bus WT Bus: 2	β	0.35423	***	0.07613	4.65	0	0.20502	0.50344
Car + Bus WT Bus: 6	β	-0.09189		0.08379	-1.1	0.2728	-0.25612	0.07233
Car + Bus TC Bus: 0	β	-0.00765		0.07947	-0.1	0.9233	-0.16341	0.14811
Car + Bus TC Bus: 0.5	β	-0.03797		0.08042	-0.47	0.6368	-0.1956	0.11965
Car + Bike TT Bike: 5	β	0.35832	***	0.07912	4.53	0	0.20326	0.51339
Car + Bike TT Bike: 10	β	-0.00011		0.08384	0	0.999	-0.16442	0.16421
Car + Bike TC Bike: 0	β	-0.00757		0.08244	-0.09	0.9269	-0.16915	0.15402
Car + Bike TC Bike: 0.5	β	0.01616		0.08207	0.2	0.8439	-0.14469	0.17701
PT + Bike TC Bike: 0	β	0.28676	***	0.08616	3.33	0.0009	0.1179	0.45562
PT + Bike TC Bike: 0.5	β	-0.09493		0.09512	-1	0.3183	-0.28136	0.0915

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

Tab. D.5.3 Gamma coefficients MNL age categories

Attributes		Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	γ	0.20203	*	0.10826	1.87	0.062	-0.01015	0.41422
Constant Car + Bike	γ	0.23599	**	0.11077	2.13	0.0331	0.01888	0.4531
Constant Public Transport + Walk	γ	0.29871	***	0.08266	3.61	0.0003	0.13671	0.46071
Constant Public Transport + Bike	γ	0.17362		0.11374	1.53	0.1269	-0.04929	0.39654
Constant Bike	γ	0.72278	***	0.09412	7.68	0	0.53831	0.90725
Car + Bus TT Reduction car: -4	γ	0.13211		0.11712	1.13	0.2593	-0.09744	0.36167
Car + Bus TT Reduction car: -2	γ	-0.09575		0.12321	-0.78	0.4371	-0.33725	0.14574
Car + Bike TT Reduction car: -4	γ	0.08321		0.12149	0.68	0.4934	-0.15491	0.32133
Car + Bike TT Reduction car: -2	γ	0.07813		0.12289	0.64	0.5249	-0.16273	0.31899
Car + Bus PC Car at Hub: 0	γ	0.19757	*	0.11335	1.74	0.0813	-0.02459	0.41972
Car + Bus PC Car at Hub: 4	γ	-0.19		0.12402	-1.53	0.1255	-0.43307	0.05307
Car + Bike PC Car at Hub: 0	γ	0.2769	**	0.11554	2.4	0.0166	0.05044	0.50336
Car + Bike PC Car at Hub: 4	γ	-0.16843		0.13654	-1.23	0.2174	-0.43605	0.09919
Car + Bus Hub fac.: Coffee & Sandwich	γ	-0.02158		0.11682	-0.18	0.8534	-0.25055	0.20738
Car + Bus Hub fac.: Parcel Pick-up	γ	-0.15273		0.12705	-1.2	0.2293	-0.40174	0.09629
Car + Bike Hub fac.: Coffee & Sandwich	γ	-0.02277		0.12252	-0.19	0.8526	-0.26291	0.21737
Car + Bike Hub fac.: Parcel Pick-up	γ	-0.00455		0.12146	-0.04	0.9701	-0.24261	0.23352
Car PC Center: 3	γ	0.18007	*	0.0921	1.96	0.0506	-0.00045	0.36058
Car PC Center: 5	γ	0.01316		0.10068	0.13	0.896	-0.18418	0.2105
Car + Bus TT Bus: 6	γ	0.03736		0.1139	0.33	0.7429	-0.18589	0.2606
Car + Bus TT Bus: 9	γ	-0.2061	*	0.12077	-1.71	0.0879	-0.44279	0.0306
Car + Bus WT Bus: 2	γ	-0.01801		0.11159	-0.16	0.8718	-0.23673	0.20072
Car + Bus WT Bus: 6	γ	0.0925		0.119	0.78	0.437	-0.14075	0.32574
Car + Bus TC Bus: 0	γ	0.27728	**	0.11373	2.44	0.0148	0.05437	0.50019
Car + Bus TC Bus: 0.5	γ	-0.14801		0.11805	-1.25	0.2099	-0.37939	0.08337
Car + Bike TT Bike: 5	γ	0.15575		0.11412	1.36	0.1723	-0.06792	0.37941
Car + Bike TT Bike: 10	γ	-0.15581		0.1236	-1.26	0.2075	-0.39806	0.08645
Car + Bike TC Bike: 0	γ	0.00929		0.11986	0.08	0.9382	-0.22562	0.24421
Car + Bike TC Bike: 0.5	γ	0.20804	*	0.11719	1.78	0.0759	-0.02164	0.43772
PT + Bike TC Bike: 0	γ	0.26761	**	0.12645	2.12	0.0343	0.01978	0.51545
PT + Bike TC Bike: 0.5	γ	-0.28843	*	0.14802	-1.95	0.0514	-0.57854	0.00169

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

Tab. D.5.4 Delta coefficients MNL age categories

Attributes		Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	δ	-0.69556	***	0.1106	-6.29	0	-0.91234	-0.47878
Constant Car + Bike	δ	-0.39471	***	0.10508	-3.76	0.0002	-0.60067	-0.18875
Constant Public Transport + Walk	δ	-0.39378	***	0.0762	-5.17	0	-0.54313	-0.24444
Constant Public Transport + Bike	δ	-0.21749	**	0.10324	-2.11	0.0351	-0.41983	-0.01515
Constant Bike	δ	-0.50959	***	0.08187	-6.22	0	-0.67005	-0.34913
Car + Bus TT Reduction car: -4	δ	-0.18145		0.12699	-1.43	0.153	-0.43034	0.06744
Car + Bus TT Reduction car: -2	δ	-0.04777		0.12691	-0.38	0.7066	-0.29651	0.20097
Car + Bike TT Reduction car: -4	δ	0.04857		0.12107	0.4	0.6883	-0.18871	0.28586
Car + Bike TT Reduction car: -2	δ	-0.03389		0.12365	-0.27	0.784	-0.27625	0.20847
Car + Bus PC Car at Hub: 0	δ	-0.06959		0.12051	-0.58	0.5636	-0.30578	0.1666
Car + Bus PC Car at Hub: 4	δ	0.22571	*	0.12652	1.78	0.0744	-0.02226	0.47368
Car + Bike PC Car at Hub: 0	δ	-0.0478		0.11498	-0.42	0.6776	-0.27315	0.17756
Car + Bike PC Car at Hub: 4	δ	0.10618		0.13105	0.81	0.4178	-0.15067	0.36304
Car + Bus Hub fac.: Coffee & Sandwich	δ	-0.0024		0.12032	-0.02	0.9841	-0.23822	0.23342
Car + Bus Hub fac.: Parcel Pick-up	δ	0.05131		0.12829	0.4	0.6892	-0.20013	0.30274
Car + Bike Hub fac.: Coffee & Sandwich	δ	0.0853		0.12147	0.7	0.4825	-0.15278	0.32338
Car + Bike Hub fac.: Parcel Pick-up	δ	-0.02748		0.12253	-0.22	0.8226	-0.26762	0.21267
Car PC Center: 3	δ	0.05021		0.0821	0.61	0.5409	-0.11071	0.21112
Car PC Center: 5	δ	-0.12486		0.0882	-1.42	0.1569	-0.29774	0.04802
Car + Bus TT Bus: 6	δ	0.06092		0.11914	0.51	0.6091	-0.17259	0.29443
Car + Bus TT Bus: 9	δ	0.19281		0.12273	1.57	0.1162	-0.04775	0.43336
Car + Bus WT Bus: 2	δ	0.18335		0.11488	1.6	0.1105	-0.04181	0.40852
Car + Bus WT Bus: 6	δ	-0.1946		0.1326	-1.47	0.1422	-0.45449	0.0653
Car + Bus TC Bus: 0	δ	-0.04783		0.12249	-0.39	0.6961	-0.2879	0.19223
Car + Bus TC Bus: 0.5	δ	-0.02699		0.12239	-0.22	0.8255	-0.26687	0.2129
Car + Bike TT Bike: 5	δ	0.10773		0.11528	0.93	0.3501	-0.11822	0.33367
Car + Bike TT Bike: 10	δ	0.0409		0.12311	0.33	0.7397	-0.20039	0.2822
Car + Bike TC Bike: 0	δ	-0.1328		0.12159	-1.09	0.2748	-0.3711	0.10551
Car + Bike TC Bike: 0.5	δ	-0.04438		0.1214	-0.37	0.7147	-0.28231	0.19356
PT + Bike TC Bike: 0	δ	-0.02838		0.12199	-0.23	0.816	-0.26747	0.2107
PT + Bike TC Bike: 0.5	δ	0.18638		0.13047	1.43	0.1531	-0.06933	0.44209

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

APPENDIX E – Output ML model estimations

Tab. E.1 Output Random Parameter ML model

	Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Random parameters in utility functions							
Constant Car + Bus	-2.00286	***	0.38922	-5.15	0	-2.76572	-1.23999
Constant Car + Bike	-3.32113	***	0.42016	-7.9	0	-4.14463	-2.49764
Constant Public Transport + Walk	0.07669		0.24509	0.31	0.7544	-0.40369	0.55706
Constant Public Transport + Bike	-5.68554	***	0.69985	-8.12	0	-7.05721	-4.31387
Constant Bike	1.34723	**	0.52533	2.56	0.0103	0.31759	2.37686
Car + Bus TT Reduction car: -4	0.36043	**	0.15008	2.4	0.0163	0.06627	0.65459
Car + Bus TT Reduction car: -2	0.15589		0.15179	1.03	0.3044	-0.14161	0.45339
Car + Bus TT Reduction car: 0	-0.51632	-					
Car + Bike TT Reduction car: -4	0.15605		0.16601	0.94	0.3472	-0.16933	0.48143
Car + Bike TT Reduction car: -2	-0.17339		0.16538	-1.05	0.2944	-0.49754	0.15076
Car + Bike TT Reduction car: 0	0.01734	-					
Car + Bus PC Car at Hub: 0	1.61168	***	0.17566	9.17	0	1.26739	1.95598
Car + Bus PC Car at Hub: 4	0.05575		0.1625	0.34	0.7315	-0.26275	0.37425
Car + Bus PC Car at Hub: 8	-1.66743	-					
Car + Bike PC Car at Hub: 0	2.00787	***	0.19346	10.38	0	1.6287	2.38704
Car + Bike PC Car at Hub: 4	-0.30594	*	0.18136	-1.69	0.0916	-0.6614	0.04951
Car + Bike PC Car at Hub: 8	-1.70193	-					
Car PC Center: 3	1.3457	***	0.15133	8.89	0	1.0491	1.6423
Car PC Center: 5	-0.21215	*	0.12544	-1.69	0.0908	-0.458	0.0337
Car PC Center: 7	-1.13355	-					
Car + Bus TT Bus: 6	0.7742	***	0.14446	5.36	0	0.49108	1.05733
Car + Bus TT Bus: 9	-0.13272		0.14339	-0.93	0.3546	-0.41375	0.14831
Car + Bus TT Bus: 12	-0.64148	-					
Car + Bus WT Bus: 2	0.74053	***	0.1442	5.14	0	0.4579	1.02317
Car + Bus WT Bus: 6	-0.17913		0.14691	-1.22	0.2227	-0.46706	0.1088
Car + Bus WT Bus: 10	-0.5614	-					
Car + Bike TT Bike: 5	0.80587	***	0.18969	4.25	0	0.43409	1.17766
Car + Bike TT Bike: 10	0.1169		0.16427	0.71	0.4767	-0.20506	0.43887
Car + Bike TT Bike: 15	-0.92277	-					
PT + Bike TC Bike: 0	0.77088	***	0.18932	4.07	0	0.39982	1.14194
PT + Bike TC Bike: 0.5	-0.15938		0.19998	-0.8	0.4255	-0.55133	0.23257
PT + Bike TC Bike: 1	-0.6115	-					
Nonrandom parameters in utility functions							
Car + Bus Hub fac.: Coffee & Sandwich	0.04758		0.14213	0.33	0.7378	-0.23098	0.32614
Car + Bus Hub fac.: Parcel Pick-up	0.07525		0.14849	0.51	0.6123	-0.21578	0.36629
Car + Bus Hub fac.: None	-0.12283	-					
Car + Bike Hub fac.: Coffee & Sandwich	-0.05887		0.16306	-0.36	0.7181	-0.37847	0.26072
Car + Bike Hub fac.: Parcel Pick-up	0.20081		0.15642	1.28	0.1992	-0.10577	0.50739
Car + Bike Hub fac.: None	-0.14194	-					
Car + Bus TC Bus: 0	-0.18883		0.14278	-1.32	0.186	-0.46867	0.091
Car + Bus TC Bus: 0.5	0.0172		0.14051	0.12	0.9025	-0.25819	0.2926
Car + Bus TC Bus: 1	0.17163	-					
Car + Bike TC Bike: 0	-0.02921		0.15729	-0.19	0.8526	-0.33749	0.27906
Car + Bike TC Bike: 0.5	-0.02677		0.1567	-0.17	0.8643	-0.3339	0.28036
Car + Bike TC Bike: 1	0.05598	-					

Distns. Of PRs. Std.Devs or limits of triangular

Constant Car + Bus	3.93268	***	0.28289	13.9	0	3.37823	4.48713
Constant Car + Bike	4.49085	***	0.34421	13.05	0	3.81622	5.16549
Constant Public Transport + Walk	6.09501	***	0.404	15.09	0	5.30319	6.88683
Constant Public Transport + Bike	6.58687	***	0.67322	9.78	0	5.26739	7.90636
Constant Bike	11.2054	***	0.92381	12.13	0	9.3948	13.016
Car + Bus TT Reduction car: -4	0.4689	**	0.19559	2.4	0.0165	0.08555	0.85226
Car + Bus TT Reduction car: -2	0.44561	*	0.23116	1.93	0.0539	-0.00746	0.89868
Car + Bike TT Reduction car: -4	0.18064		0.21302	0.85	0.3964	-0.23686	0.59815
Car + Bike TT Reduction car: -2	0.33029		0.29175	1.13	0.2576	-0.24152	0.90211
Car + Bus PC Car at Hub: 0	1.10131	***	0.24459	4.5	0	0.62192	1.5807
Car + Bus PC Car at Hub: 4	0.74889	***	0.18736	4	0.0001	0.38168	1.11611
Car + Bike PC Car at Hub: 0	1.31924	***	0.26726	4.94	0	0.79543	1.84306
Car + Bike PC Car at Hub: 4	0.10187		0.31858	0.32	0.7492	-0.52253	0.72626
Car PC Center: 3	1.45569	***	0.19744	7.37	0	1.06871	1.84267
Car PC Center: 5	0.13424		0.23838	0.56	0.5734	-0.33298	0.60145
Car + Bus TT Bus: 6	0.12186		0.35831	0.34	0.7338	-0.58043	0.82414
Car + Bus TT Bus: 9	0.02128		0.21713	0.1	0.9219	-0.4043	0.44685
Car + Bus WT Bus: 2	0.49504	**	0.21834	2.27	0.0234	0.06709	0.92299
Car + Bus WT Bus: 6	0.32332		0.24401	1.33	0.1852	-0.15493	0.80157
Car + Bike TT Bike: 5	1.19055	***	0.2048	5.81	0	0.78915	1.59194
Car + Bike TT Bike: 10	0.54461	**	0.25517	2.13	0.0328	0.04449	1.04473
PT + Bike TC Bike: 0	0.57535	***	0.19641	2.93	0.0034	0.19039	0.96031
PT + Bike TC Bike: 0.5	0.85174	***	0.26798	3.18	0.0015	0.3265	1.37698

Note: ***, **, * ==> Significance at 1%, 5%, 10% level.

AIC	5446.6
LL (β)	-2669.27801
LL (0)	-5714.65293
ρ2	0.556
K	54

Tab. E.2 Output Error Component ML model

	Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Random parameters in utility functions							
Car component	0	.....(Fixed Parameter).....					
Public transport component	0	.....(Fixed Parameter).....					
Bike component	0	.....(Fixed Parameter).....					
Nonrandom parameters in utility functions							
Constant Car + Bus	-2.48485	***	0.31196	-7.97	0	-3.09627	-1.87343
Constant Car + Bike	-3.90056	***	0.38269	-10.19	0	-4.65062	-3.15051
Constant Public Transport + Walk	-1.42229	***	0.37423	-3.8	0.0001	-2.15576	-0.68882
Constant Public Transport + Bike	-4.53486	***	0.49767	-9.11	0	-5.51029	-3.55944
Constant Bike	0.73427	***	0.06723	10.92	0	0.6025	0.86604
Car + Bus TT Reduction car: -4	0.35071	***	0.12007	2.92	0.0035	0.11538	0.58603
Car + Bus TT Reduction car: -2	0.10384		0.11977	0.87	0.386	-0.13091	0.33859
Car + Bus TT Reduction car: 0	-0.45455	-					
Car + Bike TT Reduction car: -4	0.11169		0.134	0.83	0.4046	-0.15095	0.37433
Car + Bike TT Reduction car: -2	-0.03717		0.13508	-0.28	0.7832	-0.30192	0.22757
Car + Bike TT Reduction car: 0	-0.07452	-					
Car + Bus PC Car at Hub: 0	1.36313	***	0.12398	10.99	0	1.12014	1.60612
Car + Bus PC Car at Hub: 4	-0.01196		0.12081	-0.1	0.9211	-0.24875	0.22483
Car + Bus PC Car at Hub: 8	-1.35117	-					
Car + Bike PC Car at Hub: 0	1.62442	***	0.13737	11.82	0	1.35517	1.89366
Car + Bike PC Car at Hub: 4	-0.36279	***	0.14028	-2.59	0.0097	-0.63775	-0.08784
Car + Bike PC Car at Hub: 8	-1.26163	-					
Car + Bus Hub fac.: Coffee & Sandwich	0.00511		0.1188	0.04	0.9657	-0.22773	0.23795
Car + Bus Hub fac.: Parcel Pick-up	0.08081		0.12036	0.67	0.502	-0.1551	0.31672
Car + Bus Hub fac.: None	-0.08592	-					
Car + Bike Hub fac.: Coffee & Sandwich	-0.08509		0.13408	-0.63	0.5257	-0.34789	0.17771
Car + Bike Hub fac.: Parcel Pick-up	0.10624		0.13064	0.81	0.4161	-0.14982	0.36229
Car + Bike Hub fac.: None	-0.02115	-					
Car PC Center: 3	0.7385	***	0.07358	10.04	0	0.59429	0.8827
Car PC Center: 5	-0.15575	**	0.07794	-2	0.0457	-0.30851	-0.00298
Car PC Center: 7	-0.58275	-					
Car + Bus TT Bus: 6	0.53031	***	0.11031	4.81	0	0.3141	0.74652
Car + Bus TT Bus: 9	-0.02216		0.1147	-0.19	0.8468	-0.24697	0.20264
Car + Bus TT Bus: 12	-0.50815	-					
Car + Bus WT Bus: 2	0.66615	***	0.11127	5.99	0	0.44807	0.88423
Car + Bus WT Bus: 6	-0.13899		0.11328	-1.23	0.2198	-0.36102	0.08303
Car + Bus WT Bus: 10	-0.52716	-					
Car + Bus TC Bus: 0	-0.12806		0.11285	-1.13	0.2565	-0.34925	0.09312
Car + Bus TC Bus: 0.5	0.03989		0.11224	0.36	0.7223	-0.18009	0.25987
Car + Bus TC Bus: 1	0.08817	-					
Car + Bike TT Bike: 5	0.69825	***	0.12456	5.61	0	0.45412	0.94237
Car + Bike TT Bike: 10	0.069		0.12724	0.54	0.5876	-0.18039	0.31839
Car + Bike TT Bike: 15	-0.76725	-					
Car + Bike TC Bike: 0	-0.01466		0.12596	-0.12	0.9073	-0.26155	0.23222
Car + Bike TC Bike: 0.5	-0.00557		0.12425	-0.04	0.9642	-0.24909	0.23794
Car + Bike TC Bike: 1	0.02023	-					
PT + Bike TC Bike: 0	0.59787	***	0.13608	4.39	0	0.33115	0.86459
PT + Bike TC Bike: 0.5	-0.18576		0.14178	-1.31	0.1901	-0.46365	0.09213
PT + Bike TC Bike: 1	-0.41211	-					

Distns. Of PRs. Std.Devs or limits of triangular

Car component (Car+Bus & Car+Bike)	4.13327	***	0.2999	13.78	0	3.54548	4.72106
Public transport component (PT+Walk & PT+ Bike)	6.21599	***	0.46524	13.36	0	5.30413	7.12784
Bike component (Car+Bike & PT+Bike)	3.61986	***	0.27829	13.01	0	3.07441	4.1653

Note: ***, **, * ==> Significance at 1%, 5%, 10% level.

AIC	6507.7
LL (β)	-3219.86625
LL (0)	-5714.65293
ρ2	0.465
K	34

Tab. E.3 Output Random Parameter + Error Component model

	Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Random parameters in utility functions							
Car component	0	.....(Fixed Parameter).....					
Public transport component	0	.....(Fixed Parameter).....					
Bike component	0	.....(Fixed Parameter).....					
Constant Car + Bus	-1.06201	***	0.30058	-3.53	0.0004	-1.65114	-0.47288
Constant Car + Bike	-2.13361	***	0.33715	-6.33	0	-2.79441	-1.4728
Constant Public Transport + Walk	-0.90171	***	0.31144	-2.9	0.0038	-1.51212	-0.29131
Constant Public Transport + Bike	-3.50375	***	0.39536	-8.86	0	-4.27863	-2.72886
Constant Bike	2.1146	***	0.54409	3.89	0.0001	1.0482	3.18099
Car + Bus PC Car at Hub: 0	1.68043	***	0.15644	10.74	0	1.37381	1.98704
Car + Bus PC Car at Hub: 4	-0.01658		0.14094	-0.12	0.9064	-0.29281	0.25965
Car + Bus PC Car at Hub: 8	-1.66385		-				
Car + Bike PC Car at Hub: 0	2.04951	***	0.19719	10.39	0	1.66303	2.43599
Car + Bike PC Car at Hub: 4	-0.4355	***	0.16833	-2.59	0.0097	-0.76543	-0.10558
Car + Bike PC Car at Hub: 8	-1.61401		-				
Car PC Center: 3	1.44103	***	0.15921	9.05	0	1.12899	1.75308
Car PC Center: 5	-0.14718		0.15222	-0.97	0.3336	-0.44553	0.15116
Car PC Center: 7	-1.29385		-				
Car + Bus TT Bus: 6	0.67704	***	0.13971	4.85	0	0.40321	0.95087
Car + Bus TT Bus: 9	-0.05771		0.13619	-0.42	0.6718	-0.32463	0.20922
Car + Bus TT Bus: 12	-0.61933		-				
Car + Bus WT Bus: 2	0.70439	***	0.13844	5.09	0	0.43306	0.97573
Car + Bus WT Bus: 6	-0.15344		0.13814	-1.11	0.2667	-0.42418	0.1173
Car + Bus WT Bus: 10	-0.55095		-				
Car + Bike TT Bike: 5	0.82341	***	0.17468	4.71	0	0.48105	1.16577
Car + Bike TT Bike: 10	0.12019		0.15985	0.75	0.4521	-0.19311	0.4335
Car + Bike TT Bike: 15	-0.9436		-				
PT + Bike TC Bike: 0	0.53887	**	0.21095	2.55	0.0106	0.12541	0.95232
PT + Bike TC Bike: 0.5	-0.11234		0.17867	-0.63	0.5295	-0.46253	0.23784
PT + Bike TC Bike: 1	-0.42653		-				
Nonrandom parameters in utility functions							
Car + Bus TT Reduction car: -4	0.40223	***	0.14049	2.86	0.0042	0.12686	0.67759
Car + Bus TT Reduction car: -2	0.1069		0.145	0.74	0.461	-0.1773	0.3911
Car + Bus TT Reduction car: 0	-0.50913		-				
Car + Bike TT Reduction car: -4	0.11205		0.15909	0.7	0.4813	-0.19976	0.42386
Car + Bike TT Reduction car: -2	-0.08347		0.15814	-0.53	0.5976	-0.39343	0.22649
Car + Bike TT Reduction car: 0	-0.02858		-				
Car + Bus Hub fac.: Coffee & Sandwich	0.03402		0.14196	0.24	0.8106	-0.24423	0.31226
Car + Bus Hub fac.: Parcel Pick-up	0.10811		0.13968	0.77	0.439	-0.16566	0.38188
Car + Bus Hub fac.: None	-0.14213		-				
Car + Bike Hub fac.: Coffee & Sandwich	-0.0918		0.16015	-0.57	0.5665	-0.40568	0.22208
Car + Bike Hub fac.: Parcel Pick-up	0.16297		0.15488	1.05	0.2927	-0.14059	0.46654
Car + Bike Hub fac.: None	-0.07117		-				
Car + Bus TC Bus: 0	-0.17469		0.1318	-1.33	0.185	-0.43302	0.08363
Car + Bus TC Bus: 0.5	0.02019		0.13898	0.15	0.8845	-0.25221	0.29259
Car + Bus TC Bus: 1	0.1545		-				
Car + Bike TC Bike: 0	-0.01764		0.14981	-0.12	0.9063	-0.31125	0.27598
Car + Bike TC Bike: 0.5	-0.00183		0.1459	-0.01	0.99	-0.28779	0.28412
Car + Bike TC Bike: 1	0.01947		-				

Distns. Of PRs. Std.Devs or limits of triangular							
Car component (Car+Bus & Car+Bike)	4.26475	***	0.33207	12.84	0	3.61391	4.91559
Public transport component (PT+Walk & PT+ Bike)	5.96749	***	0.39504	15.11	0	5.19322	6.74175
Bike component (Car+Bike & PT+Bike)	3.91081	***	0.51044	7.66	0	2.91036	4.91125
Constant Car + Bus	0.97735	***	0.34217	2.86	0.0043	0.30671	1.64799
Constant Car + Bike	0.42454		0.32646	1.3	0.1935	-0.21531	1.0644
Constant Public Transport + Walk	4.06979	***	0.31318	13	0	3.45597	4.6836
Constant Public Transport + Bike	0.28725		0.27118	1.06	0.2895	-0.24426	0.81876
Constant Bike	10.9945	***	1.01702	10.81	0	9.0011	12.9878
Car + Bus PC Car at Hub: 0	0.58388	**	0.28766	2.03	0.0424	0.02008	1.14768
Car + Bus PC Car at Hub: 4	0.20448		0.27868	0.73	0.4631	-0.34173	0.75069
Car + Bike PC Car at Hub: 0	0.92741	***	0.22471	4.13	0	0.48698	1.36784
Car + Bike PC Car at Hub: 4	0.02331		0.38996	0.06	0.9523	-0.74099	0.78761
Car PC Center: 3	1.57513	***	0.20874	7.55	0	1.166	1.98426
Car PC Center: 5	0.60912	*	0.3243	1.88	0.0603	-0.02649	1.24473
Car + Bus TT Bus: 6	0.22446		0.4694	0.48	0.6325	-0.69555	1.14446
Car + Bus TT Bus: 9	0.24202		0.18998	1.27	0.2027	-0.13034	0.61438
Car + Bus WT Bus: 2	0.67807	***	0.2125	3.19	0.0014	0.26158	1.09455
Car + Bus WT Bus: 6	0.45617	*	0.267	1.71	0.0875	-0.06714	0.97949
Car + Bike TT Bike: 5	0.89947	***	0.26969	3.34	0.0009	0.37088	1.42807
Car + Bike TT Bike: 10	0.43485		0.26998	1.61	0.1073	-0.09431	0.964
PT + Bike TC Bike: 0	1.08643	***	0.21186	5.13	0	0.6712	1.50167
PT + Bike TC Bike: 0.5	0.60453	*	0.34092	1.77	0.0762	-0.06365	1.27271

Note: ***, **, * ==> Significance at 1%, 5%, 10% level.

AIC	5331.8
LL (β)	-2612.91110
LL (0)	-5714.65293
ρ2	0.566
K	53

Table E.4 Comparing General MNL model, and mean parameters of Random Parameter (RP), Error Component (EC), and Random Parameter + Error Component (RP + EC) ML model

	General MNL model		RP ML model		EC ML model		RP + EC model	
Attributes	Coefficient	Sign.	Coefficient	Sign.	Coefficient	Sign.	Coefficient	Sign.
Constant Car + Bus	-0.50088	***	-2.00286	***	-2.48485	***	-1.06201	***
Constant Car + Bike	-0.73076	***	-3.32113	***	-3.90056	***	-2.13361	***
Constant PT + Walk	0.11877	**	0.07669		-1.42229	***	-0.90171	***
Constant PT + Bike	-0.91088	***	-5.68554	***	-4.53486	***	-3.50375	***
Constant Bike	1.00024	***	1.34723	**	0.73427	***	2.1146	***
Car + Bus TT Reduction car: -4	0.15493	**	0.36043	**	0.35071	***	0.40223	***
Car + Bus TT Reduction car: -2	-0.00314		0.15589		0.10384		0.1069	
Car + Bus TT Reduction car: 0	-0.15179	-	-0.51632	-	-0.45455	-	-0.50913	
Car + Bike TT Reduction car: -4	0.01233		0.15605		0.11169		0.11205	
Car + Bike TT Reduction car: -2	-0.07911		-0.17339		-0.03717		-0.08347	
Car + Bike TT Reduction car: 0	0.06678	-	0.01734	-	-0.07452	-	-0.02858	
Car + Bus PC Car at Hub: 0	0.53494	***	1.61168	***	1.36313	***	1.68043	***
Car + Bus PC Car at Hub: 4	-0.00238		0.05575		-0.01196		-0.01658	
Car + Bus PC Car at Hub: 8	-0.53256	-	-1.66743	-	-1.35117	-	-1.66385	
Car + Bike PC Car at Hub: 0	0.65338	***	2.00787	***	1.62442	***	2.04951	***
Car + Bike PC Car at Hub: 4	-0.26586	***	-0.30594	*	-0.36279	***	-0.4355	***
Car + Bike PC Car at Hub: 8	-0.38752	-	-1.70193	-	-1.26163	-	-1.61401	
Car + Bus Hub fac.: Coffee	0.12071	*	0.04758		0.00511		0.03402	
Car + Bus Hub fac.: Parcel	-0.09266		0.07525		0.08081		0.10811	
Car + Bus Hub fac.: None	-0.02805	-	-0.12283	-	-0.08592	-	-0.14213	
Car + Bike Hub fac.: Coffee	-0.03918		-0.05887		-0.08509		-0.0918	
Car + Bike Hub fac.: Parcel	0.06243		0.20081		0.10624		0.16297	
Car + Bike Hub fac.: None	-0.02325	-	-0.14194	-	-0.02115	-	-0.07117	
Car PC Center: 3	0.50649	***	1.3457	***	0.7385	***	1.44103	***
Car PC Center: 5	-0.11661	*	-0.21215	*	-0.15575	**	-0.14718	
Car PC Center: 7	-0.38988	-	-1.13355	-	-0.58275	-	-1.29385	
Car + Bus TT Bus: 6	0.19796	***	0.7742	***	0.53031	***	0.67704	***
Car + Bus TT Bus: 9	0.0013		-0.13272		-0.02216		-0.05771	
Car + Bus TT Bus: 12	-0.19926	-	-0.64148	-	-0.50815	-	-0.61933	
Car + Bus WT Bus: 2	0.28466	***	0.74053	***	0.66615	***	0.70439	***
Car + Bus WT Bus: 6	-0.03324		-0.17913		-0.13899		-0.15344	
Car + Bus WT Bus: 10	-0.25142	-	-0.5614	-	-0.52716	-	-0.55095	
Car + Bus TC Bus: 0	-0.05029		-0.18883		-0.12806		-0.17469	
Car + Bus TC Bus: 0.5	-0.01095		0.0172		0.03989		0.02019	
Car + Bus TC Bus: 1	0.06124	-	0.17163	-	0.08817	-	0.1545	
Car + Bike TT Bike: 5	0.30949	***	0.80587	***	0.69825	***	0.82341	***
Car + Bike TT Bike: 10	0.02084		0.1169		0.069		0.12019	
Car + Bike TT Bike: 15	-0.33033	-	-0.92277	-	-0.76725	-	-0.9436	
Car + Bike TC Bike: 0	0.00935		-0.02921		-0.01466		-0.01764	
Car + Bike TC Bike: 0.5	-0.0057		-0.02677		-0.00557		-0.00183	
Car + Bike TC Bike: 1	-0.00365	-	0.05598	-	0.02023	-	0.01947	
PT + Bike TC Bike: 0	0.25361	***	0.77088	***	0.59787	***	0.53887	**
PT + Bike TC Bike: 0.5	-0.06377		-0.15938		-0.18576		-0.11234	
PT + Bike TC Bike: 1	-0.18984	-	-0.6115	-	-0.41211	-	-0.42653	

Note, std. dev. not provided in overview, see Tables E.1, E.2, and E.3 for the RP, EC, and RP + EC ML model respectively.

	MNL model	RP ML model	EC ML model	RP+EC ML model
AIC	10238.7	5446.6	6507.7	5331.8
LL (β)	-5088.33494	-2669.27801	-3219.86625	-2612.91110
LL (0)	-5714.65293	-5714.65293	-5714.65293	-5714.65293
ρ2	0.110	0.556	0.465	0.566
K	31	54	34	53

APPENDIX F – Output LC models

F.1. Output General LC model

Tab. F.1.1 Coefficients classes general LC model

Attributes	Coefficient Class1	Coefficient Class2	Coefficient Class3
Constant Car + Bus	0.25812	-0.59042	-0.05335
Constant Car + Bike	-4.39673	-0.9146	0.56189
Constant Public Transport + Walk	2.72821	-2.49652	2.57114
Constant Public Transport + Bike	-4.21888	-9.56952	2.25698
Constant Bike	5.79242	-1.61484	0.02666
Car + Bus TT Reduction car: -4	-0.03586	0.14228	0.41029
Car + Bus TT Reduction car: -2	-0.09714	0.09371	-0.01754
Car + Bus TT Reduction car: 0	0.133	-0.23599	-0.39275
Car + Bike TT Reduction car: -4	-0.49112	-0.06936	0.37323
Car + Bike TT Reduction car: -2	0.41009	-0.01357	-0.10781
Car + Bike TT Reduction car: 0	0.08103	0.08293	-0.26542
Car + Bus PC Car at Hub: 0	1.56772	0.36756	1.03389
Car + Bus PC Car at Hub: 4	0.18367	0.05138	-0.17616
Car + Bus PC Car at Hub: 8	-1.75139	-0.41894	-0.85773
Car + Bike PC Car at Hub: 0	5.35644	0.39814	1.36832
Car + Bike PC Car at Hub: 4	3.15483	-0.20476	-0.27745
Car + Bike PC Car at Hub: 8	-8.51127	-0.19338	-1.09087
Car + Bus Hub fac.: Coffee & Sandwich	0.05181	0.16671	0.11552
Car + Bus Hub fac.: Parcel Pick-up	-0.44807	-0.07251	0.0351
Car + Bus Hub fac.: None	0.39626	-0.0942	-0.15062
Car + Bike Hub fac.: Coffee & Sandwich	0.58029	0.01339	-0.27259
Car + Bike Hub fac.: Parcel Pick-up	-0.16541	0.03281	0.30715
Car + Bike Hub fac.: None	-0.41488	-0.0462	-0.03456
Car PC Center: 3	1.8334	0.4168	1.4481
Car PC Center: 5	-0.29544	-0.08888	-0.94969
Car PC Center: 7	-1.53796	-0.32792	-0.49841
Car + Bus TT Bus: 6	0.3724	0.28803	0.04255
Car + Bus TT Bus: 9	-0.22434	-0.02933	0.30227
Car + Bus TT Bus: 12	-0.14806	-0.2587	-0.34482
Car + Bus WT Bus: 2	0.34837	0.22608	0.87364
Car + Bus WT Bus: 6	-0.01737	-0.03404	-0.06651
Car + Bus WT Bus: 10	-0.331	-0.19204	-0.80713
Car + Bus TC Bus: 0	0.03705	-0.01043	-0.18165
Car + Bus TC Bus: 0.5	-0.31982	0.03418	0.11973
Car + Bus TC Bus: 1	0.28277	-0.02375	0.06192
Car + Bike TT Bike: 5	0.30016	0.25823	0.60495
Car + Bike TT Bike: 10	-0.22904	0.20887	-0.47775
Car + Bike TT Bike: 15	-0.07112	-0.4671	-0.1272
Car + Bike TC Bike: 0	0.12166	-0.05216	0.25068
Car + Bike TC Bike: 0.5	0.19801	-0.07924	-0.00856
Car + Bike TC Bike: 1	-0.31967	0.1314	-0.24212
PT + Bike TC Bike: 0	-5.2644	-0.88408	0.36795
PT + Bike TC Bike: 0.5	2.61106	4.93356	-0.17393
PT + Bike TC Bike: 1	2.65334	-4.04948	-0.19402

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

AIC	7350.1
LL (β)	-3580.04568
LL (0)	-5714.65293
ρ2	0.405
K	95

Tab. F.1.2 Output Class 1 General LC model

Attributes	Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	0.25812		0.40748	0.63	0.5264	-0.54052	1.05676
Constant Car + Bike	-4.39673		63.23962	-0.07	0.9446	-128.344	119.5506
Constant Public Transport + Walk	2.72821	***	0.3023	9.02	0	2.13571	3.32071
Constant Public Transport + Bike	-4.21888		40.68817	-0.1	0.9174	-83.9662	75.52847
Constant Bike	5.79242	***	0.34271	16.9	0	5.12071	6.46412
Car + Bus TT Reduction car: -4	-0.03586		0.25224	-0.14	0.8869	-0.53024	0.45852
Car + Bus TT Reduction car: -2	-0.09714		0.23518	-0.41	0.6796	-0.55808	0.3638
Car + Bike TT Reduction car: -4	-0.49112		0.59062	-0.83	0.4057	-1.6487	0.66647
Car + Bike TT Reduction car: -2	0.41009		0.51024	0.8	0.4216	-0.58996	1.41014
Car + Bus PC Car at Hub: 0	1.56772	***	0.30524	5.14	0	0.96946	2.16598
Car + Bus PC Car at Hub: 4	0.18367		0.31179	0.59	0.5558	-0.42743	0.79477
Car + Bike PC Car at Hub: 0	5.35644		63.23805	0.08	0.9325	-118.588	129.3007
Car + Bike PC Car at Hub: 4	3.15483		63.23886	0.05	0.9602	-120.791	127.1007
Car + Bus Hub fac.: Coffee & Sandwich	0.05181		0.22815	0.23	0.8203	-0.39536	0.49898
Car + Bus Hub fac.: Parcel Pick-up	-0.44807	*	0.26747	-1.68	0.0939	-0.9723	0.07615
Car + Bike Hub fac.: Coffee & Sandwich	0.58029		0.52373	1.11	0.2679	-0.44621	1.60678
Car + Bike Hub fac.: Parcel Pick-up	-0.16541		0.39918	-0.41	0.6786	-0.94778	0.61697
Car PC Center: 3	1.8334	***	0.31249	5.87	0	1.22092	2.44588
Car PC Center: 5	-0.29544		0.38499	-0.77	0.4428	-1.05001	0.45913
Car + Bus TT Bus: 6	0.3724		0.22953	1.62	0.1047	-0.07748	0.82227
Car + Bus TT Bus: 9	-0.22434		0.26	-0.86	0.3882	-0.73393	0.28524
Car + Bus WT Bus: 2	0.34837	*	0.20792	1.68	0.0938	-0.05914	0.75588
Car + Bus WT Bus: 6	-0.01737		0.21778	-0.08	0.9364	-0.44422	0.40948
Car + Bus TC Bus: 0	0.03705		0.21797	0.17	0.865	-0.39016	0.46426
Car + Bus TC Bus: 0.5	-0.31982		0.22594	-1.42	0.1569	-0.76264	0.12301
Car + Bike TT Bike: 5	0.30016		0.33308	0.9	0.3675	-0.35267	0.95299
Car + Bike TT Bike: 10	-0.22904		0.38825	-0.59	0.5553	-0.99	0.53193
Car + Bike TC Bike: 0	0.12166		0.33835	0.36	0.7192	-0.5415	0.78481
Car + Bike TC Bike: 0.5	0.19801		0.35962	0.55	0.5819	-0.50684	0.90285
PT + Bike TC Bike: 0	-5.2644		81.36907	-0.06	0.9484	-164.745	154.2161
PT + Bike TC Bike: 0.5	2.61106		40.69177	0.06	0.9488	-77.1434	82.36546

Tab. F.1.3 Output Class 2 General LC model

Attributes	Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	-0.59042	***	0.09787	-6.03	0	-0.78224	-0.3986
Constant Car + Bike	-0.9146	***	0.10868	-8.42	0	-1.1276	-0.7016
Constant Public Transport + Walk	-2.49652	***	0.16002	-15.6	0	-2.81015	-2.18289
Constant Public Transport + Bike	-9.56952		21.56652	-0.44	0.6572	-51.8391	32.70008
Constant Bike	-1.61484	***	0.1901	-8.49	0	-1.98743	-1.24225
Car + Bus TT Reduction car: -4	0.14228		0.09232	1.54	0.1233	-0.03867	0.32323
Car + Bus TT Reduction car: -2	0.09371		0.09481	0.99	0.323	-0.09212	0.27954
Car + Bike TT Reduction car: -4	-0.06936		0.1061	-0.65	0.5133	-0.27732	0.13859
Car + Bike TT Reduction car: -2	-0.01357		0.10636	-0.13	0.8985	-0.22203	0.19489
Car + Bus PC Car at Hub: 0	0.36756	***	0.09258	3.97	0.0001	0.1861	0.54902
Car + Bus PC Car at Hub: 4	0.05138		0.09382	0.55	0.5839	-0.13251	0.23527
Car + Bike PC Car at Hub: 0	0.39814	***	0.10138	3.93	0.0001	0.19944	0.59683
Car + Bike PC Car at Hub: 4	-0.20476	*	0.10856	-1.89	0.0593	-0.41753	0.00801
Car + Bus Hub fac.: Coffee & Sandwich	0.16671	*	0.09275	1.8	0.0723	-0.01508	0.34851
Car + Bus Hub fac.: Parcel Pick-up	-0.07251		0.09569	-0.76	0.4486	-0.26006	0.11505
Car + Bike Hub fac.: Coffee & Sandwich	0.01339		0.10464	0.13	0.8982	-0.19169	0.21848
Car + Bike Hub fac.: Parcel Pick-up	0.03281		0.10387	0.32	0.7521	-0.17078	0.23639
Car PC Center: 3	0.4168	***	0.0811	5.14	0	0.25786	0.57575
Car PC Center: 5	-0.08888		0.07961	-1.12	0.2642	-0.24492	0.06716
Car + Bus TT Bus: 6	0.28803	***	0.08789	3.28	0.001	0.11577	0.46029
Car + Bus TT Bus: 9	-0.02933		0.09029	-0.32	0.7453	-0.2063	0.14764
Car + Bus WT Bus: 2	0.22608	**	0.08782	2.57	0.01	0.05396	0.3982
Car + Bus WT Bus: 6	-0.03404		0.08963	-0.38	0.7041	-0.2097	0.14162
Car + Bus TC Bus: 0	-0.01043		0.09062	-0.12	0.9084	-0.18804	0.16718
Car + Bus TC Bus: 0.5	0.03418		0.09071	0.38	0.7063	-0.14361	0.21197
Car + Bike TT Bike: 5	0.25823	***	0.09808	2.63	0.0085	0.066	0.45046
Car + Bike TT Bike: 10	0.20887	**	0.09739	2.14	0.032	0.01799	0.39975
Car + Bike TC Bike: 0	-0.05216		0.10037	-0.52	0.6033	-0.24887	0.14455
Car + Bike TC Bike: 0.5	-0.07924		0.09963	-0.8	0.4264	-0.27451	0.11604
PT + Bike TC Bike: 0	-0.88408		23.23082	-0.04	0.9696	-46.4157	44.64749
PT + Bike TC Bike: 0.5	4.93356		21.57021	0.23	0.8191	-37.3433	47.2104

Tab. F.1.4 Output Class 3 General LC model

Attributes	Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	-0.05335		0.32819	-0.16	0.8709	-0.69658	0.58988
Constant Car + Bike	0.56189	*	0.29897	1.88	0.0602	-0.02409	1.14787
Constant Public Transport + Walk	2.57114	***	0.23614	10.89	0	2.10831	3.03396
Constant Public Transport + Bike	2.25698	***	0.2421	9.32	0	1.78248	2.73148
Constant Bike	0.02666		0.35323	0.08	0.9398	-0.66566	0.71898
Car + Bus TT Reduction car: -4	0.41029	*	0.24106	1.7	0.0888	-0.06218	0.88276
Car + Bus TT Reduction car: -2	-0.01754		0.2547	-0.07	0.9451	-0.51675	0.48167
Car + Bike TT Reduction car: -4	0.37323	**	0.17685	2.11	0.0348	0.02662	0.71985
Car + Bike TT Reduction car: -2	-0.10781		0.18338	-0.59	0.5566	-0.46723	0.25162
Car + Bus PC Car at Hub: 0	1.03389	***	0.24291	4.26	0	0.55779	1.50998
Car + Bus PC Car at Hub: 4	-0.17616		0.26566	-0.66	0.5073	-0.69683	0.34452
Car + Bike PC Car at Hub: 0	1.36832	***	0.19331	7.08	0	0.98945	1.74719
Car + Bike PC Car at Hub: 4	-0.27745		0.21518	-1.29	0.1973	-0.69919	0.14429
Car + Bus Hub fac.: Coffee & Sandwich	0.11552		0.24089	0.48	0.6315	-0.35661	0.58765
Car + Bus Hub fac.: Parcel Pick-up	0.0351		0.2562	0.14	0.891	-0.46703	0.53723
Car + Bike Hub fac.: Coffee & Sandwich	-0.27259		0.19883	-1.37	0.1704	-0.66228	0.1171
Car + Bike Hub fac.: Parcel Pick-up	0.30715	*	0.17763	1.73	0.0838	-0.04099	0.65529
Car PC Center: 3	1.4481	***	0.27233	5.32	0	0.91435	1.98185
Car PC Center: 5	-0.94969	**	0.38035	-2.5	0.0125	-1.69515	-0.20422
Car + Bus TT Bus: 6	0.04255		0.24802	0.17	0.8638	-0.44357	0.52866
Car + Bus TT Bus: 9	0.30227		0.24296	1.24	0.2135	-0.17392	0.77846
Car + Bus WT Bus: 2	0.87364	***	0.24155	3.62	0.0003	0.40021	1.34708
Car + Bus WT Bus: 6	-0.06651		0.26118	-0.25	0.799	-0.57842	0.4454
Car + Bus TC Bus: 0	-0.18165		0.24791	-0.73	0.4637	-0.66755	0.30425
Car + Bus TC Bus: 0.5	0.11973		0.23124	0.52	0.6046	-0.33349	0.57295
Car + Bike TT Bike: 5	0.60495	***	0.16829	3.59	0.0003	0.2751	0.9348
Car + Bike TT Bike: 10	-0.47775	**	0.20371	-2.35	0.019	-0.87702	-0.07847
Car + Bike TC Bike: 0	0.25068		0.1689	1.48	0.1378	-0.08036	0.58173
Car + Bike TC Bike: 0.5	-0.00856		0.18001	-0.05	0.9621	-0.36137	0.34425
PT + Bike TC Bike: 0	0.36795	***	0.10257	3.59	0.0003	0.16692	0.56897
PT + Bike TC Bike: 0.5	-0.17393		0.10599	-1.64	0.1008	-0.38166	0.03381
Estimated class probabilities							
PrbCls1	0.40688	***	0.04446	9.15	0	0.31975	0.49402
PrbCls2	0.3111	***	0.06006	5.18	0	0.19338	0.42881
PrbCls3	0.28202	***	0.05156	5.47	0	0.18096	0.38308

F.1.1 Output multinomial logistic regression classes general LC model

Case Processing Summary

		N	Marginal Percentage
CLASS	1	128	34.2%
	2	153	40.9%
	3	93	24.9%
P_Gender	Male	191	51.1%
	Female	183	48.9%
P_Age	<= 30	106	28.3%
	31-50	118	31.6%
	> 50	150	40.1%
P_Education	Low education level	80	21.4%
	Middle education level	145	38.8%
	High education level	149	39.8%
P_Income	Low income level	72	19.3%
	Middle income level	128	34.2%
	High income level	118	31.6%
	Not provided	56	15.0%
P_Workstatus	Part-time work	66	17.6%
	Full-time work	235	62.8%
	Other	73	19.5%
P_HouseholdSize	1	62	16.6%
	2	122	32.6%
	3 or 4	143	38.2%
	5 or more	47	12.6%
P_LivingSituation	Single	62	16.6%
	Fam + Children	163	43.6%
	Fam without Children	119	31.8%
	Other	30	8.0%
P_Distance	0 - 10 km	115	30.7%
	11 - 30 km	141	37.7%
	31 - 50 km	76	20.3%
	More than 50 km	42	11.2%
P_EHVCityVillage	Eindhoven	81	21.7%
	Village	221	59.1%
	City other than Eindhoven	72	19.3%
P_Purpose	Work	94	25.1%
	Shopping	145	38.8%
	Leisure	135	36.1%
P_DurationStay	0 - 2 hours	51	13.6%
	2 - 4 hours	189	50.5%
	4 - 6 hours	66	17.6%
	6 hours or longer	68	18.2%
P_PTsubscription	PT subscription	146	39.0%
	No PT subscription	228	61.0%
Valid		374	100.0%
Missing		1	
Total		375	
Subpopulation		358[a]	

a. The dependent variable has only one value observed in 346 (96.6%) subpopulations.

Step Summary

Model		Action	Effect(s)	Model Fitting Criteria			Effect Selection Tests		
				AIC	BIC	-2 Log Likelihood	Chi-Square[b,c]	df	Sig.
Step 0	0	Entered	<all>[a]	834.072	1045.982	726.072	.		
Step 1	1	Removed	P_Gender	830.076	1034.137	726.076	.004	2	.998
	2	Removed	P_Age	824.428	1012.792	728.428	2.352	4	.671
	3	Removed	P_PTsubscription	821.588	1002.103	729.588	1.160	2	.560
	4	Removed	P_Distance	814.407	971.378	734.407	4.820	6	.567
	5	Removed	P_DurationStay	808.235	941.660	740.235	5.828	6	.443
	6	Removed	P_Workstatus	804.023	921.751	744.023	3.788	4	.435
	7	Removed	P_Income	796.685	890.867	748.685	4.661	6	.588
	8	Removed	P_Purpose	793.578	872.063	753.578	4.893	4	.298
	9	Removed	P_LivingSituation	791.817	854.605	759.817	6.239	4	.182
	10	Removed	P_HouseholdSize	785.431	824.673	765.431	5.613	6	.468

Stepwise Method: Backward Stepwise
a. This model contains all effects specified or implied in the MODEL subcommand.
b. The chi-square for entry is based on the likelihood ratio test.
c. The chi-square for removal is based on the likelihood ratio test.

Model Fitting Information

Model	Model Fitting Criteria			Likelihood Ratio Tests		
	AIC	BIC	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	794.211	802.059	790.211			
Final	785.431	824.673	765.431	24.780	8	.002

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	712.768	706	.422
Deviance	748.795	706	.128

Pseudo R-Square

Cox and Snell	.064
Nagelkerke	.072
McFadden	.031

Likelihood Ratio Tests

Effect	Model Fitting Criteria			Likelihood Ratio Tests		
	AIC of Reduced Model	BIC of Reduced Model	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	785.431	824.673	765.431[a]	.000	0	.
P_Education	787.953	811.498	775.953	10.522	4	.032
P_EHVCityVillage	795.040	818.585	783.040	17.609	4	.001

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.
a. This reduced model is equivalent to the final model because omitting the effect does not increase the degrees of freedom.

Parameter Estimates

CLASS[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
1	Intercept	.629	.364	2.994	1	.084			
	[Education_Low]	-1.192	.391	9.317	1	.002	.304	.141	.653
	[Education_Middle]	-.747	.335	4.962	1	.026	.474	.246	.914
	[Education_High]	0[b]	.	.	0	.	.	.	.
	[Urbanization_Eindhoven]	-.246	.423	.339	1	.561	.782	.341	1.791
	[Urbanization_Village]	.562	.392	2.053	1	.152	1.754	.813	3.784
	[Urbanization_OtherCity]	0[b]	.	.	0	.	.	.	.
2	Intercept	.978	.340	8.302	1	.004			
	[Education_Low]	-.751	.371	4.095	1	.043	.472	.228	.977
	[Education_Middle]	-.458	.330	1.927	1	.165	.632	.331	1.208
	[Education_High]	0[b]	.	.	0	.	.	.	.
	[Urbanization_Eindhoven]	-1.142	.418	7.451	1	.006	.319	.141	.725
	[Urbanization_Village]	.238	.359	.440	1	.507	1.269	.628	2.565
	[Urbanization_OtherCity]	0[b]	.	.	0	.	.	.	.

a. The reference category is: 3.

b. This parameter is set to zero because it is redundant.

F.2 Output LC model Urbanization category City

Tab. F.2.1 Coefficients classes LC model City

Attributes	Coefficient_Class1	Coefficient_Class2
Constant Car + Bus	0.20332	-1.22864
Constant Car + Bike	-0.33254	-1.13913
Constant Public Transport + Walk	2.98351	-0.53413
Constant Public Transport + Bike	0.16512	-1.08905
Constant Bike	5.87082	-1.74291
Car + Bus TT Reduction car: -4	0.42989	0.3843
Car + Bus TT Reduction car: -2	-0.35463	0.17019
Car + Bus TT Reduction car: 0	-0.07526	-0.55449
Car + Bike TT Reduction car: -4	0.19387	0.46744
Car + Bike TT Reduction car: -2	0.15926	-0.054
Car + Bike TT Reduction car: 0	-0.35313	-0.41344
Car + Bus PC Car at Hub: 0	1.35466	0.49477
Car + Bus PC Car at Hub: 4	0.01454	-0.16114
Car + Bus PC Car at Hub: 8	-1.3692	-0.33363
Car + Bike PC Car at Hub: 0	1.95643	0.66343
Car + Bike PC Car at Hub: 4	-0.39491	-0.2134
Car + Bike PC Car at Hub: 8	-1.56152	-0.45003
Car + Bus Hub fac.: Coffee & Sandwich	0.28537	0.05432
Car + Bus Hub fac.: Parcel Pick-up	-0.16611	-0.15241
Car + Bus Hub fac.: None	-0.11926	0.09809
Car + Bike Hub fac.: Coffee & Sandwich	-0.50126	0.26809
Car + Bike Hub fac.: Parcel Pick-up	0.38885	-0.11478
Car + Bike Hub fac.: None	0.11241	-0.15331
Car PC Center: 3	2.09829	0.62917
Car PC Center: 5	-0.56864	-0.15009
Car PC Center: 7	-1.52965	-0.47908
Car + Bus TT Bus: 6	-0.03919	0.39849
Car + Bus TT Bus: 9	-0.2864	-0.28752
Car + Bus TT Bus: 12	0.32559	-0.11097
Car + Bus WT Bus: 2	-0.38706	0.40047
Car + Bus WT Bus: 6	0.4961	-0.15904
Car + Bus WT Bus: 10	-0.10904	-0.24143
Car + Bus TC Bus: 0	-0.01633	-0.11891
Car + Bus TC Bus: 0.5	-0.33659	0.26761
Car + Bus TC Bus: 1	0.35292	-0.1487
Car + Bike TT Bike: 5	0.60826	0.20966
Car + Bike TT Bike: 10	-0.97431	-0.05876
Car + Bike TT Bike: 15	0.36605	-0.1509
Car + Bike TC Bike: 0	0.15566	-0.16691
Car + Bike TC Bike: 0.5	0.42313	0.15153
Car + Bike TC Bike: 1	-0.57879	0.01538
PT + Bike TC Bike: 0	1.4083	0.10141
PT + Bike TC Bike: 0.5	-0.62	-0.13486
PT + Bike TC Bike: 1	-0.7883	0.03345

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

AIC	2942.9
LL (β)	-1408.43836
LL (0)	-2367.06389
ρ2	0.430
K	63

Tab. F.2.2 Output Class 1 LC model City

Attributes	Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	0.20332		0.6567	0.31	0.7569	-1.08379	1.49043
Constant Car + Bike	-0.33254		0.72411	-0.46	0.6461	-1.75176	1.08669
Constant Public Transport + Walk	2.98351	***	0.55193	5.41	0	1.90175	4.06527
Constant Public Transport + Bike	0.16512		0.68037	0.24	0.8082	-1.16838	1.49862
Constant Bike	5.87082	***	0.57116	10.28	0	4.75136	6.99028
Car + Bus TT Reduction car: -4	0.42989		0.32967	1.3	0.1922	-0.21626	1.07604
Car + Bus TT Reduction car: -2	-0.35463		0.37678	-0.94	0.3466	-1.0931	0.38384
Car + Bike TT Reduction car: -4	0.19387		0.37489	0.52	0.6051	-0.5409	0.92864
Car + Bike TT Reduction car: -2	0.15926		0.34231	0.47	0.6418	-0.51166	0.83018
Car + Bus PC Car at Hub: 0	1.35466	***	0.35398	3.83	0.0001	0.66087	2.04845
Car + Bus PC Car at Hub: 4	0.01454		0.39491	0.04	0.9706	-0.75948	0.78856
Car + Bike PC Car at Hub: 0	1.95643	***	0.44076	4.44	0	1.09256	2.8203
Car + Bike PC Car at Hub: 4	-0.39491		0.55242	-0.71	0.4747	-1.47764	0.68782
Car + Bus Hub fac.: Coffee & Sandwich	0.28537		0.32538	0.88	0.3805	-0.35236	0.9231
Car + Bus Hub fac.: Parcel Pick-up	-0.16611		0.36057	-0.46	0.645	-0.8728	0.54059
Car + Bike Hub fac.: Coffee & Sandwich	-0.50126		0.41771	-1.2	0.2301	-1.31995	0.31744
Car + Bike Hub fac.: Parcel Pick-up	0.38885		0.35733	1.09	0.2765	-0.31151	1.08921
Car PC Center: 3	2.09829	***	0.50255	4.18	0	1.11331	3.08327
Car PC Center: 5	-0.56864		0.8291	-0.69	0.4928	-2.19365	1.05637
Car + Bus TT Bus: 6	-0.03919		0.34318	-0.11	0.9091	-0.71181	0.63343
Car + Bus TT Bus: 9	-0.2864		0.37341	-0.77	0.4431	-1.01827	0.44548
Car + Bus WT Bus: 2	-0.38706		0.35932	-1.08	0.2814	-1.09131	0.31719
Car + Bus WT Bus: 6	0.4961		0.30844	1.61	0.1077	-0.10843	1.10064
Car + Bus TC Bus: 0	-0.01633		0.33362	-0.05	0.961	-0.67021	0.63755
Car + Bus TC Bus: 0.5	-0.33659		0.34917	-0.96	0.3351	-1.02095	0.34776
Car + Bike TT Bike: 5	0.60826	*	0.33427	1.82	0.0688	-0.04691	1.26342
Car + Bike TT Bike: 10	-0.97431	**	0.45945	-2.12	0.034	-1.8748	-0.07381
Car + Bike TC Bike: 0	0.15566		0.33591	0.46	0.6431	-0.5027	0.81403
Car + Bike TC Bike: 0.5	0.42313		0.32853	1.29	0.1978	-0.22078	1.06703
PT + Bike TC Bike: 0	1.4083	***	0.39191	3.59	0.0003	0.64017	2.17643
PT + Bike TC Bike: 0.5	-0.62		0.61015	-1.02	0.3096	-1.81587	0.57587

Tab. F.2.3 Output Class 2 LC model City

Attributes	Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	-1.22864	***	0.17653	-6.96	0	-1.57464	-0.88264
Constant Car + Bike	-1.13913	***	0.19078	-5.97	0	-1.51306	-0.76521
Constant Public Transport + Walk	-0.53413	***	0.14181	-3.77	0.0002	-0.81206	-0.25619
Constant Public Transport + Bike	-1.08905	***	0.14694	-7.41	0	-1.37704	-0.80106
Constant Bike	-1.74291	***	0.26424	-6.6	0	-2.26081	-1.22502
Car + Bus TT Reduction car: -4	0.3843	**	0.18278	2.1	0.0355	0.02607	0.74254
Car + Bus TT Reduction car: -2	0.17019		0.18684	0.91	0.3623	-0.196	0.53639
Car + Bike TT Reduction car: -4	0.46744	***	0.17622	2.65	0.008	0.12206	0.81282
Car + Bike TT Reduction car: -2	-0.054		0.18952	-0.28	0.7757	-0.42545	0.31746
Car + Bus PC Car at Hub: 0	0.49477	***	0.18133	2.73	0.0064	0.13937	0.85016
Car + Bus PC Car at Hub: 4	-0.16114		0.19044	-0.85	0.3975	-0.53439	0.21211
Car + Bike PC Car at Hub: 0	0.66343	***	0.17628	3.76	0.0002	0.31793	1.00893
Car + Bike PC Car at Hub: 4	-0.2134		0.19369	-1.1	0.2706	-0.59302	0.16622
Car + Bus Hub fac.: Coffee & Sandwich	0.05432		0.18631	0.29	0.7706	-0.31083	0.41948
Car + Bus Hub fac.: Parcel Pick-up	-0.15241		0.18933	-0.8	0.4208	-0.52349	0.21868
Car + Bike Hub fac.: Coffee & Sandwich	0.26809		0.17607	1.52	0.1279	-0.077	0.61318
Car + Bike Hub fac.: Parcel Pick-up	-0.11478		0.18622	-0.62	0.5376	-0.47975	0.25019
Car PC Center: 3	0.62917	***	0.12749	4.94	0	0.3793	0.87905
Car PC Center: 5	-0.15009		0.12767	-1.18	0.2398	-0.40031	0.10014
Car + Bus TT Bus: 6	0.39849	**	0.17823	2.24	0.0254	0.04917	0.74782
Car + Bus TT Bus: 9	-0.28752		0.20913	-1.37	0.1692	-0.6974	0.12236
Car + Bus WT Bus: 2	0.40047	**	0.17316	2.31	0.0207	0.06108	0.73987
Car + Bus WT Bus: 6	-0.15904		0.19209	-0.83	0.4077	-0.53553	0.21744
Car + Bus TC Bus: 0	-0.11891		0.19168	-0.62	0.535	-0.4946	0.25678
Car + Bus TC Bus: 0.5	0.26761		0.17598	1.52	0.1283	-0.0773	0.61253
Car + Bike TT Bike: 5	0.20966		0.176	1.19	0.2335	-0.13529	0.55461
Car + Bike TT Bike: 10	-0.05876		0.18629	-0.32	0.7524	-0.42389	0.30637
Car + Bike TC Bike: 0	-0.16691		0.19164	-0.87	0.3838	-0.54252	0.20869
Car + Bike TC Bike: 0.5	0.15153		0.17162	0.88	0.3773	-0.18485	0.4879
PT + Bike TC Bike: 0	0.10141		0.17866	0.57	0.5703	-0.24875	0.45157
PT + Bike TC Bike: 0.5	-0.13486		0.18738	-0.72	0.4717	-0.50211	0.2324
Estimated class probabilities							
PrbCls1	0.60513	***	0.09206	6.57	0	0.4247	0.78556
PrbCls2	0.39487	***	0.09206	4.29	0	0.21444	0.5753

F.2.1 Output binary logistic regression classes LC model City

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	153	99.4
	Missing Cases	1	.6
	Total	154	100.0
Unselected Cases		0	.0
Total		154	100.0

a. If weight is in effect. see classification Table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
1	0
2	1

Categorical Variables Codings

		Frequency	Parameter coding		
			(1)	(2)	(3)
P_HouseholdSize	1	38	1.000	.000	.000
	2	46	.000	1.000	.000
	3 or 4	53	.000	.000	1.000
	5 or more	16	.000	.000	.000
P_DurationStay	0 - 2 hours	33	1.000	.000	.000
	2 - 4 hours	71	.000	1.000	.000
	4 - 6 hours	21	.000	.000	1.000
	6 hours or longer	28	.000	.000	.000
P_Distance	0 - 10 km	81	1.000	.000	.000
	11 - 30 km	23	.000	1.000	.000
	31 - 50 km	25	.000	.000	1.000
	More than 50 km	24	.000	.000	.000
P_LivingSituation	Single	38	1.000	.000	.000
	Fam + Children	57	.000	1.000	.000
	Fam without Children	45	.000	.000	1.000
	Other	13	.000	.000	.000
P_Income	Low income level	40	1.000	.000	.000
	Middle income level	54	.000	1.000	.000
	High income level	39	.000	.000	1.000
	Not provided	20	.000	.000	.000
P_Purpose	Work	43	1.000	.000	
	Shopping	52	.000	1.000	
	Leisure	58	.000	.000	
P_Age	<= 30	70	1.000	.000	
	31-50	50	.000	1.000	
	> 50	33	.000	.000	
P_Workstatus	Part-time work	19	1.000	.000	
	Full-time work	94	.000	1.000	
	Other	40	.000	.000	
P_Education	Low education level	22	1.000	.000	
	Middle education level	41	.000	1.000	
	High education level	90	.000	.000	
P_PTsubscription	PT subscription	90	1.000		
	No PT subscription	63	.000		
P_Gender	Male	79	1.000		
	Female	74	.000		

Block 0: Beginning Block

Classification Table[a,b]

			Predicted		
			CLASS		Percentage Correct
	Observed		1	2	
Step 0	CLASS	1	87	0	100.0
		2	66	0	.0
	Overall Percentage				56.9

a. Constant is included in the model.
b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-.276	.163	2.864	1	.091	.759

Variables not in the Equation[a]

			Score	df	Sig.
Step 0	Variables	P_Gender(1)	.394	1	.530
		P_Age	1.228	2	.541
		P_Age(1)	.154	1	.695
		P_Age(2)	.298	1	.585
		P_Education	.089	2	.957
		P_Education(1)	.056	1	.813
		P_Education(2)	.013	1	.908
		P_Income	4.532	3	.209
		P_Income(1)	.217	1	.641
		P_Income(2)	.195	1	.658
		P_Income(3)	.467	1	.495
		P_Workstatus	.405	2	.817
		P_Workstatus(1)	.350	1	.554
		P_Workstatus(2)	.237	1	.627
		P_HouseholdSize	3.787	3	.285
		P_HouseholdSize(1)	1.642	1	.200
		P_HouseholdSize(2)	2.190	1	.139
		P_HouseholdSize(3)	.152	1	.696
		P_LivingSituation	4.675	3	.197
		P_LivingSituation(1)	1.642	1	.200
		P_LivingSituation(2)	.764	1	.382
		P_LivingSituation(3)	1.652	1	.199
		P_Distance	5.195	3	.158
		P_Distance(1)	2.737	1	.098
		P_Distance(2)	3.208	1	.073
		P_Distance(3)	.288	1	.591
		P_Purpose	1.255	2	.534
		P_Purpose(1)	.857	1	.355
		P_Purpose(2)	.022	1	.882
		P_DurationStay	5.817	3	.121
		P_DurationStay(1)	.092	1	.762
		P_DurationStay(2)	1.219	1	.270
		P_DurationStay(3)	5.759	1	.016
		P_PTsubscription(1)	.003	1	.953

a. Residual Chi-Squares are not computed because of redundancies.

Block 1: Method = Backward Stepwise (Conditional)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	34.438	24	.077
	Block	34.438	24	.077
	Model	34.438	24	.077
Step 2[a]	Step	-.240	1	.624
	Block	34.198	23	.062
	Model	34.198	23	.062
Step 3[a]	Step	-.489	1	.484
	Block	33.709	22	.053
	Model	33.709	22	.053
Step 4[a]	Step	-2.184	2	.335
	Block	31.524	20	.049
	Model	31.524	20	.049
Step 5[a]	Step	-1.653	2	.438
	Block	29.872	18	.039
	Model	29.872	18	.039
Step 6[a]	Step	-2.363	2	.307
	Block	27.509	16	.036
	Model	27.509	16	.036
Step 7[a]	Step	-4.105	3	.250
	Block	23.403	13	.037
	Model	23.403	13	.037
Step 8[a]	Step	-4.124	2	.127
	Block	19.279	11	.056
	Model	19.279	11	.056
Step 9[a]	Step	-4.285	3	.232
	Block	14.994	8	.059
	Model	14.994	8	.059
Step 10[a]	Step	-4.262	2	.119
	Block	10.732	6	.097
	Model	10.732	6	.097
Step 11[a]	Step	-4.419	3	.220
	Block	6.313	3	.097
	Model	6.313	3	.097

a. A negative Chi-squares value indicates that the Chi-squares value has decreased from the previous step.

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	174.773[a]	.202	.270
2	175.013[a]	.200	.269
3	175.503[a]	.198	.265
4	177.687[a]	.186	.250
5	179.340[a]	.177	.238
6	181.703[a]	.165	.221
7	185.808[a]	.142	.190
8	189.933[b]	.118	.159
9	194.217[b]	.093	.125
10	198.480[b]	.068	.091
11	202.898[b]	.040	.054

a. Estimation terminated at iteration number 5 because parameter estimates changed by less than .001.

b. Estimation terminated at iteration number 4 because parameter estimates changed by less than .001.

F.3 Output LC model Urbanization category Village

Tab. F.3.1 Coefficients classes LC model Village

Attributes	Coefficient_Class1	Coefficient_Class2	Coefficient_Class3
Constant Car + Bus	1.5717	-1.85923	1.25264
Constant Car + Bike	1.23682	-2.18001	0.1586
Constant Public Transport + Walk	-1.56664	-1.9946	3.68813
Constant Public Transport + Bike	-4.93712	-0.8426	-2.36549
Constant Bike	4.89257	-2.8781	1.47649
Car + Bus TT Reduction car: -4	0.05878	0.32705	-0.08902
Car + Bus TT Reduction car: -2	0.21599	-0.01867	-0.14841
Car + Bus TT Reduction car: 0	-0.27477	-0.30838	0.23743
Car + Bike TT Reduction car: -4	-0.23581	0.20562	0.10083
Car + Bike TT Reduction car: -2	0.08639	-0.23775	-0.11311
Car + Bike TT Reduction car: 0	0.14942	0.03213	0.01228
Car + Bus PC Car at Hub: 0	0.6432	0.56942	1.40563
Car + Bus PC Car at Hub: 4	0.11601	0.05046	0.1206
Car + Bus PC Car at Hub: 8	-0.75921	-0.61988	-1.52623
Car + Bike PC Car at Hub: 0	0.52214	1.22926	1.91421
Car + Bike PC Car at Hub: 4	-0.11313	0.07199	-0.38407
Car + Bike PC Car at Hub: 8	-0.40901	-1.30125	-1.53014
Car + Bus Hub fac.: Coffee & Sandwich	0.03303	0.22305	0.02454
Car + Bus Hub fac.: Parcel Pick-up	0.00787	0.14717	-0.55645
Car + Bus Hub fac.: None	-0.0409	-0.37022	0.53191
Car + Bike Hub fac.: Coffee & Sandwich	-0.217	-0.07693	0.1705
Car + Bike Hub fac.: Parcel Pick-up	0.19578	0.11302	0.10663
Car + Bike Hub fac.: None	0.02122	-0.03609	-0.27713
Car PC Center: 3	0.83392	0.37203	2.13057
Car PC Center: 5	-0.51891	0.000014213	-1.1841
Car PC Center: 7	-0.31501	-0.372044213	-0.94647
Car + Bus TT Bus: 6	0.36408	0.10047	0.48364
Car + Bus TT Bus: 9	0.04384	0.15892	0.00863
Car + Bus TT Bus: 12	-0.40792	-0.25939	-0.49227
Car + Bus WT Bus: 2	0.16009	0.24744	1.06997
Car + Bus WT Bus: 6	0.0893	-0.05265	-0.47988
Car + Bus WT Bus: 10	-0.24939	-0.19479	-0.59009
Car + Bus TC Bus: 0	-0.11579	0.29754	-0.19211
Car + Bus TC Bus: 0.5	0.09693	-0.30911	-0.20882
Car + Bus TC Bus: 1	0.01886	0.01157	0.40093
Car + Bike TT Bike: 5	0.28901	0.62291	0.57151
Car + Bike TT Bike: 10	0.21266	0.10768	-0.24373
Car + Bike TT Bike: 15	-0.50167	-0.73059	-0.32778
Car + Bike TC Bike: 0	-0.06684	0.22117	0.22698
Car + Bike TC Bike: 0.5	0.01797	-0.23043	-0.18448
Car + Bike TC Bike: 1	0.04887	0.00926	-0.0425
PT + Bike TC Bike: 0	2.81456	0.07706	3.63445
PT + Bike TC Bike: 0.5	2.19019	-0.00088	2.9947
PT + Bike TC Bike: 1	-5.00475	-0.07618	-6.62915

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

AIC	4577.7
LL (β)	-2193.86185
LL (0)	-3347.58905
ρ2	0.381
K	95

Tab. F.3.2 Output Class 1 LC model Village

Attributes	Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	1.5717	***	0.20724	7.58	0	1.16551	1.97788
Constant Car + Bike	1.23682	***	0.21995	5.62	0	0.80572	1.66791
Constant Public Transport + Walk	-1.56664	***	0.37899	-4.13	0	-2.30945	-0.82384
Constant Public Transport + Bike	-4.93712		11.4832	-0.43	0.6672	-27.4438	17.56954
Constant Bike	4.89257	***	0.49329	9.92	0	3.92573	5.8594
Car + Bus TT Reduction car: -4	0.05878		0.20233	0.29	0.7714	-0.33778	0.45535
Car + Bus TT Reduction car: -2	0.21599		0.19545	1.11	0.2691	-0.16709	0.59907
Car + Bike TT Reduction car: -4	-0.23581		0.21267	-1.11	0.2675	-0.65263	0.18101
Car + Bike TT Reduction car: -2	0.08639		0.2084	0.41	0.6785	-0.32206	0.49485
Car + Bus PC Car at Hub: 0	0.6432	***	0.20823	3.09	0.002	0.23508	1.05131
Car + Bus PC Car at Hub: 4	0.11601		0.19453	0.6	0.5509	-0.26527	0.49729
Car + Bike PC Car at Hub: 0	0.52214	**	0.2122	2.46	0.0139	0.10622	0.93805
Car + Bike PC Car at Hub: 4	-0.11313		0.20484	-0.55	0.5807	-0.5146	0.28834
Car + Bus Hub fac.: Coffee & Sandwich	0.03303		0.19501	0.17	0.8655	-0.34919	0.41524
Car + Bus Hub fac.: Parcel Pick-up	0.00787		0.19818	0.04	0.9683	-0.38056	0.39631
Car + Bike Hub fac.: Coffee & Sandwich	-0.217		0.20523	-1.06	0.2904	-0.61925	0.18525
Car + Bike Hub fac.: Parcel Pick-up	0.19578		0.19756	0.99	0.3217	-0.19142	0.58299
Car PC Center: 3	0.83392	***	0.2213	3.77	0.0002	0.40019	1.26766
Car PC Center: 5	-0.51891	*	0.27265	-1.9	0.057	-1.05331	0.01548
Car + Bus TT Bus: 6	0.36408	***	0.13957	2.61	0.0091	0.09053	0.63764
Car + Bus TT Bus: 9	0.04384		0.13714	0.32	0.7492	-0.22494	0.31262
Car + Bus WT Bus: 2	0.16009		0.13697	1.17	0.2425	-0.10838	0.42856
Car + Bus WT Bus: 6	0.0893		0.13915	0.64	0.521	-0.18343	0.36203
Car + Bus TC Bus: 0	-0.11579		0.1401	-0.83	0.4085	-0.39038	0.1588
Car + Bus TC Bus: 0.5	0.09693		0.1406	0.69	0.4906	-0.17865	0.37251
Car + Bike TT Bike: 5	0.28901	**	0.14043	2.06	0.0396	0.01377	0.56426
Car + Bike TT Bike: 10	0.21266		0.13725	1.55	0.1213	-0.05635	0.48166
Car + Bike TC Bike: 0	-0.06684		0.14333	-0.47	0.641	-0.34777	0.21409
Car + Bike TC Bike: 0.5	0.01797		0.14411	0.12	0.9007	-0.26447	0.30042
PT + Bike TC Bike: 0	2.81456		11.48872	0.24	0.8065	-19.7029	25.33203
PT + Bike TC Bike: 0.5	2.19019		11.49634	0.19	0.8489	-20.3422	24.72261

Tab. F.3.3 Output Class 2 LC model Village

Attributes	Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	-1.85923	***	0.17262	-10.77	0	-2.19755	-1.5209
Constant Car + Bike	-2.18001	***	0.19687	-11.07	0	-2.56587	-1.79414
Constant Public Transport + Walk	-1.9946	***	0.16961	-11.76	0	-2.32702	-1.66218
Constant Public Transport + Bike	-0.8426	***	0.09976	-8.45	0	-1.03813	-0.64707
Constant Bike	-2.8781	***	0.43677	-6.59	0	-3.73416	-2.02204
Car + Bus TT Reduction car: -4	0.32705	*	0.18543	1.76	0.0778	-0.03638	0.69049
Car + Bus TT Reduction car: -2	-0.01867		0.19083	-0.1	0.9221	-0.39269	0.35535
Car + Bike TT Reduction car: -4	0.20562		0.18756	1.1	0.2729	-0.16199	0.57322
Car + Bike TT Reduction car: -2	-0.23775		0.19913	-1.19	0.2325	-0.62804	0.15254
Car + Bus PC Car at Hub: 0	0.56942	***	0.18744	3.04	0.0024	0.20204	0.9368
Car + Bus PC Car at Hub: 4	0.05046		0.18939	0.27	0.7899	-0.32073	0.42165
Car + Bike PC Car at Hub: 0	1.22926	***	0.20548	5.98	0	0.82653	1.63199
Car + Bike PC Car at Hub: 4	0.07199		0.22597	0.32	0.7501	-0.37091	0.51489
Car + Bus Hub fac.: Coffee & Sandwich	0.22305		0.1873	1.19	0.2337	-0.14405	0.59015
Car + Bus Hub fac.: Parcel Pick-up	0.14717		0.18624	0.79	0.4294	-0.21785	0.51219
Car + Bike Hub fac.: Coffee & Sandwich	-0.07693		0.20025	-0.38	0.7009	-0.46941	0.31556
Car + Bike Hub fac.: Parcel Pick-up	0.11302		0.18539	0.61	0.5421	-0.25034	0.47638
Car PC Center: 3	0.37203	***	0.11599	3.21	0.0013	0.14469	0.59936
Car PC Center: 5	.14213D-04		0.10864	0	0.9999	-.21292D+00	.21295D+00
Car + Bus TT Bus: 6	0.10047		0.18849	0.53	0.594	-0.26896	0.46991
Car + Bus TT Bus: 9	0.15892		0.18681	0.85	0.3949	-0.20722	0.52506
Car + Bus WT Bus: 2	0.24744		0.17635	1.4	0.1606	-0.0982	0.59307
Car + Bus WT Bus: 6	-0.05265		0.18551	-0.28	0.7766	-0.41625	0.31095
Car + Bus TC Bus: 0	0.29754		0.18714	1.59	0.1118	-0.06924	0.66433
Car + Bus TC Bus: 0.5	-0.30911		0.20758	-1.49	0.1365	-0.71595	0.09773
Car + Bike TT Bike: 5	0.62291	***	0.17726	3.51	0.0004	0.27548	0.97034
Car + Bike TT Bike: 10	0.10768		0.19464	0.55	0.5801	-0.27381	0.48916
Car + Bike TC Bike: 0	0.22117		0.18061	1.22	0.2207	-0.13282	0.57515
Car + Bike TC Bike: 0.5	-0.23043		0.19384	-1.19	0.2345	-0.61036	0.1495
PT + Bike TC Bike: 0	0.07706		0.12479	0.62	0.5369	-0.16751	0.32164
PT + Bike TC Bike: 0.5	-0.00088		0.12409	-0.01	0.9943	-0.24409	0.24233

Tab. F.3.4 Output Class 3 LC model Village

Attributes	Coefficient	Sign.	Standard Error	z	Prob |z|>Z*	95% Confidence Interval	
Constant Car + Bus	1.25264	**	0.56196	2.23	0.0258	0.15122	2.35406
Constant Car + Bike	0.1586		0.67312	0.24	0.8137	-1.16069	1.47789
Constant Public Transport + Walk	3.68813	***	0.53244	6.93	0	2.64457	4.73169
Constant Public Transport + Bike	-2.36549		16.99667	-0.14	0.8893	-35.6784	30.94737
Constant Bike	1.47649	**	0.61119	2.42	0.0157	0.27857	2.6744
Car + Bus TT Reduction car: -4	-0.08902		0.2335	-0.38	0.703	-0.54666	0.36863
Car + Bus TT Reduction car: -2	-0.14841		0.2377	-0.62	0.5324	-0.61429	0.31747
Car + Bike TT Reduction car: -4	0.10083		0.34398	0.29	0.7694	-0.57335	0.77502
Car + Bike TT Reduction car: -2	-0.11311		0.35131	-0.32	0.7475	-0.80166	0.57544
Car + Bus PC Car at Hub: 0	1.40563	***	0.25285	5.56	0	0.91006	1.9012
Car + Bus PC Car at Hub: 4	0.1206		0.26266	0.46	0.6461	-0.3942	0.6354
Car + Bike PC Car at Hub: 0	1.91421	***	0.42645	4.49	0	1.07839	2.75004
Car + Bike PC Car at Hub: 4	-0.38407		0.5259	-0.73	0.4652	-1.41482	0.64668
Car + Bus Hub fac.: Coffee & Sandwich	0.02454		0.22631	0.11	0.9136	-0.41902	0.46811
Car + Bus Hub fac.: Parcel Pick-up	-0.55645	**	0.28138	-1.98	0.048	-1.10793	-0.00496
Car + Bike Hub fac.: Coffee & Sandwich	0.1705		0.34179	0.5	0.6179	-0.4994	0.84039
Car + Bike Hub fac.: Parcel Pick-up	0.10663		0.34178	0.31	0.7551	-0.56326	0.77651
Car PC Center: 3	2.13057	***	0.51242	4.16	0	1.12625	3.1349
Car PC Center: 5	-1.1841		0.80233	-1.48	0.14	-2.75664	0.38844
Car + Bus TT Bus: 6	0.48364	**	0.22111	2.19	0.0287	0.05028	0.91701
Car + Bus TT Bus: 9	0.00863		0.22818	0.04	0.9698	-0.4386	0.45587
Car + Bus WT Bus: 2	1.06997	***	0.20706	5.17	0	0.66414	1.47579
Car + Bus WT Bus: 6	-0.47988	*	0.24611	-1.95	0.0512	-0.96226	0.00249
Car + Bus TC Bus: 0	-0.19211		0.23116	-0.83	0.4059	-0.64518	0.26096
Car + Bus TC Bus: 0.5	-0.20882		0.22048	-0.95	0.3436	-0.64096	0.22332
Car + Bike TT Bike: 5	0.57151	*	0.3002	1.9	0.0569	-0.01688	1.1599
Car + Bike TT Bike: 10	-0.24373		0.33382	-0.73	0.4653	-0.89801	0.41055
Car + Bike TC Bike: 0	0.22698		0.30904	0.73	0.4627	-0.37872	0.83268
Car + Bike TC Bike: 0.5	-0.18448		0.3473	-0.53	0.5953	-0.86518	0.49622
PT + Bike TC Bike: 0	3.63445		16.98875	0.21	0.8306	-29.6629	36.93178
PT + Bike TC Bike: 0.5	2.9947		16.98935	0.18	0.8601	-30.3038	36.29322
Estimated class probabilities							
PrbCls1	0.25966	***	0.04944	5.25	0	0.16275	0.35656
PrbCls2	0.48369	***	0.05705	8.48	0	0.37187	0.59551
PrbCls3	0.25665	***	0.05087	5.04	0	0.15694	0.35636

F.3.1 Output multinomial logistic regression classes LC model Village

Case Processing Summary

		N	Marginal Percentage
CLASS	1	76	34.4%
	2	88	39.8%
	3	57	25.8%
P_Gender	Male	112	50.7%
	Female	109	49.3%
P_Age	<= 30	36	16.3%
	31-50	68	30.8%
	> 50	117	52.9%
P_Education	Low education level	58	26.2%
	Middle education level	104	47.1%
	High education level	59	26.7%
P_Income	Low income level	32	14.5%
	Middle income level	74	33.5%
	High income level	79	35.7%
	Not provided	36	16.3%
P_Workstatus	Part-time work	47	21.3%
	Full-time work	141	63.8%
	Other	33	14.9%
P_HouseholdSize	1	24	10.9%
	2	76	34.4%
	3 or 4	90	40.7%
	5 or more	31	14.0%
P_LivingSituation	Single	24	10.9%
	Fam + Children	106	48.0%
	Fam without Children	74	33.5%
	Other	17	7.7%
P_Distance	0 - 10 km	34	15.4%
	11 - 30 km	118	53.4%
	31 - 50 km	51	23.1%
	More than 50 km	18	8.1%
P_Purpose	Work	51	23.1%
	Shopping	93	42.1%
	Leisure	77	34.8%
P_DurationStay	0 - 2 hours	18	8.1%
	2 - 4 hours	118	53.4%
	4 - 6 hours	45	20.4%
	6 hours or longer	40	18.1%
P_PTsubscription	PT subscription	56	25.3%
	No PT subscription	165	74.7%
Valid		221	100.0%
Missing		0	
Total		221	
Subpopulation		211[a]	

a. The dependent variable has only one value observed in 205 (97,2%) subpopulations.

Step Summary

Model		Action	Effect(s)	Model Fitting Criteria			Effect Selection Tests		
				AIC	BIC	-2 Log Likelihood	Chi-Square[b,c]	df	Sig.
Step 0	0	Entered	<all>[a]	487.944	657.853	387.944	.		
Step 1	1	Removed	P_Income	477.117	626.636	389.117	1.173	6	.978
	2	Removed	P_LivingSituation	469.863	605.789	389.863	.745	4	.946
	3	Removed	P_Purpose	463.605	585.939	391.605	1.743	4	.783
	4	Removed	P_Gender	460.996	576.533	392.996	1.390	2	.499
	5	Removed	P_DurationStay	455.848	550.996	399.848	6.852	6	.335
	6	Removed	P_Age	451.423	532.979	403.423	3.575	4	.467
	7	Removed	P_Workstatus	448.236	516.200	408.236	4.814	4	.307
	8	Removed	P_HouseholdSize	444.744	492.318	416.744	8.507	6	.203
	9	Removed	P_Education	442.607	476.589	422.607	5.864	4	.210

Stepwise Method: Backward Stepwise

a. This model contains all effects specified or implied in the MODEL subcommand.

b. The chi-square for entry is based on the likelihood ratio test.

c. The chi-square for removal is based on the likelihood ratio test.

Model Fitting Information

Model	Model Fitting Criteria			Likelihood Ratio Tests		
	AIC	BIC	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	474.480	481.276	470.480			
Final	442.607	476.589	422.607	47.872	8	.000

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	416.344	412	.431
Deviance	414.290	412	.459

Pseudo R-Square

Cox and Snell	.195
Nagelkerke	.220
McFadden	.100

Likelihood Ratio Tests

Effect	Model Fitting Criteria			Likelihood Ratio Tests		
	AIC of Reduced Model	BIC of Reduced Model	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	442.607	476.589	422.607[a]	.000	0	.
P_Distance	446.523	460.115	438.523	15.915	6	.014
P_PTsubscription	472.013	499.199	456.013	33.406	2	.000

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.

a. This reduced model is equivalent to the final model because omitting the effect does not increase the degrees of freedom.

Parameter Estimates

CLASS[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B) Lower Bound	Upper Bound
1	Intercept	2.752	.842	10.688	1	.001			
	[P_Distance=1]	-1.808	.935	3.739	1	.053	.164	.026	1.025
	[P_Distance=2]	-2.205	.852	6.694	1	.010	.110	.021	.586
	[P_Distance=3]	-1.737	.895	3.770	1	.052	.176	.030	1.016
	[P_Distance=4]	0[b]	.	.	0	.	.	.	.
	[P_PTsubscription=1]	-1.870	.427	19.215	1	.000	.154	.067	.356
	[P_PTsubscription=2]	0[b]	.	.	0	.	.	.	.
2	Intercept	1.709	.933	3.356	1	.067			
	[P_Distance=1]	-.653	1.022	.409	1	.523	.520	.070	3.855
	[P_Distance=2]	-.525	.940	.313	1	.576	.591	.094	3.730
	[P_Distance=3]	-.991	.995	.992	1	.319	.371	.053	2.609
	[P_Distance=4]	0[b]	.	.	0	.	.	.	.
	[P_PTsubscription=1]	-2.072	.414	25.099	1	.000	.126	.056	.283
	[P_PTsubscription=2]	0[b]	.	.	0	.	.	.	.

a. The reference category is: 3.
b. This parameter is set to zero because it is redundant.

Master thesis | Construction Management & Engineering

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Final Colloquium | 02/05/2019

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