Bus preferences and usage amongst elderly in urban areas of The Netherlands

Master Thesis

E.M. van Gorp

Technische Universiteit Delft

Bus preferences and usage amongst elderly in urban areas of The Netherlands

Master Thesis

by

E.M. van Gorp

Submitted to Delft University of Technology in partial fullfillment of the requirements for the degree of

Master of Science
In Transport, Infrastructure and Logistics

To be defended in public on November 12, 2019

Student number:	4229746	
Date:	November 12th, 2019	
Thesis committee:	Prof. dr. ir. S.P. Hoogendoorn,	TU Delft, chairman
	Dr. ir. N. van Oort,	TU Delft, supervisor
	Dr. ir. S. van Cranenburgh,	TU Delft, supervisor
	Ir. A.F. Scheltes,	Goudappel Coffeng, external supervisor
	Ir. E.M.J. van der Werff,	Goudappel Coffeng, external supervisor

TU Delft

lab Smart Public Transport

adviseurs mobiliteit Goudappel Coffeng

Preface

In front of you lies the final deliverable of the master Transport, Infrastructure and Logistics at Delft University of Technology and the end of my time as student: my master thesis. The aim of this master thesis is to gain insight into the socio-demographic factors and mode attributes influencing the bus preferences and usage of the elderly in urban areas of The Netherlands. This study is conducted on behalf of Goudappel Coffeng in association with the Delft University of Technology and the Smart Public Transport Lab.

I would like to thank everybody who helped me during the my master thesis. First of all, I want to thank my graduation committee for all their help, guidance and feedback during this process. I would like to thank Serge Hoogendoorn for being enthusiastic about the subject and for the feedback. I would like to thank Sander van Cranenburgh for being critical about the research and helping me with the model estimations. I would like to thank Niels van Oort for the regular meetings and providing advice, tips and lots of extra information in a positive and enthusiastic way.

Second, I would like to thank the colleagues at Goudappel Coffeng for their interest in me and my research. They have been open and welcoming from the first time I walked in, included me in their work environment and in the sporty and fun activities outside working hours. A special thanks to Arthur Scheltes, for always making time for me to help me, for coming up with new ideas, for providing feedback and for bringing me in contact with other colleagues and the municipality of Groningen. Also thanks to you Ellen van der Werff, for making time for me, being positive, providing feedback, and for catching up. And thank you Daphne van den Hurk, for always responding to me quickly and calling me during setbacks to convince me that everything would turn out right.

Lastly, I would like to thank my family and friends. Mom and dad, for always being there for me and supporting me in all the choices I made regarding extracurricular activities and study options during my student time, even though this caused some years of study delay. Mom, for always texting me with positive words and reminding me how special it is to be allowed to study at the university. Lies, thank you for being my sister. Last year has been a tough year for you and I got to know you as the strongest and most positive person I know. I am very very proud of you. Thanks to my friends and roommates, for listening to all the complaining, for the motivational talks, and for discussing ideas. And Martijn, thank you for being there for me, for always helping me to put things into perspective, reading through my work, and for distracting me with weekend getaways and trips.

I am grateful to have been able to study in Delft and at this university. I really enjoyed the seven years of student time and I am thankful for all the friends I made, for the opportunities I got to study two times abroad, for being part of several committees and for all the new things I learned during these years. I am happy that I had the opportunity to do my master thesis at Goudappel Coffeng. I met a lot of interesting new people and ended up in a nice working environment. Therefore, I am glad that I can start working here and change my status as an intern to a consultant in public transport at Goudappel Coffeng.

E.M. van Gorp
Delft, November 2019

Summary

The population is ageing worldwide. In The Netherlands, currently 19% of the population is 65 years and older. It is expected that this will increase to almost 25% in 2030. The current and future generation of elderly is more mobile, prosperous and vital compared to previous generations, and is travelling more. They grew up in a period in which travelling became more common as part of an active, mobile and independent lifestyle. However, an important part of the elderly, 14% of the people aged 65-75 and 35% of the people aged 75 years or older, is limited in their mobility. They experience loneliness and a decline in the quality of life due to a lack of suitable transportation options.

Different transportation options were already researched to make travelling easier for the elderly. However, these options are often futuristic, expensive, complex to organize or only applicable locally, such as self-driving cars, customized transport, or ambassadors making trips with the elderly. No structural solutions which can be applied in the short term throughout The Netherlands are available yet.

The bus network in The Netherlands is extensive, with 1800 lines and having the highest density compared to the other public transport modes. Therefore, the bus could be a suitable transport option for the elderly. However, the average public transport usage of the elderly, and thus the bus usage, is very low with 10%.

It is currently unknown which socio-demographic characteristics and bus attributes influence the preferences and usage of bus services of the elderly, and to which extent. Besides that, elderly are often treated as a homogeneous group with similar preferences, while elderly are different (heterogeneous) regarding their preferences and travel behaviour. Therefore, the objective of this research is to find the socio-demographic characteristics and mode attributes which influence the preferences and bus usage of the elderly, and to investigate whether they have heterogeneous preferences. The results of this study could be used to guide policy makers to design bus networks which are more attractive for the different groups of elderly in The Netherlands. This could keep the elderly mobile and facilitate a way to stimulate participating in social and daily activities.

The main research question for this study is:

Which factors influence the preference and use of bus services among elderly people in urban areas of The Netherlands and what is the corresponding heterogeneity?

A literature study and expert interviews with public transport and behaviour experts from Goudappel Coffeng were conducted to define the socio-demographic factors and attributes that could influence the preferences and usage of bus services. In total, 21 socio-demographics and 5 attributes were considered. A Stated Preference (SP) choice survey was used to examine which socio-demographic factors and bus attributes influence the preferences and bus usage of the elderly, and to which extent. The Stated Preference data is based on the individuals' reactions to hypothetical situations: it is asked what an individual would choose in a specific situation. Preferences regarding the bus attributes were collected via the different hypothetical choice situations. The attributes included were 'travel time', 'travel cost', 'frequency', 'transfers', and 'distance to nearest bus stop'. The socio-demographic characteristics were collected via general questions in the survey.

The questionnaire was distributed online among the elderly and resulted in 256 valid responses which were used for the data analysis. The statistics of the survey showed that 22% of the respondents uses the bus one day per week or more, against 29% of the respondents who never use the bus. The share of elderly possessing a car and driving license is high, with 80% and 81% respectively. Most of the respondents, 79%, is able to cycle. About 33% of the

respondents possesses a public transport card subscription including the elderly discount. More than half of the respondents indicate that they do not have a public transport card subscription at all.

Results of the descriptive analysis showed that the socio-demographic characteristics 'able to cycle', 'taken to or from destination by friends or family sometimes', 'possessing a transport subscription' and 'able to reach bus stop without help' have a positive influence on the bus usage, while 'car possession' and 'driving license possession' have a negative influence on the bus usage.

Based on the stated preference data, a multinomial logit (MNL) model was estimated to quantify the values elderly place on the bus attributes and to explore heterogeneity with by including interaction effects. Besides that, a latent class (LC) choice model was estimated to explore the heterogeneity and the nature of the heterogeneity in preferences among the elderly. The multinomial logit model showed that all the included attributes influence the bus choice of the elderly. The attribute 'frequency' has a positive influence on the bus choice of the elderly. The attributes 'travel time', 'travel costs', 'transfers', and 'distance to the nearest bus stop' on the other hand negatively influence the choice. In contrast to the expectations, for the attribute level range used in this choice experiment, travel costs has the largest impact on the preference for a bus service , followed by frequency, as shown in table 1. Distance to the nearest bus stop and transfers have the lowest impact.

Table 1: Contribution to utility per attribute

Parameter estimate	Relative importance
Frequency	0.80
Stop distance	-0.46
Travel costs	-1.16
Transfers	-0.36
Travel time	-0.63

Socio-demographic characteristics were included in the multinomial logit model as interaction effect to test if these characteristics affect the attributes that influence the bus choice of the elderly. The results showed the following remarkable interaction effects which were not expected in advance, but can be explained:

- Men are less sensitive for 'transfers'. A reason for this might be that women are generally more insecure and sensitive to factors that influence the risk perception on the road, and that this also applies to women travelling independently by public transport.
- Elderly which make use of a walking tool are less sensitive for travel costs. An explanation might be that elderly with walking difficulties make fewer trips and are willing to pay more if they finally make a trip.

The latent class choice model distinguished four classes with different preferences regarding the bus service as shown in figure 1: (1) the 'price sensitive elderly', (2) the 'transfers and frequency fans', (3) the 'nearby and direct bus service lovers' and (4) the 'time sensitive elderly'. Only the socio-demographic 'able to cycle' can explain the membership of the classes significantly.

- The size of the first class is the smallest, with 7% of the elderly assigned to it. Those elderly have the highest preference for low travel cost. Besides that, they prefer low distance to the nearest bus stop and no transfers. A descriptive analysis showed that the first class mainly consists of elderly who are able to cycle.
- The size of the second class is large, with 39% of the elderly assigned to it. This class mainly consists of elderly with a preference for high frequency and low travel costs. Since frequency was associated with having a transfer in the choice experiment, this class is positive towards having a transfer. The descriptive analysis showed that both elderly who are not able to cycle and who are able to cycle belong to this class.

- The third class is the largest, with 43% of the elderly assigned to it. This class prefers a bus service without transfers. Besides that, they prefer low distance to the nearest bus stop and low travel costs. Most of the elderly who are not able to cycle belong to this class. However, the absolute number of elderly who can cycle is higher.
- The size of the fourth class is small, with 11% of the elderly assigned to it. Only the elderly in this class have a clear preference for low travel time. Next to that, they prefer high frequency, low travel costs and no transfers. Mainly elderly who are able to cycle belong to this class.

The results of this latent class choice model show that different groups of elderly have opposite preferences regarding the attributes of the bus service. Most of the elderly (50%) prefer a high-frequent bus service with low travel costs, but another large part of the elderly (43%) prefers a direct bus service with a low distance to the nearest bus stop.

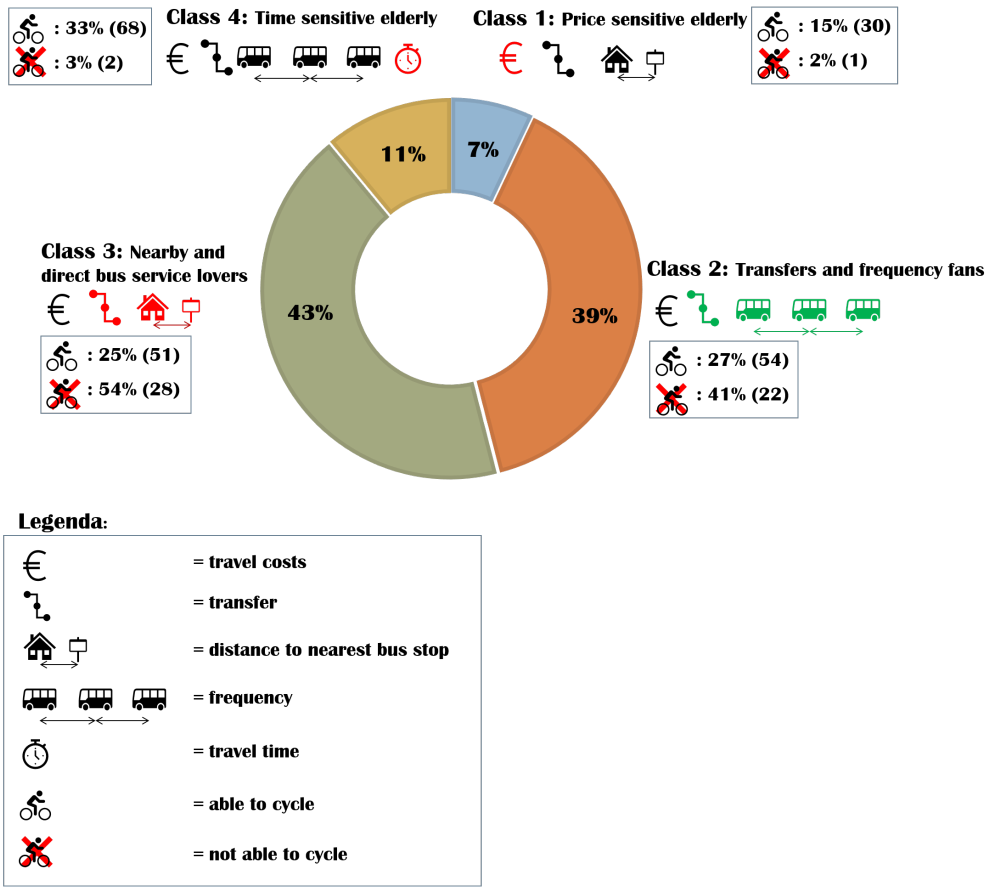


Figure 1: Classes of the LC choice model, size and important attributes per class (own work)

To compare whether the results of the models match with findings in practice, public transport chip card data of Groningen was analysed. The results showed that elderly in Groningen are expected to use the fast and high-frequent bus services the most. This is in line with the results from the multinomial logit and latent class choice model, that most of the elderly prefer a high-frequent bus service with low travel costs. The results also showed that the bus usage of elderly is highest during off-peak hours in the afternoon. The bus lines going through the city are used the most, with the bus stops at the train station, city centre, hospitals and park and ride facilities used the most for boarding and alighting.

Directions for policy regarding the bus network in The Netherlands are related the design of the bus network, the travel costs of the bus and the threshold to use public transport. First, in order to meet the opposite preferences of the different groups of elderly, it is advised to

offer different types of bus services: not only fast and high-frequent bus services, but also dense low-frequent bus service with a low distance to the nearest bus stop. Although the largest group of elderly prefers a high-frequent bus service, it is not advisable to stretch and straighten all the bus lines as suggested in the public transport vision of Groningen, since this could be disadvantageous for the other part of the elderly.

Travel costs has the largest negative effect on the bus choice of the elderly. Therefore, it is advised to offer bus services for lower prices or for free to attract the elderly to make more use of the bus. Currently, the elderly can travel by bus with a discount of 34%, but the sample in this research showed that not all the elderly use this discount when using the bus. It is advisable to promote the discount, since it is possible not all elderly know that they can get discount.

Lastly, not only the bus usage of the elderly is low, but also the usage of all other public transport modes. This research shows that most of the elderly prefer a fast high-frequent bus service and another important part of the elderly prefer a bus service without transfers and low distance to the nearest bus stop. Currently, these types of bus services are already available in The Netherlands, such as Q-link and city bus services in Groningen. Nevertheless, this appears not to be sufficient for most elderly to use the bus. Probably, most elderly are not used to travel by public transport, among other things due to the increase in car use. When elderly are no longer able to use the car, it is a challenge to start using public transport. Using public transport can be complicated, such as buying tickets and checking-in, especially if you are disabled. It is advisable to investigate how to make the switch from using the car to using public transport easier.

Further research is required to examine the influence of other socio-demographic and attributes on the preferences and choice for bus, such as the kind of walking tool and other types of special transport elderly use, comfort level of the bus and seat availability. Only two bus options were considered, while it is interesting to include other alternatives and to research whether elderly will use other means of transport, or will not travel at all. Additionally, research is needed to look into the preferences and choices of elderly living in less urban areas or urban areas with tram and metro. Lastly, elderly who are not using a computer or internet are not considered, while a large part of the elderly, 10% of the elderly aged 65 to 75 and 32% of the elderly aged 75 and over, has never used internet. For policy making, it is important to know the preferences and bus usage of the non-digital elderly.

Contents

List of Figures

List of Tables

Abbreviations

SP Stated Preference

RP Revealed Preference

MNL Multinomial Logit

DCM Discrete Choice Modelling

LC Latent Class

LRS Likelihood Ratio Statistic

BIC Bayesian Information Criterion

LL Log-likelihood

PT Public Transport

WTP Willingness to Pay

OD Origin-destination

1 Introduction

It is expected that the current worldwide population of nearly 7.6 billion people is growing by 1.1 percent per year (The Department of Economic and Social Affairs, 2017). With this, the life expectancy of people is rising as well, which is leading to an increasing proportion of people aged over 60. This phenomenon of population ageing is happening worldwide. It was estimated that in 2017, 13 percent of the global population was aged 60 years or older. Given the large number of people born in recent decades, it is expected that this older population will keep growing, reaching 1.4 billion older persons in 2030 and 3.1 billion in 2100 (The Department of Economic and Social Affairs, 2017).

Currently, in Europe the population aged 60 or over is 25% (The Department of Economic and Social Affairs, 2017). It is expected that this proportion will be 35% in 2050. In The Netherlands, the expectation is that the number of people over 65[1] years will increase to 4,2 million in 2030, which is almost 25% of the population (CBS, 2018f). Especially the number of people of 80 years and older will increase, reaching 1,2 million in 2030.

The current and future generation of elderly is more mobile, prosperous, and vital compared to previous generations (Van Dam & Hilbers, 2013). They grew up in a period in which travelling became more common as part of an active, mobile and independent lifestyle. Because of this, the current and future generation will travel more and further distances compared to the generations before. The current and future elderly more often have a car and will use this until high age. However, the aging of the population will also lead to more people with disabilities participating in the traffic (Goldenbeld, 2015). Especially for the elderly with disabilities, such as functional disorders, or those without a car it can be problematic to continue to meet their own transport needs. The ability to drive decreases when they become older, which makes public transport more important for them to stay independent (Su & Bell, 2009). However, less than 10% of the elderly aged 65 or older make their trips by public transport (Szeto et al., 2017).

In the Netherlands, the bus network forms the basis of the public transport network. About 90% of all lines in the complete schedule of public transport is a bus line, which is 1800 bus lines in total (Zijlstra et al., 2017). This makes the density of the bus network the biggest compared to the other modes of public transport. The proportion of elderly making use of the city bus service is limited, an estimated 5% of the bus passengers is 65 years or older. The infrequent use of public transport services are among other things caused by unreliability, difficulties and distances to access bus stops and stations, the fear of crime, and unavailability of some destinations (Cui et al., 2017; Hess, 2012; Wong et al., 2018). Besides that, the bus network is changing, since bus lines get bundled and stretched. This leads to faster

[1] Definition of the elderly varies across global research, but in most (Dutch) papers 65 years and above is used. Therefore, this definition will be used in this research as well (CBS, 2018f; Cui et al., 2017). For resources mentioning aging worldwide, elderly are described as persons aged 60 and above.

and high-frequent buses on the one hand, but also to larger distances to the bus stop.

When the ability to live independently and autonomously and to participate in activities outside the door are lost, this can lead to isolation and deterioration of health, both physically and mentally (Goldenbeld, 2015; Johnson et al., 2017; Rosenbloom & Smiley, 1999). Through this, elderly will experience a decline in their quality of life (Aguiar & Macário, 2017). Therefore, it is necessary to offer good mobility and transportation alternatives for the older population to keep them participating in social and daily activities (Kim, 2011).

To keep elderly participating in outside activities, different options are already researched to make travelling easier. Discounted or free bus travel is offered in some cities for all older people to make public transport more attractive (Mackett, 2015; van Wijk, 2015; Wong et al., 2018). In Zeeland, Public transport ambassadors were introduced to provide information and answer questions about public transport usage. In addition, the ambassadors make trips with small groups of elderly to let them experience the usage of public transport (van Wijk, 2015). In other areas, such as in The London Borough of Camden, specialised transport services are providing more suitable services for older people (Su & Bell, 2009). In Hervey Bay, Australia, they respond to the needs of the elderly by offering flexible route bus transport instead of fixed routes (Broome et al., 2012).

Although several transportation options have been researched to make transport accessible for everyone, those options are often expensive, futuristic or only applicable locally. Yet, there are no structural solutions that can be applied in the short term throughout The Netherlands. Since the bus network in the Netherlands is extensive, it could be a suitable transport option for the elderly. However, the bus usage of the elderly is very low. Therefore, it is interesting to do more research to this mode. The focus in this research is on investigating the bus usage and bus preferences of the elderly and factors influencing these preferences. These results could be used by governments to develop their policy regarding the bus network to make it more attractive for the elderly. The goal is to stimulate the bus usage of the elderly to keep them participating in social and daily activities. Not only bus users are included, but also non-users. Yet, little is known about the differences and similarities in preferences and travel behaviour by bus among various groups of the elderly, related to their lifestyles, health, geographic location, and mobile phone possession, as confirmed by Choo et al. (2016); Cui et al. (2017); de Haas et al. (2018); Fiedler (2007); Figueroa et al. (2014); Harms et al. (2007); Hess (2012); Hildebrand (2003); Kim & Ulfarsson (2013); Szeto et al. (2017).

1.1. Problem description

The number of elderly is increasing. With this, the elderly are more mobile these days and are travelling more. Older people are using the car as primate mode. On the other hand, aging will also lead to a bigger group of elderly with disabilities, which does not have the ability to drive themselves anymore. Besides that, not all elderly have a driver's license or own a car. This group becomes dependent of other people and other modes of transport, such as the bus, as part of public transport. However, most elderly do not use the bus and there is often a lack of other suitable transport. This leads to loneliness and health problems.

To make it possible and more easy for elderly to keep travelling, several (public) transportation options are researched and still in development, using new technologies. However, these options are expensive, futuristic or only applicable locally. No structural solutions which can be applied in the short term throughout The Netherlands are yet available. The bus network is already extensive with 1800 bus lines throughout The Netherlands and has the highest density compared to other public transport modes. Besides that, the bus contributes to autonomy of the people and is affordable compared to other modes (Savelberg & Kansen, 2019). Therefore, the bus could be a suitable transport option for the elderly. However, the bus usage of elderly is very low. It is unknown which socio-demographic characteristics and mode attributes influence to what extent the low bus usage and preferences of the elderly towards bus services. These factors might be important to take into account to obtain better understanding of the preferences of the elderly. Besides that, elderly are mostly treated as a homogeneous group, while there are heterogeneous preferences and differences in travel behaviour among various groups among the elderly. Up to now, the mobility measures used for the elderly are mainly for the group of elderly with disabilities, while higher age does not necessarily mean more immobility (Haustein, 2011).

This research investigates which socio-demographic factors and mode attributes influence the preferences and usage of the bus, and to which extent. Besides that, it researches whether there is heterogeneity in how the elderly value the attributes of the bus network, and whether there are socio-demographic factors to which this heterogeneity can be attributed. The results of this study could be used for policy making regarding bus network designs which respond to the preferences of the elderly.

1.2. Scope

Since elderly and mobility is a broad subject for research and the time period for the thesis research is short, the research is narrowed down on the following aspects.

- The thesis focuses on the elderly in urban areas in The Netherlands.
- The elderly are defined as the part of the population aged 65 and over, since this is definition is most commonly used in literature.
- This research focuses on bus lines and bus types driving within urban areas/cities.

1.3. Research objective and research questions

The objective of this research is to find the socio-demographic characteristics and mode attributes that influence the usage and preferences of the elderly regarding bus services. The results could be used to guide policy makers to design bus networks which are more attractive for the different groups of elderly. This could keep the elderly mobile and facilitate a way to stimulate participating in social and daily activities. The elderly in the Netherlands living in different urban municipalities will be used as respondents for a survey.
The main research question for this study is:

Which factors influence the preference and use of bus services among elderly people in urban areas of The Netherlands and what is the corresponding heterogeneity?

In order to answer the main research question, several sub-questions need to be answered which are formulated as follows:

1. Which socio-demographic characteristics influence the bus usage of the elderly?
2. Which bus attributes are most important for the elderly, and to which extent?
3. To which extent does heterogeneity in preferences exist among elderly regarding the values of bus attributes, and to which socio-demographic characteristics can this unobserved heterogeneity be attributed?

1.4. Scientific and societal relevance

This research will be relevant both scientifically and socially. The scientific relevance and contribution can be found in the following aspects. First of all, insight is obtained in the heterogeneity in bus usage of elderly aged 65 and over. This study attempts to fill the knowledge gap regarding the differences and similarities in bus usage among different groups of the elderly. Secondly, there is some literature about the mobility preferences and needs of the elderly related to several socio-economic characteristics. However, the mobility preferences of the elderly related to their geographic location, preferences, resources, new technologies and health is missing. Thirdly, insight is obtained about the implications of the preferences of the elderly for the current bus network design.

Socially, the results of this study will show the preferences of elderly related to the distance to the bus stop, travel time, travel cost, frequency and transfers. These results can be used by policy makers and developers of bus networks when developing the current bus networks in such a way that it meets the preferences of the increasing elderly population. Furthermore, the lack of mobility of the elderly appears to result in health problems. The chance that they lose abilities earlier, and to suffer from psychological, mental and physical diseases is larger (Fiedler, 2007). Using the insights from this research, bus transport systems can be adapted to the preferences of the elderly to stimulate bus usage and improve the quality of life of the elderly population. Furthermore, older people who are not able to lead an active and independent life cause costs related to services such as care and home deliveries. Reducing the lack of mobility of the elderly helps saving these social costs (Fiedler, 2007).

1.5. Report structure

The problem, research objective and research questions were identified and formulated in chapter 1. In chapter 2, the methodology is explained. Chapter 3 reviews literature regarding development of the elderly, public transport network design dilemmas, factors and mode attributes influencing travel behaviour of the elderly, and heterogeneity among elderly. The design of the stated preference survey is described in chapter 4. Chapter 5 elaborates on the descriptive statistics of the data coming from the survey and the model estimation is explained in chapter 6. After this, the findings from the model estimations are compared with findings from prractice in chapter 7. Based on public transport chip card data of Groningen, elderly and all bus users are compared. Besides that, a scenario analysis is done. Finally, chapter 8 shows the conclusion, discussion and recommendations. The structure of the thesis is visualised in figure 1.1.

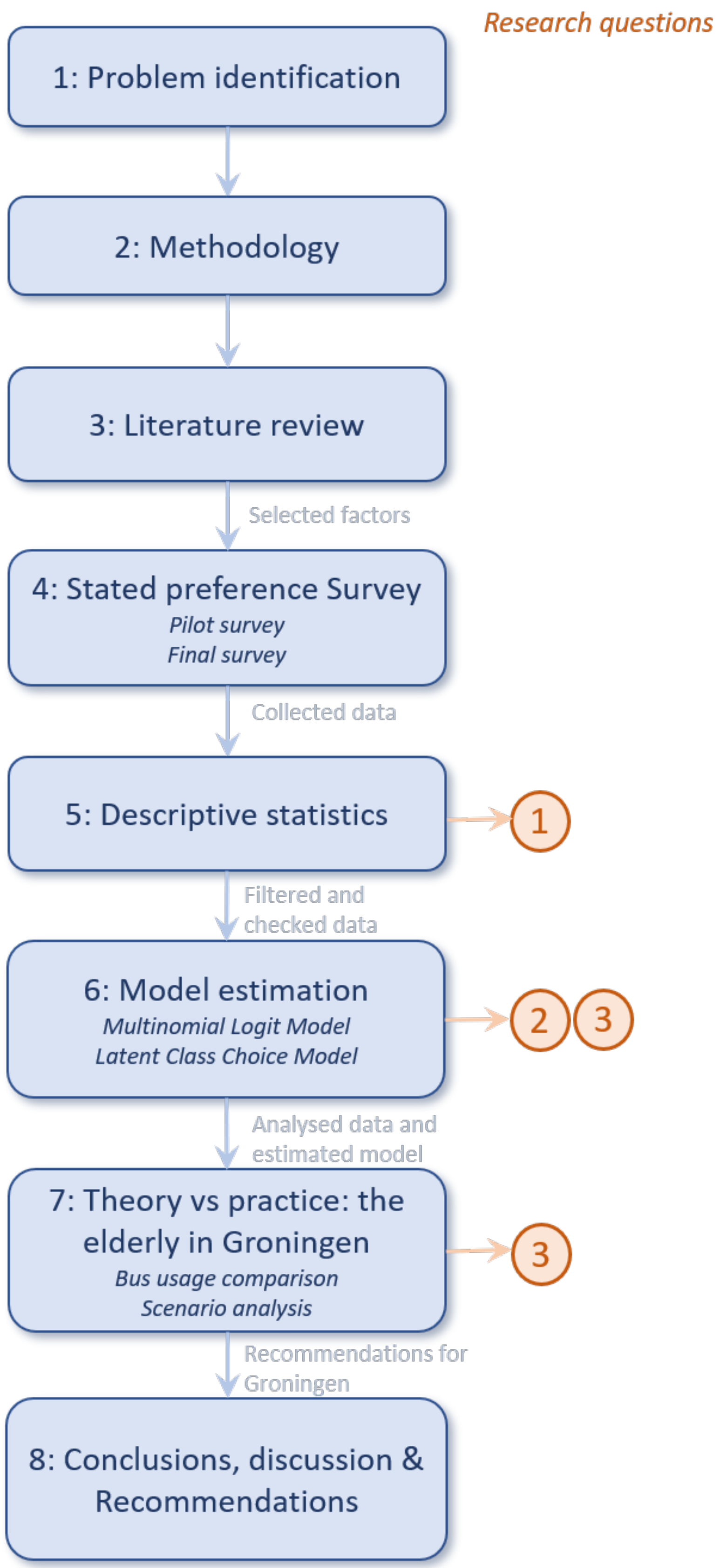


Figure 1.1: Visualisation of the research methodology

2 Methodology

This chapter describes the methods used to answer the main research question. Firstly, knowledge on the current travel behaviour and mode choice, developments and known factors influencing the travel behaviour of the elderly, is gathered. A literature study and expert interviews are used for this, as explained in section 2.1. Based on the factors found in literature and coming from expert conversations, a survey is designed and conducted to gain more insight in the preferences of (potential) bus users and the impact of the factors. The method used to design the survey is explained in section 2.2. Section 2.3 describes the methods used to analyse the gathered data from the survey. The chapter ends with a conclusion in section 2.4.

2.1. Literature Study

A literature study is conducted to provide insight into the current developments of the elderly and their travel behaviour, mode choice, and the public transport design dilemmas. Besides that, the literature study is used to identify the socio-demographic factors and mode attributes influencing the choice of the elderly for public transport services, more specifically the choice for bus. Moreover, this part is used to get insight in existing knowledge about heterogeneity in travel behaviour among different groups of the elderly.

Online databases of scientific research like Google scholar, Science Direct and Scopus are used to search for relevant studies. Keywords are used for searching such as 'mobility', 'elderly', 'public transport', 'choice behaviour' and 'ageing'. Besides this, the snowball technique is used to search for interesting articles.

Next to a literature study, interviews with colleagues from Goudappel Coffeng are conducted to find socio-demographic factors and mode attributes which influence the bus usage of the elderly and are not researched yet. These colleagues are experts and have knowledge of the research object from practical experience.

With the results of the literature study and interviews with public transport experts and research and behaviour experts from Goudappel Coffeng, the current elderly trend becomes clear. It is be determined which factors are not researched yet and which factors influencing mode choice should be included in the survey. Lastly, insight into the design dilemmas is useful when giving recommendations how the design of the current bus network can be improved for elderly.

2.2. Stated Preference Survey

To collect data of choice behaviour, people can be asked for trade-offs directly. However, there are several reasons why this method is not suitable (Chorus, 2018a). Firstly, people do not know what their trade-off is. Evolution programmed people to make choices instead of trade-offs. Second, people hesitate to give true trade-offs in many cases. Thirdly, judgment is more sensitive to bias than choices. Therefore, data based on choice observations is collected. To analyse choice behaviour, revealed preference data and stated preference data can be used.

Revealed Preference
The revealed preference (RP) method can generate information about the actual travel choice behaviour of people in real situations. This provides high valid results (Patuelli et al., 2016; Tseng et al., 2013). Besides that, it is suitable for forecasting choices if the choice alternatives and market conditions do not change much (Molin, 2018a). However, revealed preference data has some limitations. First of all, it is not possible to observe choices for new alternatives and attributes. Secondly, there is insufficient variation in the data, since it is difficult to model choices in rare circumstances. Next to that, RP data shows only the chosen alternative. This means that the choice set is unknown and assumptions have to be made which can not be controlled. Another limitation is multi-collinearity. Correlations are often too high. Some parameters are unreliable or cannot be estimated. Lastly, many respondents are required, because the output is only one choice per respondent. this makes the data collection time consuming and expensive (Molin, 2018a; Yang & Mesbah, 2013).

Stated Preference
With stated preference (SP), choice sets can be pre-specified, in-existent options and new attributes can be included, and levels outside the current value range can be tested (Ben-Akiva et al., 1992; Yang & Mesbah, 2013). Presenting choice sets to respondents makes it possible to gain more insight in ”the relative importance of attributes to individuals” (Kløjgaard et al., 2012). Furthermore, stated choice data collection is easier and multiple observations per individual are possible, which results in a larger sample size. A disadvantage of stated preference is that the intended choice of an individual may not correspond with their actual choice. What people say they will do is not always similar to their actual behaviour. This is called hypothetical bias (Wardman, 1988). To limit the hypothetical bias, Hensher (2010) mentions several suggestions such as explaining the objectives of the choice experiment clearly. Another limitation in designing SP experiments is that it depends on the researcher whether all the important attributes, and alternatives are considered, since he needs to identify these aspects himself (Bourguignon, 2015).

For this study, stated preference is chosen. SP is based on precise documented information and is overall better in retrieving significant effects of factors with important influence (Beelaerts van Blokland, 2008). This research focuses also on the answers to hypothetical situations, in which is asked what an respondent would choose in a certain situation. Since this is impossible to test with revealed preference data, SP is be used. Besides that, to the best of the author’s knowledge, the factors used in literature represent the important factors influencing travel choices of elderly just partly. There might be factors which describe the choice more concrete. These factors, mentioned in chapter 3.4 can be included in the experiment.

2.3. Discrete Choice Modelling

Discrete choice modelling is used to analyse the data from the stated preference survey. This method makes it possible to quantify the values respondents place on the attributes. Besides that, this method can explore whether and to which extent respondents are willing to trade-off between attributes. The method of discrete choice modelling is explained in this section. The general mathematical model is described and different types of models are discussed.

2.3.1. Data analysis and model estimation

Descriptive and inferential data analysis are used insights on the behaviour of the respondents. Descriptive statistics is used to describe and summarise the features of the sample and observations (Hinton, 2014). Inferential statistics is done to test hypotheses and estimate the sample variables and their reliability in order to improve the knowledge about the population (Asadoorian & Kantarelis, 2005). The software SPSS is used to conduct this analysis.

According to Chorus (2018a): "To understand and be able to forecast transportation systems and the effects of transport policies, you have to understand and be able to forecast choices". There are different options to understand and predict these choices. The manual approach can be used to predict the choices for other levels of attributes (Chorus, 2018a). However, this method has limitations. First of all, the choices are assumed to be made deterministically. This method ignores the heterogeneity across decision-makers and the inconsistency of decision-makers. Secondly, it does not enable rigorous econometric analysis. Lastly, the manual approach is very time-consuming and complex, especially for multinomial, multi-attribute choices.

Based on this insight, a model should be used allows for the inconsistency and heterogeneity of the decision makers. Besides that, the model should be usable for multi-attribute and multinomial choice situations. Therefore, discrete choice models (DCM) are suitable for this research (Chorus, 2018a). Discrete choice model obtain insight into the extent to which the choice is influenced by specific characteristics, such as socio-demographic characterisitcs or attributes. The consequences of adapting services or products or introducing new services or products on the use can be predicted. In this research, the discrete bus choice of the elderly is studied.

Discrete choice analysis uses the principle of utility maximization, which means that a decision-maker n chooses the alternative with the highest utility (U_{ni}) (Chorus, 2018a; Hensher & Greene, 2003; Wittink, 2011). Alternative i is chosen if:

$$U_{ni} > U_{nj} \quad \forall j \neq i \tag{2.1}$$

The utility is decomposed in a systematic component V_i and a random component ε_i, see equation (2.2). The systematic component includes everything that can be related to observed factors, such as travel time, cost, age and gender. The random component or error term captures the unobserved factors and randomness in choices.

$$U_{ni} = V_{ni} + \varepsilon_{ni} \tag{2.2}$$

When all parameters are considered to be linear, the utility function for an alternative can be formulated as shown in equation (2.3). In this function, β_m is the coefficient of attribute m, and χ_{im} is the value or attribute level of attribute m. However, the attributes are tested for non-linearity. Quadratic components are added to the utility function for non-linear attributes.

$$U_i = \Sigma\beta_m \mathrm{X}_{im} + \varepsilon_i \tag{2.3}$$

2.3.2. Model types

To predict choices, different models can be used. In this section, the most common used models are described and discussed.

Multinomial logit model

The most widely used and easiest model in discrete choice modelling is the multinomial logit (MNL) model (Amaya-Amaya et al., 2008; Hausman & McFadden, 1981). The probability P that an individual n chooses alternative i is:

$$P_{ni} = \frac{e^{V_{ni}}}{\sum_{j=1}^{J} e^{V_{nj}}} \tag{2.4}$$

Where J is the choice set of j alternatives and e is the base number for a natural logartihm. A limitation of this model is that it does not consider random taste variation for the attributes of alternatives. It assumes that everybody has the same preferences. However, in this research one of the goals is to investigate whether the elderly have different preferences. Another limitation is that the model does not account for correlated choice situations when observations are drawn from the same individual (Chorus, 2018a; Hensher & Greene, 2003; Train, 2002; Wittink, 2011). This might be problematic for this research, since each respondent has to answer more than one choice situations. However, MNL models are used in the reviewed literature and therefore it is justified to use MNL models in this study as well for a first insight in the preferences and bus usage of the elderly.

Mixed logit model
To overcome the limitations of the multinomial model, a mixed logit (ML) model can be used. The mixed logit model considers random taste variation, unrestricted substitution patterns, and captures panel effects. The random taste variation is captured by assuming the β differs across individuals, resulting in a distribution of the β estimates. An extra error term is added that represents variation across individuals of the utility of the common unobserved factors. The panel effect is captured by using each draw for computing the entire sequence of logit probabilities for an individual (Chorus, 2018b; Hensher & Greene, 2003; Train, 2002). Although this model can overcome the limitations of the multinomial model, it can not explain the nature of the heterogeneity . Therefore, the latent class choice model is more suitable in this research.

Latent class choice Model
The latent class (LC) choice model also overcomes the limitations of the MNL model. With a latent class choice model, the population is separated into several classes with homogeneous preferences (Molin & Maat, 2015). Across these classes, the preferences are different. For each class a set of parameters is estimated by applying the latent class model. The classes are not directly observable, and thus latent (Train, 2002). The number of classes is not known beforehand. Therefore, multiple models with different numbers of classes will be estimated. Based on the model fit of the models, the number of classes will be chosen (Shen et al., 2006). Together with the estimation of the parameters, a class membership model is estimated, modelling the probability of an individual belonging to a class based on the socio-demographic and other characteristics (Molin & Maat, 2015). By weighting the choice probabilities for each class by the estimated share of each segment, the choice probabilities for each choice alternative can be predicted.

The formula (2.5) shows the latent class choice model. In this formula, $P_n(i|\beta)$ indicates the probability of an individual n choosing alternative i, conditional on the model parameters β. The class membership probability is indicated by π_{ns}, which gives the probability that an individual n belongs to class s.

$$P_n\,(i|\beta) = \sum_{s=1}^{S} \pi_{ns} P_n\,(i|\beta_s) \tag{2.5}$$

The class membership model, shown in (2.6) uses class-specific constants δ_s and a vector of parameters γ_s, which are jointly estimated.

$$\pi_{ns} = \frac{e^{\delta_s + g(\gamma_s, z_n)}}{\sum_{l=1..S} e^{\delta_l + g(\gamma_l, z_n)}} \tag{2.6}$$

The functional form of the utility for in the class allocation is given by the linear-additive function $g(\circ)$. This function is based on observed variables such as socio-demographics, shown as z_n.

Conclusion
Both mixed logit and latent class choice models account for preference heterogeneity across individuals. However, their approaches in capturing the heterogeneity is different (Wen & Lai, 2010). With mixed logit, it cannot be investigated what the nature of the heterogeneity is. latent class choice models assume that different groups or classes with internally homogeneous preferences exist in the population, but the preferences between the classes differ.

For this study it is interesting to know why people choose a certain alternative, thus where the heterogeneity can be attributed to. Therefore, a latent class model is estimated in this study and not a mixed logit model.

2.3.3. Goodness of fit

To check whether the model fits with the data, McFaddens' rho-square based on the log-likelihood (LL) can be used. It compares the performance of the estimated model with the performance of the null model (Chorus, 2018a). The higher the log-likelihood of the final model, the better the model fits with the data. McFaddens' rho-square can be calculated with equation:

$$\rho^2 = 1 - \frac{LL(\beta)}{LL(0)} \tag{2.7}$$

Where:
ρ^2 = McFaddens' rho-square
$LL(\beta)$ = final log-likelihood
$LL(0)$ = null log-likelihood
To compare model fit across the models, two statistics can be used:

1. **Likelihood Ratio Statistic (LRS)**
   This test is used to compare two models, in which one model is a simpler case of the other model, in other words it compares two nested models. The base model is rejected when the LRS has a higher value than the threshold of the significance level (Chorus, 2018a).
   $$LRS = -2 * (LL_A - LL_B), \tag{2.8}$$
2. **Bayesian Information Criterion (BIC)**
   This criterion weighs both model fit and parsimony. The likelihood of models can be increased when adding parameters. However, this can lead to overfitting. BIC introduces a penalty term for the number of parameters used in the model to solve this problem. The lower the BIC value, the better the model. This criterion is best suited for latent classchoice models (Van Cranenburgh, 2018).
   $$BIC = -2 * LL + k * ln(N) \tag{2.9}$$
   Where:
   LL = final log-likelihood
   k = number of parameters to be estimated
   N = number of observations

Since adding more classes will always increase the model fit, because of more degrees of freedom, LL is not a good measure to assess model performance. Parsimony needs to be taken into account. Besides that, the models in this research are non-nested models. Therefore, the Bayesian Information Criterion is used.

2.4. Conclusion

The used methodology is described and elaborated on in this chapter. First, a literature study is used to gather background information and existing knowledge about factors influencing travel behaviour of elderly and heterogeneity among elderly. To gather data, a stated preference survey with choice experiments is designed. To analyse the data coming from the survey, discrete choice modelling is used. First a multinomial logit model is estimated. Secondly, a latent class choice model is applied, since this model overcomes the limitations of the MNL model and can investigate the nature of the heterogeneity.

3
Literature review

The goal of this literature study is to provide background information to get insight in existing knowledge about the elderly, their travel behaviour and factors influencing their behaviour. Section 3.1 discusses the existing knowledge on the development of the mobility and travel behaviour of elderly. Next, section 3.2 describes the mode choice of elderly. Section 3.3 focuses on the public transport network design problems. After this, section 3.4 discusses the heterogeneity and factors influencing the mode choice of the elderly. The chapter ends with a conclusion in section 3.5.

3.1. Developments of the elderly and their travel behaviour

As mentioned in the introduction, the world population is increasing and ageing. The health of the population has improved and the mortality rates are declined (CBS, 2018e). With this, the number of older people, aged 65 and over, is rising as well. This trend is shown in figure 3.1. Not only the life expectancy of people is increasing, also the number of years without lim-

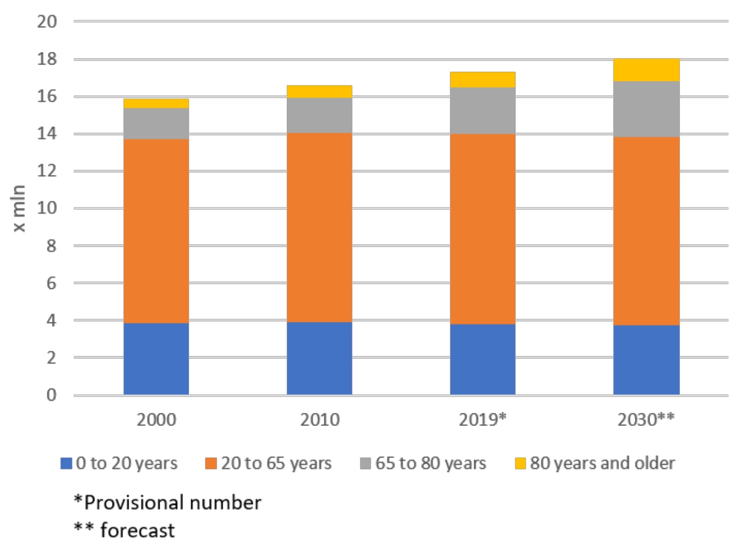


Figure 3.1: Population increase from 2000 to 2030 (CBS, 2018a)

itations and in good health is rising (CBS, 2018a; Rosenbloom & Smiley, 1999). The current elderly travel more than the comparable age groups twenty to twenty-five years ago (Siren & Haustein, 2019). They make more and longer trips and they participate in a greater variety of activities outside the door (Rosenbloom & Smiley, 1999; Szeto et al., 2017). Although the work-related trips decrease after retirement, the leisure and shopping trips do not decline before elderly have reached high age (Choo et al., 2016; Cui et al., 2017; Hjorthol et al., 2010).

Even though the life expectancy of people and the years in good health are increasing, at a certain time the travel behaviour of the elderly, in particular after the age of 75, will change (Cui et al., 2017). They are more likely to make less trips, travel less distances and travel less during peak hours or at night. These trends are shown in figure 3.2. Their purposes to travel become simpler and the mode choice options decrease (Johnson et al., 2017).

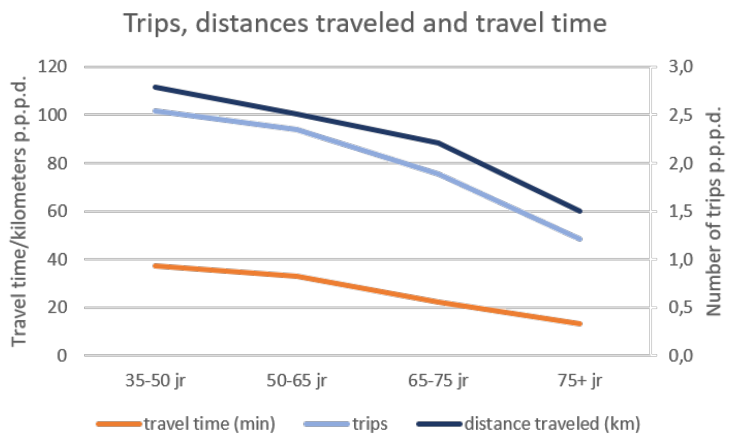


Figure 3.2: Trips, distances traveled and travel time per age group (own work, based on (CBS, 2018b))

3.2. Mode choice

The type of mode older people choose depends partly on the type of trip they are going to make and on location and personal factors (Rahman et al., 2016; Rosenbloom & Smiley, 1999). In European countries, car is the most important travel mode for the elderly, as being the driver or passenger (Szeto et al., 2017). The share of cars is much higher than those of rail and buses. When people age, the number of trips decrease (CBS, 2018c). Besides that, the travel characteristics and mode choices change. The willingness and ability to drive decreases and driving as a passenger increases. The use of public transport and walking become more important for people's independence (Su & Bell, 2009; Szeto et al., 2017). These differences in modal split based on age are shown in figure 3.3.

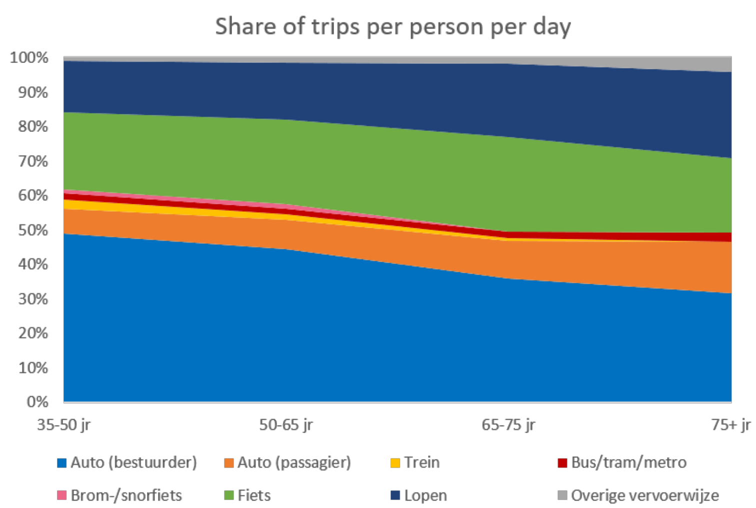


Figure 3.3: Share of trips per person per day by age and means of transport (own work, based on (CBS, 2018c))

3.2.1. Car usage

Although the number of trips and trip distances become less when people get older, older people have become more dependent on the private car as primary transport mode (Cui et al., 2017; Rosenbloom & Smiley, 1999). The new cohort of elderly uses cars more, since the car appears to have given older people more choices, a wider range of possible activities, flexibility, comfort, and independence (Buys et al., 2012).

Driver licensing among the older people is very high and still increasing, due to the rise in number of elderly and the rise in percentage of people who obtained a driver's license in general (CBS, 2016; Rosenbloom & Smiley, 1999). This increase in driver licensing between 2014 and 2019 is shown in figure 3.4.

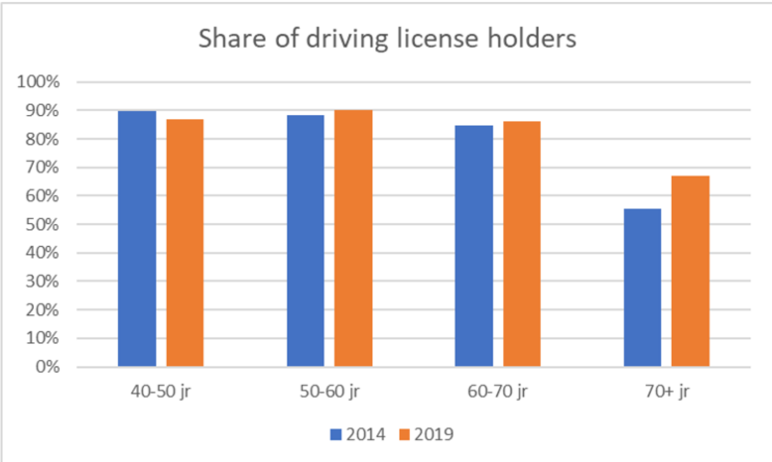


Figure 3.4: Share of driving license holders by age in 2014 and 2019 (own work, based on (CBS, 2019a))

Nowadays, 67% of the people aged 70 and older in The Netherlands has a driver's license (CBS, 2019a). This is an increase of 11% compared to 2014. The share of driving license holders is much higher for the people aged between 60 and 70, with 86%. Besides this increase in drivers licenses, the percentage of older people owning a car increased as well. The share of car owners by age from 2010 to 2015 is shown in figure 3.5.

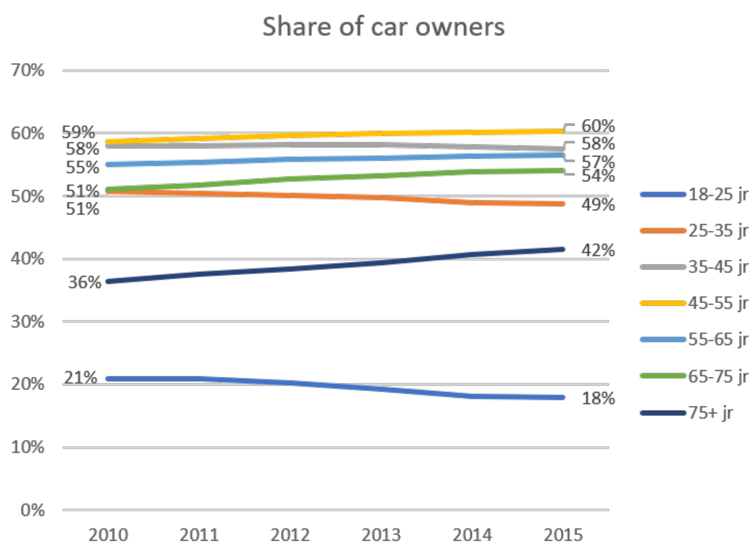


Figure 3.5: Share of car owners by age from 2010 to 2015 (own work, based on (CBS, 2018c))

The increase in car usage amongst elderly has a turning point. Older people lose the ability to drive safely at a certain point and the number of crashes of the elderly gets higher. This risk of crashes is especially the case if the older drivers do not realize they are losing skills or do not adjust their driving behaviour to drive safely. Next to this, crashes lead to more serious injuries for elderly, since vulnerability increases when people age (Rosenbloom & Smiley, 1999; SWOV, 2019).

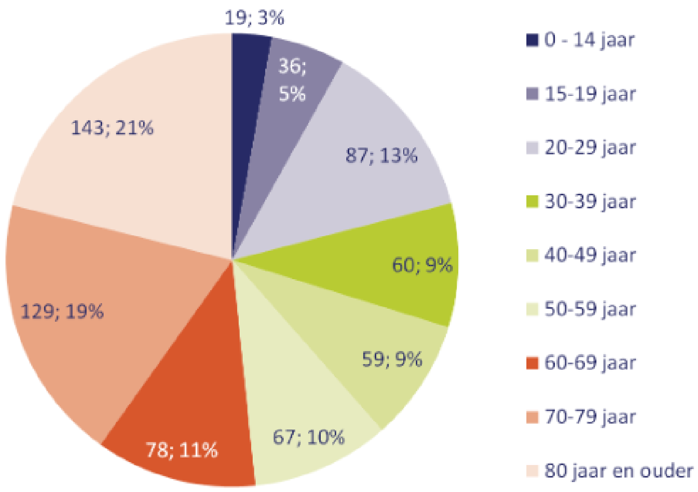


Figure 3.6: Traffic deaths in The Netherlands by age in 2018 (SWOV, 2019)

In 2018, the majority of the traffic deaths in The Netherlands were 80 years and older with 21%, followed by people aged between 70 and 80 with 19%, as shown in figure 3.6.

3.2.2. Public transport usage

Although the use of public transport can be a viable alternative to car dependency for mobile elderly and becomes more important for elderly for their independence as they age, research showed that the PT usage remains low in many parts of the world (Johnson et al., 2017). In the Netherlands, less than 10% of the elderly aged 65 or older make their trips by public transport (Szeto et al., 2017).

Various causes of this infrequent use of public transport services can be identified. Among other things unreliability, difficulties and distances to access bus stops and stations, the fear of crime, and unavailability of some destinations are important reasons (Goldenbeld, 2015). Also, concerns about personal safety at night, difficulties with carrying heavy loads, difficulties entering and alighting vehicles, behaviour of passengers, lack of toilets and the cleanliness of public transport services are barriers for usage (Buys et al., 2012; Transport, 2002).

Besides the causes mentioned, also the place of living and changes in population density influence the design and the use of public transport. In areas with a shrinking population and a declining concentration of services the public transport services are limited and under pressure (Goldenbeld, 2015; Wong et al., 2018; Yang et al., 2018). This makes it even harder for the people living here to use public transport. Next to this, suburbanization - caused by increasing car usage - has speed up the decline of public transport services and makes the option to walk impractical. This makes the problems for the elderly without a car of limited access to a car even bigger (Rosenbloom & Smiley, 1999).

Looking at the usage of the bus, in The Netherlands, seven out of ten people hardly or do not use the bus (Zijlstra et al., 2018). About three out of ten Dutch people do use the bus.

This includes people who use the bus at least one time per six months. A big part of the bus users (15%) are occasional users which use the bus less than once per month. Only a small group of less than 3% of the Dutch people uses the bus 4 days per week or more. The share of elderly is limited, an estimated 5% of the bus passengers is 65 years or older. However, the share of elderly bus passengers varies between different datasets such as OViN, KBOV and wROOV, but is never higher than 8 percent.

3.3. Public transport network design dilemma

When designing a public transport network, several dilemmas have to be considered. Opposite objectives need being balanced. As can be seen in figure 3.7, the biggest conflict in network design is between the traveller and the operator. The operator of the network wants the network with the minimum spanning tree, because of the costs. The traveller wants the fully connected network with the shortest travel time.

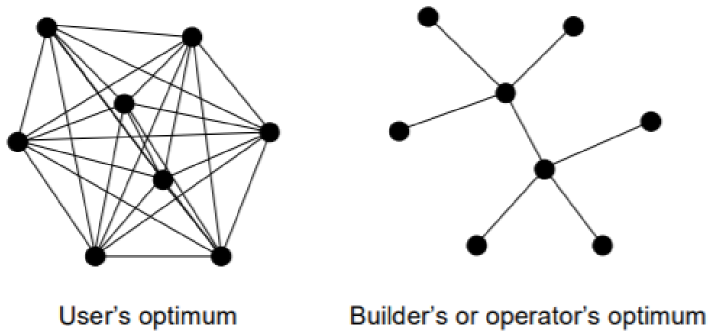


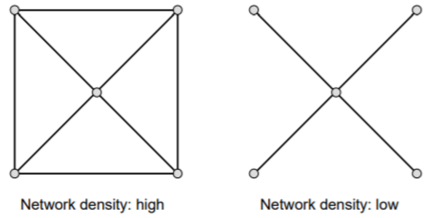
Figure 3.7: Illustration of user's optimum and operator's optimum (van Nes, 2015)

Focussing on a specific perspective, here the view of the traveller, design dilemmas do still exist. Given a fixed operational budget, five design dilemmas are defined (van Nes, 2015; Van Oort & Van Nes, 2009).

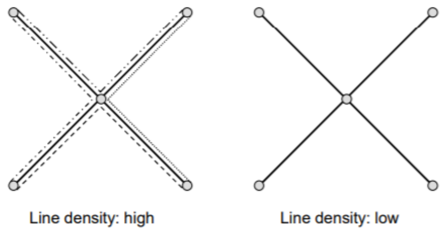
The first dilemma is short in-vehicle times versus short access times (figure 3.8a). Many stops leads to less distance to the stop. However, public transport services have to stop at every stop, resulting to large in-vehicle times. The second dilemma, shown in figure 3.8b, represents short waiting times versus short in-vehicle times. Dense networks results to short in-vehicle times because of direct routes. However, the number of buses per link will be lower, leading to less frequent services and longer waiting times. The third dilemma is minimization of transfers versus short waiting times, shown in figure 3.8c. High density of lines leads to less transfers needed. On the other hand, this results in a decrease in frequencies and to large waiting times. The fourth dilemma involves short travel times versus minimization of transfers, as shown in figure 3.8d. More network levels will lead to more transfers. However, each network will be suitable for specific trip lengths and will decrease the travel times. The fifth dilemma is the length of line versus reliability. Less transfers are needed because of longer lines, since this leads to more direct connections. On the other hand, longer lines often lead to less variability. This results to more deviations from the schedule and increased waiting times for travellers (Van Oort & Van Nes, 2009).

For urban public transport networks the key design variables are line spacing and stop spacing (van Nes, 2015). This research focuses on the urban public bus transport network. This is a single level urban network. To determine the optimal proportion for line spacing and stop spacing for urban public transport networks, only the first, third, and fifth design dilemma are important to take into account (van Nes, 2015). Therefore, the second and fourth design dilemmas are not relevant for this research. The optimum values for the mentioned network characteristics depend on the formulated objective and the movement pattern (Eck, 2010). Research showed that the option with fewer lines and stops but higher frequency is preferred

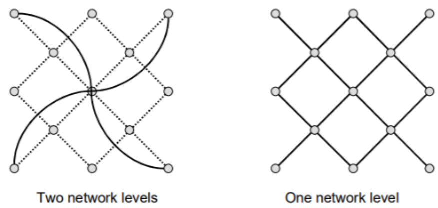
(a) Stop densities design dilemma (van Nes, 2015)



(b) Network density design dilemma (van Nes, 2015)



(c) Line density design dilemma (van Nes, 2015)



(d) Network levels design dilemma (van Nes, 2015)

Figure 3.8: Public transport network design dilemmas

the most by passengers, because of less waiting time and less in-vehicle time (KiM Netherlands Institute for Transport Policy Analysis, 2016). This means passengers will reach their destination faster. Besides that, it makes planning a trip and reaching connections easier since the frequency of the service is high.
However, for the 6% of people in the Netherlands with disabilities, such as for an important group of the elderly, the distance to a public transport service stop can be problematic (Bakker et al., 2018). For them, it is desirable to have access to public transport services nearby their homes.

3.4. Heterogeneity and factors influencing mode choice of elderly

Older people are different from each other in terms of their characteristics and level of mobility and thus prefer different types of modes (Rosenbloom & Smiley, 1999; Shrestha et al., 2017). For example, many older people are active and healthy for years or decades after retirement, but an important part of the elderly is not. Most of the elderly have a driver's license, but a substantial part has not. Among the older population aged 60 to 70, 13,9% does not have a driver's license (CBS, 2018d). This is even higher among the elderly aged 70 and above, with 32,8%. Older women are less likely to own a driver's license or to own a car than men. This difference is the biggest among the age group of 70 years and over, where 80% of man have a driver's license against 53% of women (CBS, 2018d). This section elaborates on the factors influencing the mode choice of elderly and in particular the choice for public transport found in literature. Besides that, this section discusses the heterogeneity among elderly.

3.4.1. Factors influencing the mode choice of elderly

There are various studies available in which factors are defined that influence travel behaviour, and thus the mode choice, of the elderly. Cui et al. (2017) reviewed 19 scientific articles and retrieved insight in the travel behaviour and mobility needs of the elderly. The articles are reviewed to investigate among others the most important factors influencing the travel behaviour of the elderly. Eight of the reviewed articles fit within the scope of this research and are reviewed again. These studies are separated in papers exploring important factors influencing the mode choice of elderly in general and papers exploring important factors influencing the choice of elderly to use public transport specifically. Besides the articles mentioned in Cui et al. (2017), the studies of Böcker et al. (2017); Haustein (2011); Kim & Ulfarsson (2004); Schmöcker et al. (2008) are valuable and added to the list (studies [7], [8],

[9] and [12]), since they focus on the same topic. The list of the studies with its location, age group, study goals, type of factors, used data and model are summarized in table B.1 in appendix B.

The literature review shows many factors influencing the travel behaviour of the elderly and the choice to use public transport specifically. Besides personal characteristics and mode attributes, other factors such as trip attributes, mobility related attitudes and built- and environmental factors influence the travel behaviour. However, this research focuses on the personal characteristics and mode attributes influencing the travel behaviour of the elderly. Therefore, only these types of factors are included in the research and study review.

The results of the reviewed studies are shown in the tables below. First, the results of reviewed studies indicating the factors influencing mode choice of the elderly (studies [1] until [9]) are shown in table 3.1. The results of the reviewed studies indicating the factors influencing the use of public transport specifically (studies [7] until [12]) are shown in table 3.2.

Table 3.1: Factors influencing the mode choice of the elderly per study

Factors	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Personal characteristics									
Age	x	x	x	x			x	x	x
Gender		x	x	x	x		x		x
Ethnicity							x		
Driver's license				x					
Car ownership		x		x			x	x	x
PT card							x		
Bicycle ownership							x		
Household size		x	x		x		x	x	
Geographical location living					x			x	x
Health (disabilities)		x	x		x		x		x
Income							x	x	x
Educational level		x					x		
Size of social network								x	
Mode attributes									
Travel time	x								x
Stop density									x
Costs									x
Distance to stop								x	
Safety						x			
Comfort									x

Where: [1] (Yang et al., 2013); [2] (van den Berg et al., 2011); [3] (Boschmann & Brady, 2013); [4] (Hjorthol et al., 2010); [5] (Davey, 2019); [6] (Zeitler et al., 2012); [7] (Böcker et al., 2017); [8] (Kim & Ulfarsson, 2004); [9] (Schmöcker et al., 2008)

From the literature review of the studies [1] to [9] it can be concluded that the factors influencing the travel behaviour of elderly are varying per study. Some factors are mentioned in several studies, such as the personal characteristics 'age', 'gender', 'car ownership', 'household size', 'geographical location living', 'health (disabilities)', 'income' and 'educational level'. However, it cannot be concluded that these factors are more important than the other factors. Possibly less attention has been paid to the other factors or they are not taken into account in most of the reviewed studies. For example, the influence of size of social network is only studied in Kim & Ulfarsson (2004) and not even mentioned in the other studies.

Table 3.2: Factors influencing the choice of the elderly for Public transport

Factors	Study [7]	[8]	[9]	[10]	[11]	[12]	Sign	Significant
Personal characteristics								
Age	x	x	x	x	x	x	+/-	yes
Gender (male, ref = female)	x		x	x	x	x	-	yes
Ethnicity (non-Western, ref = Western)	**x**						+	yes
Driver's license (yes, ref = no)				x	**x**		-	yes
Car ownership (yes, ref = no)	**x**	**x**				x	-	yes
PT card (yes, ref = no)	x						+	yes
Bicycle ownership (yes, ref = 0)	x						-	no
Household size	x			**x**	x	x	-	yes
Location living (the more urban)			x	x			+	yes
Health (disabilities)	x		**x**	x		x	-	yes
Income	x	**x**	x	x	**x**	x	-	yes
Educational level				x		x	+/-	yes
Children living nearby				**x**			-	yes
Mobile phone possession				x			+	yes
Employed					x	x	+/-	yes
Mode attributes								
Travel time			x				-	yes
Stop density			**x**	x			+	yes
Costs			x				-	yes
Distance to stop		x		x		**x**	-	yes
Safety (accidents)						x	-	no
Safety (harassment)						x	-	no
PT excitement						**x**	+	yes
PT easiness of use						x	+	yes
Seat availability			x				+	?
Reliable services			x				+	?
Time to get on and off PT			x				+	?

Where: [7] (Böcker et al., 2017); [8] (Kim & Ulfarsson, 2004); [9] (Schmöcker et al., 2008); [10] (Truong & Somenahalli, 2015); [11] (Moniruzzaman et al., 2013); [12] (Haustein, 2011)

Signs with value '+/-' indicate a difference in the results of the different studies. Signs with value '?' indicate lack of clarity of the significance of a factor.

Table 3.2 shows the factors influencing the choice for public transport specifically according to literature. In this table also the sign and significance of the parameters are shown. In each study the parameters of the factors are estimated. The values of these parameters are different per factor and different in each study. The two factors with the highest parameter values of each study are shown in the table with bold crosses.

The definitions of the different factors are explained below:

- **Age:** The age of the elderly.
- **Gender:** The gender of the elderly, male or female.
- **Ethnicity:** The ethnicity of elderly, non-western or Western.
- **Driver's license:** The possession a driver's license or not.
- **Car ownership:** The possession of a car or not.
- **PT card:** The possession of a Public Transport card or not.
- **Bicycle ownership:** The possession of a bicycle or not.
- **Household size:** The number of person in the household.
- **Location living:** The closeness of home to CBD, or whether living urban or rural.
- **Health:** The degree of disabilities elderly have.
- **Income:** The height of the personal net income.

- **Educational level:** The height of the level of education.
- **Size of social network:** The number of people with whom the elderly have social contact.
- **Children living nearby:** Whether children are living close to the elderly or not.
- **Mobile phone possession:** The possession of a mobile phone or not.
- **Employed:** Having a job or not.
- **Travel time:** The travel time when using public transport.
- **Stop density:** The distance between stops.
- **Costs:** The public transport fare.
- **Distance to stop:** The distance to a public transport stop.
- **Safety (accidents):** The extent to which an individual feels safe with regard to be involved in an accident.
- **Safety (harassments):** The extent to which an individual feels safe with regard to harassments and attacks.
- **PT excitement:** The extent to which positive aspects are associated with the use of public transport, e.g. social communication and relaxing.
- **PT easiness of use:** The extent to which individuals perceive the use of public transport as easy and the extent to which individuals feel autonomous when using public transport.
- **Seat availability:** The availability of seats.
- **Reliable services:** The extent to which public transport services are available and stick to their timetables and schedules.
- **Time to get on and off PT:** The time to board or alight from public transport.

As shown in the table, not all factors are significant in each study. The factors with a question mark are mentioned in the study in a qualitative way, but do not have a quantitative value. Therefore, it is impossible to conclude whether these values are significant. The circumstances of a study influence the significance of the factors in that particular study. A significant factor in one study does not guarantee that it is also significant in another study (Kløjgaard et al., 2012). Therefore, all factors coming from the literature review in this table can be considered for this research.

It can be concluded from the literature review that the factors with the most influence on the travel behaviour, the choice for public transport specifically, are different per study and thus scattered. The factors 'car ownership' and 'income' are marked two times as factors with highest parameter values. It should be taken into account that the studies differ in their usability and reliability. First of all, the locations of the studies are spread worldwide, except from study of Böcker et al. (2017) [7], which is is coming from Rotterdam. These cities have their own public transport service networks with corresponding characteristics. Secondly, the data sets used in the studies [8] and [9] are coming from 2000 and 2001, respectively. In the meantime there have been many developments in the areas of transport, mobility and characteristics of the elderly. Besides that, the number of respondents of study [10] is 177, which might influence the reliability of the research.

Since the results are scattered and the studies are scattered in terms of their location, number of respondents, year of the research and used model, all factors mentioned in the table can be considered to include in the survey. However, the number of factors is too high to include them all. Therefore, a selection is made in chapter 4.1.2.

3.4.2. Relevant socio-demographic factors according to experts

Experts from Goudappel Coffeng with many years of practical experience are asked about factors which might be important and are not researched yet, or should be researched in more detail. Arthur Scheltes and Anne Koot are experts in public transport. According to Koot (2019), it is interesting to include social environment, indicating whether there are people in the immediate vicinity which are willing to drive the older person somewhere. Having many people around willing to drive you might lead to less bus usage of elderly. Another interesting factor is car ownership of the household, which might lead to less bus usage as well. Besides that, the health factor of the people could be included in other ways, such as the ability to cycle. Being able to cycle increases your mobility, which makes it also easier to walk to reach a bus stop and might lead to more bus usage. According to Scheltes (2019), it is interesting to include whether elderly make use of the Valys, since this might lead to less bus usage. Also the distance to the nearest bus stop in meters and minutes walking, since the expectation is that elderly dislike a high distance to the nearest bus stop. Therefore, it is also interesting to include the question whether the elderly are able to reach the bus stop without help of other people.

3.4.3. Missing factors and gaps in literature

Although research has been done about mode choice of elderly and the choice for public transport, to the best of the author's knowledge, almost no research has been examined specifically on the bus usage of the elderly. Several socio-demographic characteristics and mode attributes have been taken into account in existing research. However, some of the attributes can be more specified, such as health. Health is a broad concept, with multiple definitions (Davey, 2019). People give a different meaning to this concept. Studies use 'disabilities' in terms of yes or no, which is unclear since disabilities can be anything (Böcker et al., 2017; Haustein, 2011). Other studies asked respondents to indicate their mobility level and health status on a rating scale (Haustein, 2011), which is very subjective. The study of Truong & Somenahalli (2015) only takes health into account in terms of difficulty with walking. This is not a complete indicator for the overall health of a person. The attribute should be more specified and give information about the distances respondents are able to walk or the extent to which they are able to use different modes of transport.

Another attribute which can be defined more specifically is the geographic location. In research from Schmöcker et al. (2008) the postcode of the residence of respondents is included to determine the location of residence in inner or outer London. Truong & Somenahalli (2015) considers the location in terms of distance to the Central Business District by car and asking for the perceived walking time to the nearest public transport stop. These studies do not consider distance to a bus stop specifically, and the perceived walking time to a bus stop, which might be different from the real distance.

Besides that, just one study, the study of Truong & Somenahalli (2015) uses the attribute mobile phone possession. This research suggests that the possession of a mobile phone increases the likelihood to use public transport among older adults. However, this relationship according to bus usage specifically is not researched yet. Next to that, internet connection and frequency of mobile phone usage are not considered and might be important to reveal deeper relationships.

3.4.4. Clusters among the elderly

To get more insight in the heterogeneity in travel behaviour amongst the elderly and to differentiate subgroups, already several cluster studies have been done. Haustein (2011) did research in Germany and made a mobility-related segmentation for the elderly, relying on the most important determinants of elderly mobility behaviour. Hildebrand (2003) distinguished six different lifestyle clusters with differences in travel behaviour based on socio-demographic variables in Portland, United States. However, the used data is coming from 1994 and the travel behaviour, mobility options and characteristics of the elderly have been changed in the meantime. Siren et al. (2013) analysed the travel behaviour and expectations of Danish baby boomers in order to better understand how the ageing baby boomers may affect future travel demand. The study identified three sub-groups with different expectations regarding the future. These sub-groups also differed in terms of their current travel behaviour and living conditions. The three studies have some disadvantages in common. All three of them used the k-means approach for cluster analysis. This approach has some problems (Kroesen, 2018). First of all, the cases are deterministically assigned, which leads to biases in cluster centers. Secondly, it is impossible to include nominal variables. Thirdly, there are no statistical criteria to choose the number of clusters. Another lack in these studies is that geographic location is not taken into account.

3.5. Conclusion

This chapter provided background knowledge about elderly and their travel behaviour, public transport network design dilemmas, factors influencing the mode choice of elderly, and heterogeneity among the elderly.

Elderly have become more dependent on car as primary mode of transport. The number of cars and driving licenses has increased among the elderly. The usage of public transport, specifically the bus, is very low. Around 5% of the bus passengers is 65 years or older.

When designing a public transport network, five dilemmas have to be considered. Only three of them are important to take into account when designing an urban bus network, since the key design variables for a urban public transport network are line spacing and stop spacing. These dilemmas include the stop density, line density, and length of line versus reliability design dilemmas.

There are many factors influencing the mode choice of elderly. All factors resulting from the literature review about the choice for public transport can be considered to use in the survey. These factors are: age, gender, ethnicity, driver's license, car ownership, PT card, bicycle ownership, household size, location living, health, income, educational level, children living nearby, mobile phone possession, employed, travel time, stop density, costs, distance to stop, safety, PT excitement, PT easiness of use, seat availability, reliable services, and time to get on and off PT. This list of factors will be extended with the use of expert consulting. However, a selection of factors will be included in the survey, because there are too many to include them all. This selection is made in the next chapter.

4

Survey design

This chapter presents and describes the stated preference choice experiment. A questionnaire is used in this research to examine which socio-demographic factors and bus network attributes, and to which extent, influence bus usage and preferences of the elderly.
This chapter starts with the description of the alternatives, attributes and attribute levels used in the stated preference survey in section 4.1. Section 4.2 presents the survey design with its model specification, experimental design and the construction of the questionnaire. After that, sections 4.3 and 4.4 present the design and results of the pilot survey and final survey. The chapter ends with a conclusion in section 4.5.

4.1. Alternatives, attributes and attribute levels

This section describes the alternatives, attributes and attribute levels used in the stated choice experiment.

4.1.1. Alternatives

In the stated choice experiment in this research, respondents were asked to choose between two bus options A and B. The alternatives are unlabeled, which means the alternatives have generic parameters (ChoiceMetrics, 2018). Respondents have to choose from only two alternatives in order to make the design not too complex and to get enough responses from the elderly. An opt-out alternative is left out, since the objective of this study is to compare the levels and attributes of the choice experiment by computing the marginal effects (Campbell & Erdem, 2019). When including a reference or opt-out alternative, respondents may choose this alternative when they are indifferent about the alternatives or to avoid making difficult trade-offs. When this occurs, the choices for the opt-out alternatives would not provide information about the trade-offs between other alternatives in the choice tasks. This could lead to less accurate model parameters (Chintakayala et al., 2009).

4.1.2. Attributes

In a choice experiment, the number of attributes that can be included is unrestricted. However, the more attributes included, the more complex for respondents to answer the questions leading to inconsistency and inaccuracy (Mangham et al., 2009; Snowball, 2008). Therefore, the advice is to use a maximum of 6 or 7 attributes. According to Molin (2018a) the attributes which are most important for respondents and the attributes which are relevant for policy or design should be included. The attributes used for the stated preference survey are based on the outcome of the literature study and expert interviews. Not all attributes can be tested, since this requires too many questions. Therefore, a selection has been made which mode attributes are most relevant and researched in this study. The following attributes are selected for the SP experiment:

Travel time: the time in the bus to travel from A to B in minutes.

Travel costs: the costs for using the bus service in euros.
Frequency: the time in minutes between the departure of two consecutive buses (headway time).
Transfers: the number of transfers from bus to bus needed to arrive at the destination.
Distance to bus stop: the distance from home to the nearest bus stop in meters.

The attributes 'travel time' and 'travel costs' are included in the choice experiment, since these are common attributes to design realistic alternatives and determine the willingness to pay for travel alternatives (Athira et al., 2016; Wien, 2017). The attributes 'frequency', 'transfers' and 'distance to bus stop' are included, because these are related to public transport network design dilemma variables mentioned in section 3.3.

The key design variables for urban public transport networks are stop and line spacing. As shown in section 3.3, stop spacing influences the distance to a stop and travel time. Line spacing has an effect on the number of transfers, which influences travel time and frequency on the one hand and reliability on the other hand. Since reliability can be interpreted differently, is hard to capture and is not required to include for the objective of this research, this attribute is left out in this choice experiment.

Other important aspects of public transport services are safety, comfort, easiness of use, and excitement (Haustein, 2011; Schmöcker et al., 2008). However, including these factors as attributes leads to too many attributes in the choice sets. Next to that, these factors do not influence the design dilemmas mentioned in section 3.3 and are hard to capture as attribute, since they can be interpreted in various ways. Therefore, these attributes are not included in this stated choice experiment.

4.1.3. Attribute levels

The number of levels per attribute is often limited to 2 to 4 levels (Molin, 2018a). The number of attribute levels is important, since this influences the significance of the attribute. An increase in the number of attribute levels increases the possible significance of that attribute, since respondents are likely to consider attributes with more levels as more important. By adding the same number of levels to all attributes, this problem can be avoided (Kløjgaard et al., 2012).

In this choice experiment, all attributes, except from 'transfers', have three levels to make it possible to test for linearity. The attribute 'transfers' has only two levels. The attributes with the used levels are shown in table 4.1.

Table 4.1: Attribute levels used in the choice experiment

Attribute	Attribute levels		
Travel time [min]	20	30	40
Travel costs [euro]	1,50	2,50	3,50
Frequency [headway]	60	15	7,5
Transfers [#]	0	1	
Distance to bus stop [meter]	200	400	600

The levels of 'travel time' are based on the average trip distance and speed of the bus. The average trip distance by bus is 9 kilometres (Zijlstra et al., 2018) and the average speed of the bus is 20 km/h (van Nes, 2015). This leads to an average travel time of 27 minutes. The attribute levels are set to 20, 30 and 40 minutes.

The attribute levels of 'travel costs' are based on the costs of travelling on balance, and exists of two components: a fixed basic rate plus a fixed rate per kilometer. The national determined basic rate for 2019 is 0,96 euros. The rate per kilometer is based on (9292ov, 2019; GVB, 2019; HTM, 2019) and is 16,6 cents per kilometer. With an average trip length of 9 km, the average costs are 2,45 euros. However, people aged 65 and over get a reduction of 34%, which leads to a price of 1,62 euros. The attribute levels are rounded up to 50 cents and set to 1,50, 2,50, and 3,50 euro.

The levels of 'frequency' are based on the average operating frequency per stop in the Netherlands for workdays (Zijlstra et al., 2018). The frequency in the urban areas is mostly between two and eight times per hour. The attribute levels are set to 1 bus per 60 minutes, 1 bus per 15 minutes and 1 bus per 7,5 minutes.

The attribute 'transfers' has two levels. The chosen values are set to 0 and 1, since it is unlikely to transfer more than one time during a bus trip.

The 'distance to bus stop' is based on the current values for stop spacing for urban public transport networks in the Netherlands, which ranges between 350 and 450 meter (van Nes, 2015). The attribute levels are set to 200, 400 and 600 meters.

4.2. Survey design

To create a stated choice experiment, three steps need to be taken (ChoiceMetrics, 2018). The first step is determining the model specification. The second step is choosing the type of experimental design and generating the design, in which hypothetical choice situations are created. The last step is generating the survey which is usable for collecting the data.

4.2.1. Model specification

Based on the alternatives, attributes and attribute levels, the model is specified. The utility function is specified in equation 4.1. This utility function is similar for both alternatives since the alternatives are unlabeled and have generic parameters.

$$V_i = \beta_{TT} * TT + \beta_{TC} * TC + \beta_F * F + \beta_{TF} * TF + \beta_{SD} * SD \tag{4.1}$$

Where:

V_i = utility of alternative i
β_{TT} = generic parameter for the variable 'Travel Time' (TT)
β_{TC} = generic parameter for the variable 'Travel Costs' (TC)
β_F = generic parameter for the variable 'Frequency' (F)
β_{TF} = generic parameter for the variable 'Transfers' (TF)
β_{SD} = generic parameter for the variable 'Distance to bus stop' (SD)

4.2.2. Experimental design

After the model specification, the experimental design is developed. This describes the hypothetical choice situations the respondents have to choose from in the stated choice experiment (ChoiceMetrics, 2018). There are several designs possible. The following questions are answered to find the best design for this research (ChoiceMetrics, 2018):

- Should the design be labelled or unlabelled?
- Should the design be attribute level balanced?
- How many attribute levels are used?
- What are the attribute level ranges?
- What type of design to be used?
- How many choice situations to use?

As mentioned before, the model specification has alternatives with generic parameters. Therefore, the design is unlabelled. The design is attribute level balanced, indicating that each level of an attribute will occur with equal frequency. This minimizes the variance in parameter estimates (Mangham et al., 2009).

The more attribute levels used per attribute, the more choice situations are needed in the design. Besides that, using different numbers of levels for each attributes may also lead to more choice situations needed. The number of attribute levels is set to three for all attributes except from the attribute 'transfers', which is set to two levels. The three level attributes minimizes the number of choice situations needed while making it possible to test for non-linearity of the attributes. The ranges of the attribute levels are set relatively wide, since this leads in theory lead to more significant parameters. However, using too wide ranges can lead to choice situations with dominated alternatives (ChoiceMetrics, 2018). It is important that the shown attribute levels make sense to the respondents.

Different design types can be considered for the experimental design. In a full-factorial design all possible combinations of all selected attribute levels are constructed. However, this leads to too many alternatives in the research (Molin, 2018a). Therefore, a fractional factorial design is suitable, which is a fraction of the full factorial design and has a smaller number of alternatives. Within the fractional factorial design various design types exist. Orthogonal design have statistically independent attributes and an efficient designs minimize the standard errors (Molin, 2018a). In this research an efficient design is used, because efficient designs maximize the information from each choice situation, avoid dominance of a choice alternative by utility balancing, and may increase the reliability of the parameters. Besides that, less choice sets are needed. However, this design needs accurate prior parameter estimates, which requires more effort (ChoiceMetrics, 2018; Molin, 2018a). In order to obtain designs which include the uncertainty about the prior parameter estimates, a Bayesian efficient design is used. This design uses random priors instead of fixed priors, which are described by random distributions. The determination of the prior parameter estimates is further described in the next paragraph 4.2.3.

The number of choice situations needed depends on the design. This research uses an efficient fractional factorial design which results in 12 choice sets. Per respondent, the number of choice sets should be around 10, depending on complexity of and familiarity with the alternatives, attributes and choice tasks (Molin, 2018b). Since a panel will be used in which respondents are paid for participating in the survey, it is chosen to give every respondent 12 choice set questions.

To create the choice set for the survey, the software package Ngene is used. With this software, designs with any number of alternatives, choice tasks, attributes and attribute levels can be generated. Furthermore, design properties such as attribute level balance can be controlled. The syntax of the Ngene model for the pilot survey can be found in Appendix C. The choice sets resulting from the Ngene model are presented in appendix C.2.

4.2.3. Prior parameter estimates

In order to make use of an efficient design, prior parameters need to be estimated. The efficient design depends on the prior parameter estimates and their accuracy. The last years, Bayesian efficient designs have been used in order to get more robust designs. These are less dependent on the accuracy of the prior parameter estimates, since they take the prior parameter estimates as random parameters which are described by random distributions (ChoiceMetrics, 2018).

In order to obtain the prior parameter estimates, several steps are taken. First of all, literature is used to search for coefficients for each attribute as estimated in other studies. Since it was not possible to find a single previous study that contains estimated coefficients for all attributes considered by the analyst, coefficients from multiple studies are combined.

The literature studies from Schmöcker et al. (2008), Wong et al. (2018), Truong & Somenahalli (2015) and Lucas et al. (2007) are used to obtain the priors. However, due to scale differences, the coefficients could not be used directly. The ratios of coefficients should be used, with a common attribute as the base Bliemer & Collins (2016). Unfortunately, the studies do not have a common attribute, which made it hard to compare them. Even without estimating the parameters, determining the signs of the parameters by reasoning and using literature and using a prior parameter not equal to zero would already improve the design

(ChoiceMetrics, 2018).

After trying and changing the parameters in Ngene, the prior parameters are estimated. Since only the sign of the prior parameters is known and the variance and exact magnitude are unknown, uniform distributions are used. The probabilities are checked and are in line with the expectations. The prior parameter estimates and their range in utility contribution are shown in table 4.2. Transfers has the highest utility contribution range, followed by distance to stop, since it is assumed that those attributes are very important for elderly. Frequency has the lowest utility contribution range, since it is assumed that frequency contributes to utility up to a certain height. For example, it is assumed that having a frequency of 6 times per hour or 10 times per hour is not relevant for the elderly. However, having a frequency of 1 time per hour or 4 times per hour does matter.

Table 4.2: Prior parameter estimates

Attribute	Prior parameter estimate	Utility contribution range
Travel time	-0.035	[-0.7, -1.4]
Travel costs	-0.35	[-0.53, -1.23]
Frequency	0.08	[0.08, 0.64]
Transfers	-1.4	[0, -1.4]
Distance to stop	-0.00225	[-0.45, -1.35]

4.2.4. Construction of the questionnaire

After the experimental design is created, the questionnaire is constructed. The output of the experimental design presents different rows with values for attributes. These rows are converted into choice situations. Besides asking for the respondent's preferences with regard to the choice situations, information related to the personal characteristics of the respondent is collected. The survey was constructed with the use of the software Snap Surveys (Snap, 2019). The survey is conducted two times. The first time, a pilot survey is conducted to test the survey and the second time the final survey is distributed among the target audience with the help of PanelClix, which is explained in section 5.1.1

4.3. Pilot survey design and results

The pilot survey is conducted among colleagues of Goudappel Coffeng and among some older people to test whether the respondents understand the choices they are asked to make. The pilot survey was updated according to the given feedback in section 4.3.1. The survey consists of an introduction, choice tasks and questions related to personal characteristics and is distributed in Dutch.

Introduction

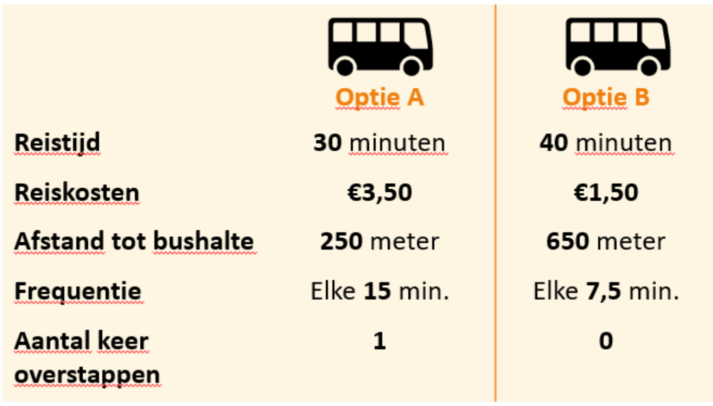
The introduction gives the respondents a description of the questionnaire.

Choice tasks

Twelve choice tasks are given to the respondents. The experimental conditions are given at the start of the questionnaire:

"Imagine you are making a trip from your home to your destination by bus. The temperature outside is 17 degrees Celsius and there is no rainfall. You do not carry any (large) luggage with you."

Respondents are asked to choose between two bus options A and B and are asked to select the option they prefer. The attributes and levels for each option are shown. A visualisation of a choice situation in the pilot survey is shown in figure 4.1.



	Optie A	Optie B
Reistijd	30 minuten	40 minuten
Reiskosten	€3,50	€1,50
Afstand tot bushalte	250 meter	650 meter
Frequentie	Elke 15 min.	Elke 7,5 min.
Aantal keer overstappen	1	0

Figure 4.1: Example of a choice situation pilot survey (own work)

Socio-demographic characteristics

Questions about the personal characteristics of the respondents are included to gain more information about the respondents. These questions are placed at the end to prevent respondents leaving the survey before finishing the choice experiment, since some questions are about privacy-sensitive information. The following socio-demographic characteristics are selected from the literature review, table 3.2, and from interviews with experts:

- Gender
- Age
- Zip code
- Household situation*
- Income (Bruto)
- Usage of walking tool
- Physically able to cycle
- Bicycle usage
- Car ownership
- Driving license
- Taken to or from destination by family or friends sometimes
- Valys** usage
- Bus usage
- Public transportation subscription/ticket
- Ability to reach nearest bus stop without help
- Distance to nearest bus stop in meters
- Distance to nearest bus stop in minutes walking
- Mobile phone possession
- Internet access mobile phone
- Internet usage mobile phone
- Usage of trip planner via mobile phone

*Household situation indicates whether the person is living together with someone else and/or with children. ** Valys is transport for travelers with reduced mobility who want to make social-recreational trips further than 25 km from their home address (Valys, 2019).

Ethnicity is left out, since this research is conducted in The Netherlands, and not in the focus of this research. Employment is not included, because the target group is people of 65 years and older. At this moment, the retirement age is 67. Therefore, it is assumed that most people are already retired. Also educational level is left out, since not all factors could be included and it is assumed that other characteristics are more important to take into account.

4.3.1. Pilot survey results

The pilot survey was distributed among colleagues, friends and elderly via e-mail. In total, 15 respondents provided feedback on the pilot survey.

Respondents indicated that it was difficult to choose between the options A and B in every choice set. The choice sets are quite similar, it is hard to see the differences between the options and there are many attributes which need to be judged again in every question. Some respondents mentioned that this is caused by the absence in use of icons instead of text and the absence in color differences in choice sets. Other respondents noticed that the context of the choice sets is unclear and only mentioned once at the start of the questionnaire. Among others the trip purpose and whether you are travelling on your own or with companions is not written down. Besides that, respondents indicated that it is not mentioned whether people must imagine that they are in the situation of the context description and have to choose one bus option, even if they never travel by bus.

Respondents commented on the second part of the survey, containing questions about socio-demographic characteristics, that the 'I don't know' option is missing at several questions. The options of the question about bus usage seems to be illogical and it is more common to ask about gross income instead of net income. The question about residence can be taken out, since there is already a question about the zip code.

4.4. Final survey design

Based on the feedback from the respondents, adjustments are made to the pilot survey. The main adjustments are described in section 4.4.1, whereafter the design of the final SP survey is shown in section 4.4.2.

4.4.1. Improvements from SP pilot survey

The Stated Preference survey is improved on the basis of the feedback on the pilot survey. The following adjustments are made:

- The explanation of the attributes are updated in more logical and understandable sentences and the choice context is adjusted by indicating travel companion and trip purpose. This context is presented at the beginning of every choice set question, so that respondents do not have to go back in order to remind the context situation.

- To make the differences between the options within a choice situation and between choice situations clearer, icons are added to the attribute values of 'travel time' and 'distance to stop' and for every new choice set the color of the lines around the choice set change.

- The income question is changed from net income to gross income and the options for bus usage are changed according to the multiple choice options used in the questionnaire of the 'OV klantenbarometer'.

- The question about residence is taken out the questionnaire, since zip code is already asked.

- A question about the usage of public transport trip planner via mobile phone is included, since it was unclear in the pilot survey why the question about 'internet usage mobile phone' was asked.

- For the entire survey some changes are made in the construction and structure of the sentences and questions.

It is chosen to do not change the number of attributes, because Dogterom (2019), expert in research and behaviour from Goudappel Coffeng, mentioned that people will make a choice based on the attributes which are most important according to them. When deleting attributes, valuable information might get lost.

4.4.2. Design of the SP final survey

The attributes, attribute levels and number of choice situations remained the same as in the pilot survey. The Ngene syntax remained the same as well. However, the model has been run again to shuffle the choice situations and options. The design is checked for dominance, attribute level balance and whether the choice probabilities for every choice set are as expected. The resulting 12 choice situations are shown in appendix C.2. The complete SP final survey in Dutch is included in Appendix D. The respondents are informed at the start of the questionnaire about the approximate completion time of 10 minutes. The survey starts with an introduction. After the introduction, 12 choice situations are given. An example of a choice situation is visualised in figure 4.2, including the context description. The last part of the survey consists of 22 questions about personal characteristics.

Example Choice Set

"Imagine you are making a trip on your own by bus from your home to family or friends. The temperature outside is 17 degrees Celsius and there is no rainfall. You do not carry any (large) luggage with you."

Which option do you prefer?

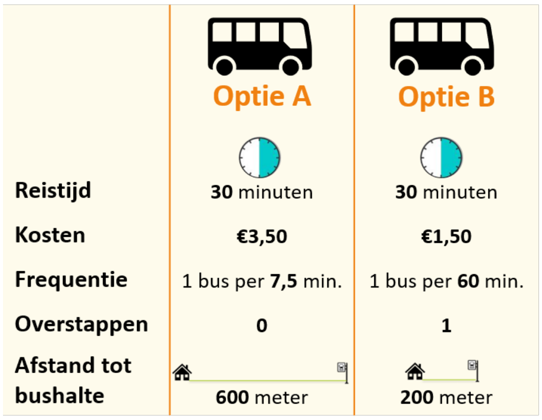


Figure 4.2: Example of a choice set

4.5. Conclusion

This chapter described the designs and results of the Stated Preference pilot survey and the design of the Stated Preference final survey. Respondents have to choose between bus options A and B for every choice set. The attributes included in the choice experiment are travel time, travel costs, frequency, distance to bus stop and transfers. A selection of socio-demographics is also included in the survey. This selection consists of 'gender', 'age', 'zip code', 'household situation', 'income (bruto)', 'usage of walking tool', 'physically able to cycle', 'bicycle usage', 'car ownership', 'driving license', 'taken to or from destination by friends or family sometimes', 'valys usage', 'bus usage', 'public transport subscription/ticket', 'ability to reach nearest bus stop without help', 'distance to nearest bus stop in meters', 'distance to nearest bus stop in minutes walking', 'mobile phone possession', 'internet access mobile phone', 'internet usage mobile phone', 'usage of trip planner via mobile phone'. The pilot survey was conducted in order to design the final questionnaire. An efficient design was used to create the choice situations for both pilot and final surveys. For the efficient design of the pilot survey, prior parameter values were estimated. The final survey consists of an introduction, choice situations and questions about socio-demographic characteristics.

5 Descriptive statistics

This chapter elaborates on the distribution of the survey and descriptive statistics. Section 5.1 discusses the data collection and section 5.2 describes the sample and its representativeness. After that, section 5.3 analyses the influence of socio-demographic characteristics on the bus usage. Based on these insights, section 5.4 answers the first research question: "Which socio-demographic characteristics influence the bus usage of the elderly?".

5.1. Sampling method

This section discusses the sampling method. First, the online panel used for data collection is described. After that, the requirements which participants have to meet are explained.

5.1.1. Online panel for data collection

To spread the questionnaire and collect the data, the online panel PanelClix is used. PanelClix is a company specialised in creating panels and having online questionnaires completed (PanelClix, 2019). Participants in this panel have given permission to use their data for research. This company is used, since the size of their panel is very large and diverse. Besides that, the distribution of the survey is online and the members receive some money for completing a questionnaire. This leads to fast data collection. However, it is important to take into account that the quality of data might be lower, since only respondents capable of using computer and internet will complete the survey and respondents might only complete the questionnaire to receive the money.

To determine the minimum number of respondents needed, the value of the S-estimate of the design created in Ngene is used. This S-estimate indicates the sample size needed to obtain a statistically significant parameter estimate at the 95% confidence level (ChoiceMetrics, 2018). The S-estimate is an indication of the sample size you would need to obtain a statistically significant parameter estimate at the 95% confidence level. According to S-estimate the minimum number of respondents required is 31. However, in order to receive enough responses and to get reliable results it is recommended to obtain more respondents. The available budget of Goudappel Coffeng and the Smart Public Transport Lab of the TU Delft makes it possible to recruit 250 respondents via PanelClix.

5.1.2. Requirements online panel

PanelClix is not only used for its fast data collection, but also for its capability to compose samples based on specific profile characteristics. For this research, respondents have to fulfill the following requirements:

- The respondent needs to be 65 years or older.
- The residence of the respondent needs to be one of the following municipalities: Eindhoven, Groningen, Tilburg, Breda, Nijmegen, Apeldoorn, Haarlem, Arnhem, Enschede,

Amersfoort, Zaanstad, Den Bosch, Haarlemmermeer, Zwolle, Leiden, Leeuwarden, Maastricht, Dordrecht, Alphen aan de Rijn, Alkmaar, Venlo.

The residence of the respondent needs to be one of the selected municipalities above for several reasons. First of all, Bouwknegt (2019), public transport expert at Goudappel Coffeng, recommended to exclude municipalities having metro and/or tram networks, since these types of networks are available in just a few municipalities in The Netherlands. Using respondents living there would not be representative for The Netherlands and makes it impossible to draw general conclusions. Secondly, sufficient respondents are needed to obtain reliable results. Conducting the survey at just two municipalities to compare the bus preferences would lead to insufficient responses according to PanelClix. PanelClix came up with a list of the larger municipalities in The Netherlands, from which sufficient responses can be obtained. A complete overview of the list is shown in Appendix D. This list is screened based on the degree of urbanity, percentage of elderly and public transport modes available and resulted in the municipalities mentioned above. Zoetermeer is removed from the list, because of the RandstadRail in this city. Almere, Ede, Westland and Emmen are removed from the list based on degree of urbanity and the share of persons of 65 and older. The share of elderly in Almere is just 10,8%, while the other municipalities have a share of at elast 12,7%. Ede, Westland and Emmen are removed, because of the low and medium urbanity degree, while the degree in the other municipalities is strong urban to very strong urban.

To make the distribution of respondents between 65 to 74 years and 75 years and older as equal as possible, firstly the 75+ aged respondents were recruited, because the number of people in the panel aged 75 and over is much lower. After that, the sample was supplemented to 250 with respondents aged 65 to 74.

5.1.3. Collected data

The data was collected between the 26th and 28th of June in 2019. With the use of PanelClix, 274 responses were collected within two days. The average duration of completion was 7 minutes and 40 seconds. The 274 responses were screened and 18 were eliminated because of the following reasons:

- **13** respondents completed the survey within 4 minutes. It is assumed that completing the questionnaire in a reliable way takes at least 4 minutes.
- **1** respondent did not have an ID code in the data, this respondent probably filled in the survey two times.
- **4** respondents did not fulfill the requirements stated in section 5.1.2. Two respondents filled in a postcode which is not within one of the municipalities on the list. Two respondents filled in a year of birth of 1954 or higher, which means that these respondents are younger than 65 years.

After the screening, 256 responses remained and are used for data analysis.

5.2. Frequency distribution and representativeness of the sample

The sample is compared with the population of elderly living in the municipalities mentioned in section 5.1.2 in order to check whether the sample does not deviate to much from the population. The comparison is made based on the socio-demographic characteristics 'gender', 'age', 'income', 'driving license' and 'residence'. Due to a lack of data concerning the distribution of 'income' of the elderly in the municipalities, the sample is compared to the whole elderly population in The Netherlands for this variable. The frequency distribution of the socio-demographic variables are included in table 5.1.

To obtain significant results by using this data, it is checked if each sub group consists of at least 30 respondents. For the sub groups with less than 30 respondents, it can not be investigated if the results are significantly different than for other sub groups. Groups with less than 30 respondents are combined as described in appendix F.3. It appeared that some categories of age, income, bus usage, household situation, walking tool, public transport subscription,

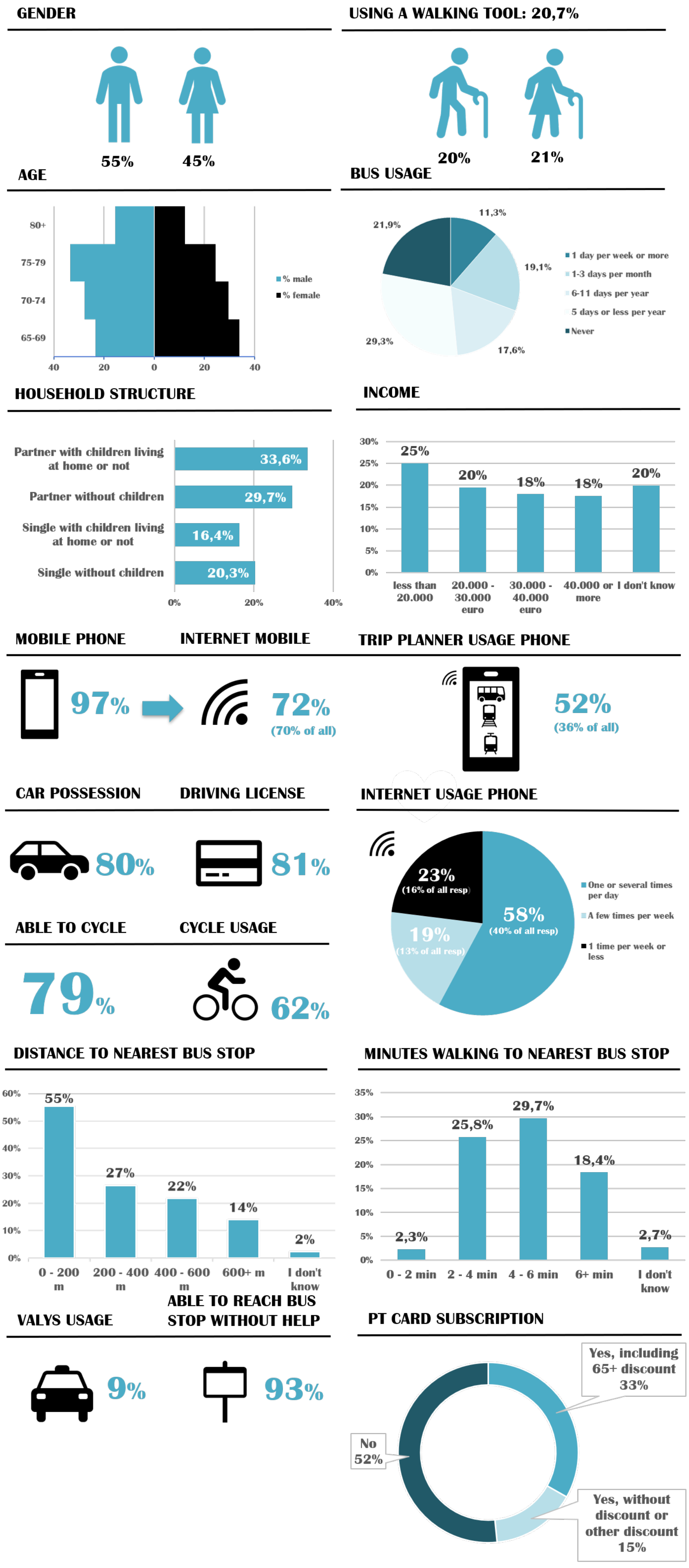
Table 5.1: Frequency distribution socio-demographic characteristics sample compared to population

Socio-demographic variable	Number of respondents	Sample share		Share NL	Share municipalities together
Gender					
Male	141	55,1%		46%	45%
Female	115	44,9%		54%	54%
Age					
65-69	72	28,1%		30,9%	30,3%
70-74	73	28,5%		26,9%	27,3%
75-79	75	29,3%		18,2%	18,0%
80-84	27	10,5%		12,6%	12,7%
85-89	8	3,1%		7,6%	7,7%
90-94	1	0,4%		3,1%	3,2%
95+	0	0%		0,8%	0,8%
Income (Bruto)					
less than 10.000 euro	6	2,3%	(2,9%)	4%	
10.000 - 20.000 euro	58	22,7%	(28,3%)	50%	
20.000 - 30.000 euro	50	19,5%	(24,4%)	22%	
30.000 - 40.000 euro	46	18,0%	(22,4%)	11%	
40.000 - 50.000 euro	26	10,2%	(12,7%)	5%	
50.000 - 100.000 euro	18	7,0%	(8,8%)	6%	
100.000 - 200.000 euro	1	0,4%	(0,5%)	1%	
200.000 euro or more	0	0,0%	(0%)	0%	
I don't know/I don't wanna say	51	19,9%	(-)	-	
Driving license					
Yes	207	80,9%		70%	
No	49	19,1%		30%	
Residence					
Alkmaar	12	5%		4%	
Amersfoort	7	3%		5%	
Apeldoorn	14	5%		6%	
Arnhem	12	5%		5%	
Breda	16	6%		6%	
Dordrecht	8	3%		4%	
Eindhoven	18	7%		8%	
Enschede	23	9%		5%	
Groningen	12	5%		7%	
Haarlem	15	6%		5%	
Haarlemmermeer	12	5%		5%	
Leeuwarden	9	4%		4%	
Leiden	10	4%		4%	
Maastricht	18	7%		4%	
Nijmegen	15	6%		6%	
Tilburg	19	7%		7%	
Venlo	10	4%		3%	
Zaanstad	16	6%		5%	
Zwolle	10	4%		4%	

and distance to nearest bus stop contained less than 30 respondents and are combined with another category. These new sub groups are used for the subsequent analyses. The answers of the respondents to the questions about socio-demographic characteristics are visualised on the next page.

STATISTICS SURVEY RESULTS

256 respondents



To determine the representativeness of the sample, the Chi-square test is used. This test is used, since the variables which need to be checked are nominal or categorical variables. This chi-square test determines the expected counts on the basis of the population values and compares these with the observed counts of the sample. When the distribution of the social-demographic characteristics do not differ significantly between sample and population, the sample is representative for these variables in the population (Molin, 2019).

First, it is checked whether the distribution of the gender of respondents is representative. This resulted in a p-value of 0.00, indicating that the distribution of gender is not representative. In general, the females are underrepresented and the males are over-represented. There are a few outliers. The sample of Breda consists of 19% males and 81% females, the sample of Groningen consists of 75% males and 25% females and the sample of Leiden contains 80% males and 20% females.

The representativeness is also checked for 'age', 'income' and 'residence', resulting in p-values of 0.00, 0.00 and 0.854, respectively. The age group '75-79' is over-represented and the age group '80+', is underrepresented. The income segment 'less than 20.000 euro' is underrepresented and the segments '30.000 - 40.000 euro' and '40.000 euro or more' are over-represented. The conducted p-values indicate that the distribution of 'age' and 'income' are not representative for the Dutch elderly population. However, the distribution of the location where the respondents are living is representative. The results of the chi-square tests are shown in appendix F.2.

Since the sample is not representative based on the personal characteristics, it is necessary to check whether the non-representative variables are related to the target variable (Molin, 2019). In this research, bus usage is the target variable. The difference between sample mean and population estimator is checked by using cross tables. The results are shown in appendix F.2 table F.3. All three non-representative variables do not distort the target variables. This means the sample can still be used.

Although the sample can be used, the results should be interpreted with care, because there is a selective bias in two ways. First of all, self-selection is occurring because questions are asked online to a group who is potentially not comfortable online. Secondly, there is selection in the recruitment process of respondents since elderly are asked about bus usage online. Members of a panel are in general willing to fill in surveys on a regular basis and probably have on average more time available than non-panel members. Besides that, they receive a compensation for completing questionnaires. As a result, the Value of Time might be lower for the sample compared to the population (Molin, 2019).

In conclusion, there are significant differences in shares between the sample and population. However, the non-representative variables do not distort the target variables, so the sample can be used in a representative way for elderly in the targeted municipalities.

5.2.1. Choice set answers

In the first part of the survey, the respondents answered twelve choice situations. The distribution of these answers of the respondents is presented in figure 5.1. For every choice situation, the percentage of the respondents choosing option A and option B is shown. The figure shows that the preferences for the bus options A and B are divided among the elderly. For choice situations 3, 4 and 10 most of the elderly in the sample have option B as preference. However, the options A and B have different attribute values in every choice situation. Therefore, it is not possible to already draw conclusions based on the shown distribution of the answers.

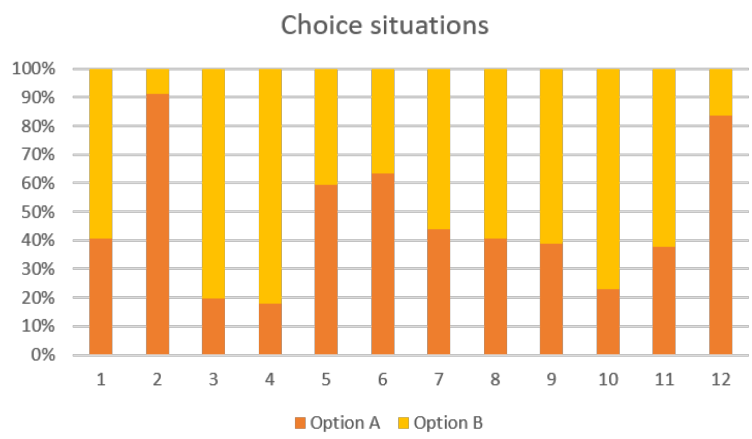


Figure 5.1: Distribution answers choice situations

5.3. Influence of personal characteristics on bus usage

To test if respondents with a certain bus usage have socio-demographic characteristics in common, cross-tables are used in the program SPSS. For each socio-demographic variable chi-square tests are used to check the significance of the relation with bus usage. The results of these tests are shown in table 5.2. The seven socio-demographic characteristics 'walking tool', 'physically able to cycle', 'car ownership household', 'driving license', 'taken by friends/family', 'public transport subscription' and 'able to reach bus stop without help' have significant results, since their p-value is lower than 0.05. The extensive results of the chi-square tests of the socio-demographic characteristics signficicant related to bus usage are shown in appendix F.5.

Table 5.2: Results chi-square tests for relation socio-demographic characteristics with bus usage

Socio-demographic variable	Chi-square	p-value
Gender	6.436	0.169
Age	7.487	0.824
Household situation	7.813	0.800
Income	9.038	0.700
Walking tool	10.468	0.033*
Physically able to cycle	11.906	0.018*
Cycle usage	0.977	0.913
Car ownership household	23.391	0.000*
Driving license	12.405	0.001*
Taken by friends/family	14.557	0.006*
Valys usage	2.746	0.601
Public transport subscription	85.24	0.000*
Able to reach bus stop without help	17.155	0.002*
Distance to nearest bus stop	21.545	0.158
Walking time to nearest bus stop	22.901	0.116
Mobile phone posession	2.451	0.653
Internet access mobile phone	1.682	0.794
Internet usage mobile phone	7.123	0.971
Trip planner usage mobile phone	8.503	0.075

** Significant on a 95% confidence interval ($p < 0.05$)*

The chi-squared statistic indicates how much difference there is between the observed counts (O) and the expected counts (E) if there is no relationship between the specific socio-demographic variable and bus usage. An example: The observed counts for elderly using the bus 1-3 days per month and having a walking tool is 13. If there is no relationship between walking tool and bus usage, the expected count would be 10,1 elderly having a walking tool and using the bus 1-3 days per week. Thus, the observed counts differ from the expected counts. The Pearson Chi-square test shows that having a walking tool or not significantly influences the bus usage, since the p-value is lower than 0.05. Elderly having a walking tool make relatively more use of the bus than elderly without having a walking tool. However the Pearson Chi-square is not always applicable: One of the assumptions of the chi-square test is that the value of the expected counts should be 5 or more in at least 80% of the cells (McHugh, 2013) and no cell should have an expected count of less than one. For the results of the relation between 'able to reach bus stop without help' and bus usage, this assumption is violated, since there are 5 cells (50%) with an expected count of 5 or less. Therefore, the Fisher-Freeman-Halton exact test is applied. This test gives a significant result indicating a significant relation between the variables. The observations for the other socio-demographic characteristics besides walking tool are:

- **Able to cycle**: Elderly who are able to cycle make relatively more (1-3 days per month or 6-11 days per year) use of the bus.
- **Car possession:** Elderly without having a car make more often use of the bus. 23% of the elderly without a car make at least 1 day per week use of the bus, against 8% of the elderly with a car.
- **Driving license:** The bus usage is higher for elderly without a driving license compared to the elderly with a driving license. From the elderly without a driving license, 49% makes use of the bus at least 1-3 days per month, against 26% of the elderly with a driving license.
- **Taken to or from destination by friends/family:** Elderly who are sometimes taken to or from a destination by friends or family make more use of the bus compared to the elderly who are never taken by friends or family.
- **Transport subscription:** The bus usage is much higher for elderly having a transport subscription including 65+ discount or having a transport subscription with other discount/without discount compared to elderly without a transport subscription. The percentage of elderly using the bus one day per week or more for these groups is 23,5%, 10% and 4%, respectively.
- **Able to reach bus stop without help:** Elderly who are not able to reach the bus stop without help make less use of the bus compared to the other elderly. 58% of the elderly who can not reach the bus stop by themselves never make use of the bus.

5.4. Conclusion

This chapter described the findings of the survey and aimed to answer the first research question. In total, 274 respondents filled in the online survey, from which 256 valid responses are used for data analysis. It can be concluded from the descriptive statistics that the sample is representative for the elderly in the urban municipalities 'Alkmaar', 'Amersfoort', 'Apeldoorn', 'Arnhem', 'Breda', 'Dordrecht', 'Eindhoven', 'Enschede', 'Groningen', 'Haarlem', 'Haarlemmermeer', 'Leeuwarden', 'Leiden', 'Maastricht', 'Nijmegen', 'Tilburg', 'Venlo', 'Zaanstad', and 'Zwolle. However, the results should be interpreted with care because a selective bias occurs as a result of the use of an online panel. The bus usage is distributed: 22% of the respondents never make use of the bus and 30% uses the bus at least 1 day per month.

SQ 1: "Which socio-demographic characteristics influence the bus usage of the elderly?"

The socio-demographic variables 'walking tool', 'physically able to cycle', 'car ownership household', 'driving license', 'taken or driven by friends or family', 'public transport subscription' and 'able to reach bus stop without help' have an significant influence on bus usage.

Elderly having a walking tool make more use of the bus than elderly without a walking tool. Elderly without a car and elderly without a drivers license make more use of the bus. It can be concluded that having a car and having a driving license probably make them less dependent on the bus service. Elderly who are sometimes taken to or from a destination by friends or family make more use of the bus compared to elderly who are never taken by friends or family. Probably the elderly who are sometimes taken are more willing to travel at all.
Elderly with a transport subscription including 65+ discount make most use of the bus, followed by elderly having a transport subscription with other discount or without discount. Elderly without a transport subscription make less use of the bus. Having a transport subscription, with or without discount makes it cheaper and probably easier to use the bus. Elderly who are not able to reach the bus stop without help make less use of the bus. This result is obvious, since those elderly are dependent of help and are not able to use the bus by themselves.

6 Model estimation

The answers of respondents on the choice situations in the survey are used as input for the estimation of different models. This chapter elaborates on the model estimation of two types of models. First, a base MNL model is estimated, which is extended by including socio-demographic variables to test for heterogeneity. Second, a Latent Class choice model is estimated to account for panel effects and test for heterogeneity in a different way.
Section 6.1 describes the data preparation before using it for model estimation. Section 6.2 elaborates on the estimation of the base MNL model. Section 6.3 extends the base MNL model with testing for interaction effects. After that, the estimation of the latent class choice models is described in section 6.4. In section 6.5, the models are estimated again, but now only considering data of bus users. The chapter ends with a conclusion in section 6.6, in which an answer will be given to sub-question 2: "Which bus attributes are most important for the elderly, and to which extent?" and sub-question 3: "To which extent does heterogeneity in preferences exist among elderly regarding the values of bus attributes, and to which socio-demographic characteristics can this unobserved heterogeneity be attributed?"

6.1. Data preparation

The data coming from the survey needs to be re-coded to use it for model estimation. As socio-demographic variables are often categorical, the levels need to be re-coded for use in Biogeme. In the choice literature, the most widely used coding for levels of categorical variables is dummy coding (Molin & Timmermans, 2010). With dummy coding, a variable with L levels is coded by L-1 indicator variables. On each respective indicator variable the first L-1 levels are coded with 1 and the other indicator variables are coded with 0. For the Lth level, all indicator variables are coded with 0. By using dummy coding, the estimated parameters can be used for calculating the utility contribution of the attribute levels compared to the reference level. In this research, the reference level is always the lowest level of an socio-demographic variable or attribute. As an example, the dummy coding for the socio-demographic variables characteristics gender, age and household situation are given in table 6.1. The complete coding scheme can be found in appendix G.1.

Table 6.1: Dummy coding scheme for the personal characteristics

Gender	**GENDER**		
Male	1		
Female	0		
Age	**AGE1**	**AGE2**	**AGE3**
80+	1	0	0
75-79	0	1	0
70-74	0	0	1
65-69	0	0	0
Household situation	**HH1**	**HH2**	**HH3**
Together with children living at home or somewhere else	1	0	0
Together without children	0	1	0
Single with children living at home or somewhere else	0	0	1
Single without children	0	0	0

6.2. MNL model estimation

The first model estimated is a base MNL model. This model only includes the attributes which are used in the choice experiment. The utility functions of option A (V_1) and option B (V_2) are shown in equations 6.1 and 6.2. As can be seen, the utility functions of both options are similar, because the alternatives are unlabeled and have generic parameters.

$$V_1 = \beta_{TT} * TT_A + \beta_{TC} * TC_A + \beta_{FREQ} * FREQ_A + \beta_{TF} * TF_A + \beta_{SD} * SD_A \tag{6.1}$$

$$V_2 = \beta_{TT} * TT_B + \beta_{TC} * TC_B + \beta_{FREQ} * FREQ_B + \beta_{TF} * TF_B + \beta_{SD} * SD_B \tag{6.2}$$

To check whether the attributes are non-linear, different MNL models are estimated with a quadratic component for one specific attribute in each model. Only the quadratic component for the attribute 'frequency' became significant. The results of the MNL model estimations are included in appendix G.2. The base MNL model and the models with a quadratic parameter are compared based on the goodness of fit. Since the models use different numbers of parameters, the goodness of fit is checked with the adjusted rho-square value, which makes a correction for the amount of parameters. The model with a quadratic component for 'frequency' has the highest adjusted Rho-square of 0.155 and the highest final log-likelihood. Besides that, all parameters are significant an have a logical parameter sign.

6.2.1. MNL model interpretation

The model fit of the base MNL model as indicated by the adjusted rho-square is not that high. This might be because the model does not test for heterogeneity. Therefore, in section 6.3, heterogeneity is included in the MNL model by including the socio-demographic characteristics. It is expected that the model fit will increase by the implementation of these aspects.

The model that explains the data the best, only consists of significant parameters. The linear and quadratic parameters for 'frequency' are incorporated. The utility functions for the alternatives for the best MNL model are presented in equation 6.3 and 6.4.

$$V_1 = \beta_{TT} * TT_A + \beta_{TC} * TC_A + \beta_{FREQl} * FREQ_A + \beta_{FREQq} * FREQ_A^2 + \beta_{TF} * TF_A + \beta_{SD} * SD_A \tag{6.3}$$

$$V_2 = \beta_{TT} * TT_B + \beta_{TC} * TC_B + \beta_{FREQl} * FREQ_B + \beta_{FREQq} * FREQ_B^2 + \beta_{TF} * TF_B + \beta_{SD} * SD_B \tag{6.4}$$

Where:
V_1 = utility of option 1
V_2 = utility of option 2
β_{TT} = generic parameter for the variable 'Travel Time' (TT)
β_{TC} = generic parameter for the variable 'Travel Costs' (TC)
β_{FREQl} = generic parameter for the linear component of the variable 'Frequency' (FREQ)

β_{FREQq} = generic parameter for the quadratic component of the variable 'Frequency' ($FREQ^2$)
β_{TF} = generic parameter for the variable 'Transfers' (TF)
β_{SD} = generic parameter for the variable 'Distance to stop' (SD)

The biogeme syntax is included in Appendix G.2.3. The estimated model resulted in a final log-likelihood of -1792.918, a Likelihood ratio test of 672,861 and an adjusted Rho-square of 0.155, as shown in appendix G.2.4. The estimated values are shown in table 6.2.

Table 6.2: Parameter estimates MNL model estimation

Parameter name	Parameter	Parameter estimate	Robust Std err	Robust t-test	p-value
Frequency	β_{FREQl}	0.357	0.0979	3.65	0.00*
	β_{FREQq}	-0.0269	0.0106	-2.55	0.01*
Distance to bus stop	β_{SD}	-0.00114	0.000158	-7.22	0.00*
Travel costs	β_{TC}	-0.580	0.0290	-19.99	0.00*
Transfers	β_{TF}	-0.364	0.0520	-6.99	0.00*
Travel time	β_{TT}	-0.0316	0.00334	-9.46	0.00*

** Significant on a 95% confidence interval (p < 0.05)*

The parameters are all significant, since the p-values are less than 0.05. All parameters have the expected sign. Higher frequency results in higher utility. The quadratic parameter for frequency has a negative value, which means that at a certain moment, the utility is not increasing anymore for an increase in frequency. Higher 'travel time', 'travel costs', 'transfers' and 'distance to bus stop' result in lower utilities, since these parameter values have, as expected, a negative sign.

Besides this, the parameter estimates are interpreted. The parameter estimates give the gain or loss in utils when the attribute increases with one unit. The parameter estimate for 'travel costs' is -0.580 which indicates that utility will decrease with 0.580 utils when the travel costs increase with 1 euro. The estimated parameters for the linear and quadratic components of 'frequency' are 0.357 and -0.0269 respectively. Utility does not increase linearly with the increase in frequency, because the parameter for the quadratic component is significant. The quadratic component has a negative value, thus the curve for 'frequency is concave down. The parameter estimate for 'distance to bus stop' is -0.00114, which indicates that when the 'distance to bus stop' increases with 1 meter, utility will decrease with 0.00114 utils. This is 0.114 utils per 100 meter. The parameter estimate for 'transfers' is -0.364, which indicates that when having a transfer to another bus during the bus trip, utility decreases with 0.364 utils. The parameter 'travel time' is estimated -0.0316, which indicates that when the 'travel time' increases with 1 minute, utility will decrease with 0.0316 utils. this is 0.316 utils per 10 minutes.

Since the parameters are measured within different ranges, it is not possible to compare them directly. Therefore, the relative importance is calculated by multiplying the parameter values with the attribute range. Table 6.3 shows the relative importance of the parameters as well as the 95% confidence interval and utility range of the parameter estimates.

The table shows that hightes relative importance for the linear parameter of 'frequency', indicating that this parameter has the largest impact on utility for the range used. However, the utility contribution of 'frequency' depends on both the linear and quadratic component, resulting in a relative importance of 0,80. Therefore, it is 'travel costs' which has the highest impact on utility for the attribute range. When varying the travel costs over the used attribute range, the utility decreases with -1.16. After 'travel costs', 'travel time' has the highest negative impact on utility for the attribute range used.

Table 6.3: Contribution to utility per attribute

Parameter estimate	Value	95% C.I.		Attribute range	Utility range		Relative importance
β_{FREQl}	0.357	0.37485	0.357	7	0.357	2.856	2.50
β_{FREQq}	-0.0269	-0.02556	-0.0269	7	-0.0269	-1.7216	-1.69
β_{FREQl} + β_{FREQq}				7	0.3301	1.1344	0.80
β_{SD}	-0.00114	-0.00108	-0.00114	400	-0.228	-0.684	-0.46
β_{TC}	-0.58	-0.551	-0.58	2	-0.87	-2.03	-1.16
β_{TF}	-0.364	-0.3458	-0.364	1	0	-0.364	-0.36
β_{TT}	-0.0316	-0.03002	-0.0316	20	-0.632	-1.264	-0.63

6.2.2. Changes in utilities

To calculate the changes in utilities for all the attribute levels, the parameter outcomes of the MNL estimation are used. The changes are visualised in figure 6.1. The sensitivity of the elderly for a change in the attribute level for the attribute range used in the choice experiment is indicated by the steepness of the line. Travel costs has the largest decrease in utility per level. Distance to the nearest bus stop and travel time have the lowest decrease in utility per unit change and frequency the largest increase. For the attribute level range used in the choice experiment, travel costs and frequency have the largest impact.

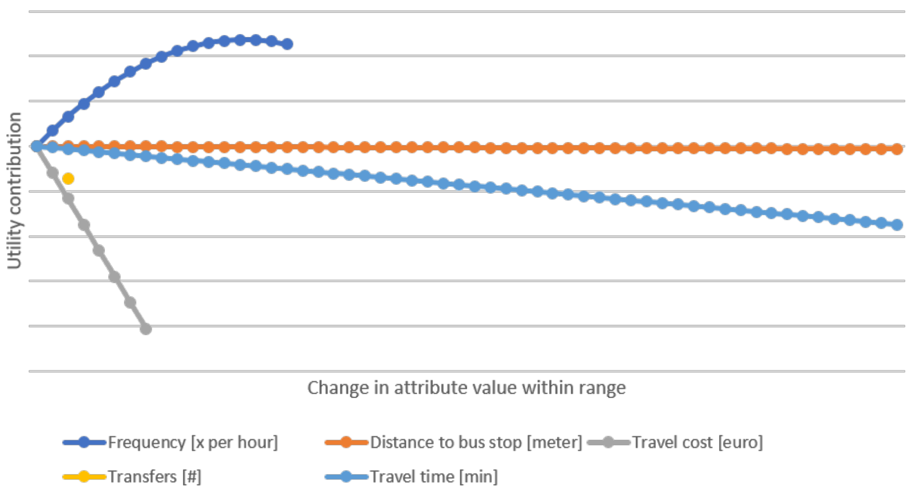


Figure 6.1: Attributes and the change in utility for the values within the range

6.2.3. Willingness to Pay

For the linear attributes 'travel time', 'transfers' and 'distance to bus stop' the willingness to pay (WTP) is calculated. The willingness to pay indicates elderly are willing to pay for a one unit improvement of attributes of the bus service (Hensher, 2010). The WTP can be calculated by dividing the estimated parameter with the estimated cost parameter of the choice model. This equation is shown in Equation 6.5. The results of the calculated WTPs for 'distance to bus stop', 'transfers' and 'travel time' are shown in table 6.4. The results are compared with the WTP of average bus users at the end of this section.
The WTP for transportation attribute k comes from:

$$WTP_k = \frac{\beta_k}{\beta_{tc}} \tag{6.5}$$

Respondents are willing to pay €0,20 for 100 meters decrease in distance to the nearest bus stop. The WTP of transfers is €0,63 for one transfer less. For a hour reduction in travel time,

Table 6.4: Willingness to pay for distance to bus stop, transfers and travel time

Willingness to Pay	Value	Unit	Value	Unit
Distance to bus stop	0.002	[euro/ meter]	0.20	[euro/ 100 meter]
Transfers	0.63	[euro/ transfer]		
Travel time	0.046	[euro/ minute]	2.76	[euro/ hour]

the WTP is €2,78. This means that respondents have a higher dis-utility towards travel time than towards distance to the nearest bus stop and transfers. However, it depends on which unit is used to define the value: the WTP for a 10 minute reduction in travel time instead of a hour reduction is 0,46 euro, which is lower than the WTP for having less transfers. Therefore, the results should be compared with care.

6.3. MNL model with interaction

One shortcoming of the MNL model is the assumption that everybody has the same preferences. It does not consider that individuals can prefer different attributes of an alternative. To take into account this heterogeneity, the socio-demographic variables obtained from the survey are included as interaction variables in the MNL model. It is estimated what the effects of the socio-demographic variables are on the attributes of the bus choice.

To include interaction variables in the MNL model, the dummy coded variables from section 6.1 are used. The MNL model estimated in section 6.2.1 is used as base model and the socio-demographic variables are incorporated sequentially to find the influence of each variable. An example of the incorporation of 'driving license' in the utility function of the MNL model is presented in equations 6.6 and 6.7. The Biogeme model syntax is included in Appendix G.3.1.

$$\begin{aligned} V_1 = \quad & \beta_{TT} * TT_A + \beta_{TC} * TC_A + \beta_{FREQl} * FREQ_A + \beta_{FREQq} * FREQ_A^2 + \beta_{TF} * TF_A + \beta_{SD} * SD_A + \\ & \beta_{LICENSE} * LICENSE + \beta_{LICENSEtt} * TT_A * LICENSE + \beta_{LICENSEtc} * TC_A * LICENSE + \\ & \beta_{LICENSEfreql} * FREQ_A * LICENSE + \beta_{LICENSEfreqq} * FREQ_A^2 * LICENSE + \\ & \beta_{LICENSEtf} * TF_A * LICENSE + \beta_{LICENSEsd} * SD_A * LICENSE \end{aligned} \tag{6.6}$$

$$\begin{aligned} V_2 = \quad & \beta_{TT} * TT_B + \beta_{TC} * TC_B + \beta_{FREQl} * FREQ_B + \beta_{FREQq} * FREQ_B^2 + \beta_{TF} * TF_B + \beta_{SD} * SD_B + \\ & \beta_{LICENSE} * LICENSE + \beta_{LICENSEtt} * TT_B * LICENSE + \beta_{LICENSEtc} * TC_B * LICENSE + \\ & \beta_{LICENSEfreql} * FREQ_B * LICENSE + \beta_{LICENSEfreqq} * FREQ_B^2 * LICENSE + \\ & \beta_{LICENSEtf} * TF_B * LICENSE + \beta_{LICENSEsd} * SD_B * LICENSE \end{aligned} \tag{6.7}$$

6.3.1. Model results of the interaction with personal characteristics

The MNL models including interactions with socio-demographic variables are estimated by using Biogeme. The results of interaction effects are shown in table 6.5. An extended version of the results including the robust standard errors, t-test and p-values is included in appendix G.3. A comparison of the MNL interaction models with their loglikelihood and rho-square is shown in appendix G.3.3.

The lowest line for every socio-demographic variable represents the base case. For example, the base case for gender equals female (female = 0). A female elderly has on average a parameter value of -0.498 for the attribute 'transfers'. The parameter values above this base case level indicate the change for the base case parameter value due to a change in level of the socio-demographic variable. For example, the parameter value of the attribute 'transfers' for male lies 0.245 point higher, compared to female, which results in a value of -0.253. The positive value of the male indicates that elderly males are less sensitive for 'transfers'.

The results in table 6.5 shows that different parameters for the interaction effects are found to be significant on a 95% confidence interval, since these parameters have a p-value lower than 0.05. These parameters are marked in green. The table also shows many insignificant interaction effects. Insignificant interaction effects indicate that this interaction effect is not relevant.

The large and notable significant interaction effects are the following:

- **Gender & Transfers:** Men are less sensitive for 'Transfers' than women. According to research of Derriks (2011) and Molengraaff (2016) women are generally more insecure and sensitive to the factors that influence the risk perception on the road than men. It is possible that this also applies for women travelling independently by public transport, where having a transfer makes women more insecure.
- **Age & Travel time:** Elderly aged 75 - 79 are less sensitive for travel time than individuals aged 65 - 69. Since most elderly are retired, the elderly in general have more time available. Therefore, it is possible that travel time is less important for them.
- **Age & Travel costs:** Elderly aged 70 and over are less sensitive for travel costs than individuals aged 65 - 69. An explanation might be that those older elderly travel less, so if they travel then the costs are less important. Another explanation might be that people getting older care less about money, since in general they have a fixed income from retirement and no longer have children living at home for whom they have to save money.
- **Income & Travel costs:** Elderly with a household income of 20.000 - 30.000 and 30.000 - 40.000 are less sensitive for travel costs than individuals with a household income of less than 20.000 euro. These elderly with higher incomes probably have less worries about money and consider costs as less important.
- **Walking tool & Travel costs:** Elderly with a walking tool are less sensitive for travel costs than individuals without a walking tool. Research from Schmöcker et al. (2005) shows that people with walking difficulties make fewer trips. Possibly those elderly are willing to pay more if they finally make a trip.
- **Driving license & travel costs:** Elderly with a drivers license are less sensitive for travel costs than individuals without a driving license. This can be explained by the fact that the use of a car is generally more expensive than using the bus, so these bus costs will probably be considered as less important.
- **Minutes to nearest bus stop & Travel costs:** Elderly who have to walk 6 minutes or more to the nearest bus stop are less sensitive for travel costs than individuals who have to walk 0 - 2 minutes to the nearest bus stop. Two possible explanations are: the elderly in the sample living 0 - 2 minutes from a bus stop have lower incomes, or elderly living more than 6 minutes walk from a bus stop make less use of the bus, and therefore might not care about the price. However, the cross-tables in appendix F.6 and F.7 disprove these explanations. Further research is required why elderly living nearby a bus stop are more sensitive for travel costs.

Table 6.5: Interaction effects on socio-demographic characteristics

Socio-demographic characteristics	Travel time	Travel costs	Frequency	Frequency2	Transfers	Distance to busstop
Gender						
Male	-0.00143	-0.0595	-0.00806	0.000919	**0.245**	-5.06E-05
Female	**-0.031**	**-0.55**	**0.363**	-0.0275	**-0.498**	**-0.00112**
Age						
80+	0.0157	**0.21**	-0.0652	0.00945	0.112	2.32E-05
75-79	**0.0186**	**0.248**	-0.00106	0.000292	0.0406	-0.000172
70-74	0.00319	**0.193**	0.0948	-0.00605	-0.269	0.00019
65-69	**-0.041**	**-0.748**	0.349	-0.0273	**-0.322**	**-0.00116**
Household situation						
Together with children living at home or somewhere else	-0.019	-0.135	0.349	-0.0332	-0.0652	-0.000319
Together without children	-0.00926	-0.0551	0.156	-0.0122	-0.0758	0.000132
Single with children living at home or somewhere else	-0.00483	-0.0669	0.101	-0.00824	-0.15	-0.000391
Single without children	**-0.0224**	**-0.515**	0.186	-0.0115	**-0.299**	**-0.00103**
Income (Bruto)						
40.000 or more	9.40E-05	0.44	0.515	-0.0624	0.101	9.31E-05
30.000 - 40.000 euro	0.0014	**0.54**	0.508	-0.0658	-0.24	-0.000164
20.000 - 30.000 euro	0.0146	**0.455**	0.347	-0.0478	-0.103	0.000266
less than 20.000	-0.0386	**-1.05**	-0.111	0.0322	-0.303	-0.00123
Walking tool						
Yes	**0.0162**	**0.175**	-0.223	0.0212	0.138	-0.000226
No	**-0.0357**	**-0.624**	**0.412**	**-0.032**	**-0.399**	**-0.0011**
Physically able to cycle						
Yes	**-0.0237**	**-0.194**	-0.113	0.0118	0.0214	0.00063
No	-0.0139	-0.438	**0.456**	-0.037	**-0.391**	**-0.00164**
Cycle usage						
Yes	0.0054	0.0775	-0.447	0.0428	-0.0674	-0.000556
No[1]	**-0.0425**	**-0.704**	**0.739**	-0.063	-0.31	-0.000524
Car ownership						
Yes	-0.00444	0.146	0.0734	-0.0104	0.16	6.62E-05
No	**-0.0281**	**-0.699**	0.3	-0.0187	**-0.494**	**-0.0012**
Driving license						
Yes	0.00757	**0.27**	-0.248	0.0197	0.12	0.000203
No	**-0.0386**	**-0.808**	**0.568**	-0.0436	**-0.467**	**-0.00133**
Taken to or from destination by friends/family sometimes						
Yes	-0.00214	-0.0255	0.179	-0.0159	0.0115	-4.62E-05
No	**-0.0308**	**-0.571**	**0.279**	-0.0199	**-0.369**	**-0.00113**
Valys usage						
Yes[1]	0.017	0.0798	0.1	-0.00958	-0.01	0.000406
No	**-0.0332**	**-0.588**	**0.35**	**-0.0262**	**-0.364**	**-0.00118**
Bus usage						
1 day per week or more	-0.0176	-0.147	0.185	-0.0128	-0.0549	-0.000193
1-3 days per month	0.0125	0.0746	4.18E-05	0.00108	-0.017	0.000662
6-11 days per year	-0.00545	-0.0391	-0.102	0.0146	-0.119	0.000418
5 days or less per year	-0.00544	-2.51E-15	3.23E-16	0.00268	4.43E-17	**0.000798**
Never	**-0.0303**	**-0.581**	**0.366**	**-0.03**	**-0.338**	**-0.00159**
Public transport subscription/ticket						
Yes. including 65+ discount	7.62E-17	7.62E-17	0.123	-0.00955	-0.0972	-0.000109
Yes. without discount or other discount	-1.30E-16	-1.30E-16	0.127	-0.0103	-0.163	-0.000288
No	**-0.0271**	**-0.559**	**0.301**	-0.0225	**-0.309**	**-0.00107**
Able to get to nearest bus stop without help						
Yes	-0.0213	-0.174	-0.376	0.0348	-0.321	-0.321
No[1]	-0.0121	**-0.421**	0.715	-0.06	-0.0692	**-0.00181**
Distance to nearest bus stop						
600 meters or more	-0.00171	-0.000589	0.197	-0.0226	-0.0174	-0.000523
400 - 600 meters	-0.0055	0.0265	0.356	-0.0422	0.122	0.000502
200 - 400 meters	-0.00525	-0.0148	-0.0662	0.00383	0.0649	0.00033
0 - 200 meters	**-0.0287**	**-0.588**	0.268	-0.0153	-0.413	**-0.00127**
Minutes to nearest bus stop						
6 minutes or more	0.0177	**0.19**	0.213	-0.0263	-0.12	-0.000333
4-6 minutes	-0.00601	-0.0485	0.337	-0.0364	-0.0529	-2.28E-05
2-4 minutes	-0.0119	0.0333	0.264	-0.0296	-0.216	-0.00034
0-2 minutes	**-0.0303**	**-0.626**	0.151	-0.00338	**-0.278**	**-0.000984**
Mobile phone posession						
Yes	0.00139	0.227	-0.637	0.0635	0.0922	-0.000242
No[1]	-0.0331	**-0.801**	0.977	-0.0886	-0.454	-0.000909
Internet access mobile phone						
Yes	2.05E-17	0.016	0.155	-0.0141	0.0982	0.000106
No	**-0.0276**	**-0.588**	0.229	-0.015	**-0.433**	**-0.00123**
Internet usage mobile phone						
One or several times per day	-0.00345	0.141	-0.113	0.0132	0.0516	0.000391
A few times per week	-0.0201	-0.226	0.22	-0.0212	-0.0482	-5.40E-05
1 time per week or less	**-0.0285**	**-0.623**	0.42	-0.0338	**-0.363**	**-0.00137**
Trip planner usage mobile phone						
Yes	-0.00185	0.0115	-0.257	0.0317	0.107	0.000575
No	**-0.0325**	**-0.581**	**0.517**	**-0.0455**	**-0.391**	**-0.00143**

*Significant values are marked in green and with a * ($p < 0.05$)*

[1] = *N < 30*

Comparison with average Dutch bus users

To see whether the elderly have different preferences regarding the attribute values of bus services compared to the average bus users, the results are compared. According to Ben-Akiva & Morikawa (2002) and Phanikumar & Maitra (2007), bus users dislike low frequency and transfers. Besides that, the willingness to pay is very high for the in-vehicle travel time followed by frequency. However, this WTP depends on the trip purpose. Commuting trip makers have a higher WTP value for travel time, while non-commuting trip makers have higher WTP values for qualitative attributes. Research from Zijlstra et al. (2017) showed that the average Dutch bus users with higher income experiences travel time as more important compared to those with lower income.

Comparing this with the results of the MNL model estimation, it can be concluded that the elderly have similar preferences and experience the attributes frequency and travel time as very important. However, the attribute travel costs is most important according to the elderly, which is not mentioned in literature for the average bus users. Besides that, different from the average bus users, elderly with higher income are not more sensitive for travel time than those with lower income. This can be explained by the fact that generally elderly do not have to travel for work any more.

6.4. Latent Class Choice Model

Another way to test for heterogeneity is to estimate a latent class choice model with a class membership function. This model can explain the heterogeneity and considers panel data, which is an improvement compared to the MNL model. The model assumes that there are latent classes, which cannot be observed, containing elderly with homogeneous preferences. The classes will be identified by the model. Based on the observed socio-demographic variables, it can be predicted which elderly are in which class.

The latent class choice model has the same utility function as the base MNL model in section 6.2. The quadratic parameter for frequency appeared to be insignificant, therefore this parameter is eliminated. To decide which number of classes gives the best fit for the data, different models are estimated with different number of classes. Since it is possible that a local maximum log-likelihood is found, different start values are used for the class membership parameter. The models are compared based on the Log-likelihood (LL), Bayesian Information Criterion (BIC) and Rho-squared value (R^2) (Van Cranenburgh, 2018). The results of the best models are presented in table 6.6.

Table 6.6: Results latent class choice model estimations with different numbers of classes

Classes	LL	BIC	R^2
Basic RUM model	-1796,2	3632,5	0,156
2	-1697,7	3483,7	0,203
3	-1630,5	3397,4	0,234
4	-1585,9	3356,5	0,255
5	-1567,0	3366,8	0,264

The log-likelihood and rho-squared values improve by adding more parameters. However, adding parameter can lead to overfitting. To determine which number of classes fits the best, the Bayesian Information Criterion is used (Van Cranenburgh, 2018). This criterion uses a penalty term for the number of parameters in the model to solve the problem of overfitting. The lower the value of BIC, the better the model fits the data. As shown in table 6.6, the model with 4 classes has the lowest BIC value and therefore has the best model fit.

To determine if the classes can be explained by socio-demographic characteristics, the class membership parameters and corresponding probabilities are added. All socio-demographic factors asked in the survey are modeled in the 4 class LC model. Only the factor 'able to cycle' became statistically significant. This means that the classes formed by the model cannot be explained by other socio-demographic factors. Elderly have a chance to be allocated to a class independently of all the socio-demographic characteristics. In other words, elderly have a probability to be assigned to either class and their personal characteristics do not influence this probability, except from 'able to cycle'. The Biogeme syntax of the model is included in appendix G.4.1.

6.4.1. Latent Class choice model results

The estimation of the latent class choice model with 4 classes results in the parameter values shown in table 6.7. The parameter signs are as expected, except from the parameter 'transfers' in class 2: This parameter is statistically significant and positive, which means that if the number of transfers increases, the utility increases. This is remarkable, since elderly dislike transfers in general. For the other classes 'transfers' has a negative sign. The parameter 'travel costs' is negative and significant in all classes, which means that if travel costs increase, utility decreases. The 'frequency' parameter is positive in all classes, but only significant in classes 2 and 4, suggesting that in the other classes this parameter is not of importance. The 'distance to stop' parameter is only significant, and thus only of importance, in classes 1 and 3. The parameter 'travel time' was only significant in class 4, suggesting it is only of importance in class 4.

As described in chapter 2 section 2.3.2, the class membership parameters are used to determine the probability that an elder person belongs to a class (πns) regardless the socio-demographic characteristics. The higher the estimated class membership parameter, the higher the probability to belong to that class, and the larger the size of the class (Molin & Maat, 2015). Besides that, the 'able to cycle' coefficients indicate the probability that an elder person who is able to cycle or not belongs to a class. The able to cycle coefficients of class 2 and 3 are negative, which means that the elderly not able to cycle have higher probability to belong to these classes. The class membership probabilities are shown in table 6.8.

Table 6.7: Latent 4 Class Choice model parameters including Ability to cycle

Parameter	Class 1	Class 2	Class 3	Class 4
Frequency	0,0355	0,324	0,0507	0,211
Distance to stop	-0,0025	0,0003	-0,003	-0,0006
Travel costs	-1,9	-0,498	-0,271	-0,92
Transfers	-0,345	0,251	-0,968	-0,637
Travel Time	-0,027	0,0039	-0,009	-0,127
Class membership parameter (δ)	0	1,69	1,8	0,41
Able to cycle	0	-1,12	-1,29	0,39

Significant values are marked in green

Table 6.8: Class membership probabilities

Probabilities		Class 1	Class 2	Class 3	Class 4
Class membership probability (πns)		7,2%	38,8%	43,3%	10,8%
Ability to cycle (Ablecycle)	Probability that an individual who cannot cycle belongs to a class	2%	41%	54%	3%
	Probability that an individual who can cycle belongs to a class	15%	27%	25%	33%

Each of the classes is described in more detail according to the parameters. The classes with their size and important attributes are visualised in figure 6.2. In this figure, the attributes in red indicate that the specific class has the most negative parameter value for this attribute. The attributes in green indicate that the specific class has the most positive parameter value for this attribute. Besides that, the probability that an individual who can cycle and who cannot cycle belongs to a class is shown. The number between brackets shows the absolute number of individuals. The changes in utility for the different attribute levels of the classes are shown in figures 6.3. Only the significant parameters are visualised.

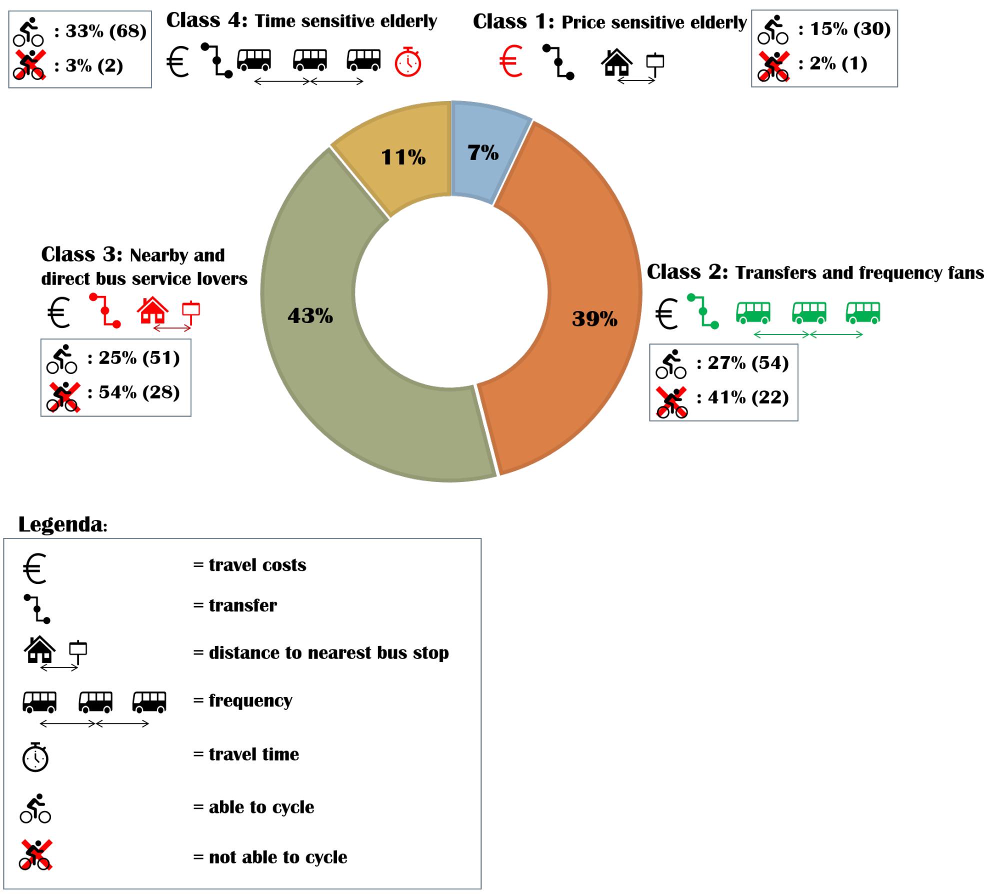


Figure 6.2: Classes of the LC choice model, size and important attributes per class

Class 1: 'Price sensitive elderly'

The first class has the lowest acceptance of travel costs of all classes. Compared to the MNL model, this class has a higher penalty for the distance to the nearest bus stop, indicating that the elderly in this class prefer a bus network with a low distance to the nearest bus stop. The transfer parameter does not have an extreme value compared to the other classes, and has the lowest willingness to pay for having one transfer less (€0, 18). The frequency and travel time parameters are not significant, suggesting these attributes are not important for the elderly in this class. The size of this class is very small: only 7% can be assigned to this class. Elderly who are able to cycle have a chance of 15% to be assigned to this class. Elderly who are not able to cycle have a minimum chance to be assigned to this class. On average, people who are able to cycle have a lower acceptance of travel costs.

Class 2: 'Transfers and frequency fans'

This second class has the highest bonus for frequency. A remarkable characteristic of elderly in this class is the positive parameter for transfers, indicating that this class prefers transfers. This can be explained by the fact that for most choice sets the bus option with higher frequency is associated with having a transfer. The respondents choosing for higher frequency will automatically choose for a transfer. The travel costs parameter does not have an extreme value. The distance to stop and travel time parameters are not significant, suggesting these attributes are not important for the elderly in this class. About 39% of the elderly belongs to this class. Elderly who are able to cycle have a high chance (41%) to be assigned to this class. For the elderly who are not able to cycle is this chance 27%. However, the number of respondents able to cycle and not able to cycle is 203 and 53, respectively. This means that in absolute numbers, the respondents who are able to cycle will be higher compared to the respondents who can not cycle in this class, with 54 compared to 22, respectively.

Class 3: 'Nearby an direct bus service lovers'
The elderly in this class the are least sensitive to travel costs. On the other hand, this class is highest sensitive for distance to stop and transfers. This suggests that the elderly in this class are willing to pay more to shorten the distance to the nearest bus stop (€1, 11 for 100 meter less) and to have less transfers (€3, 57 for a transfer less). The frequency and travel time parameters are not significant, suggesting these attributes are not important for the elderly in this class. This class is the largest with about 43% of the elderly assigned to it. The probability of elderly able to cycle being assigned to this class is high, with 54%. For the elderly who are not able to cycle is this chance 25%. However, the number of respondents able to cycle and not able to cycle is 203 and 53, respectively. This means that in absolute numbers, the respondents who are able to cycle will be higher compared to the respondents who can not cycle in this class, with 51 compared to 28, respectively.

Class 4: 'Time sensitive elderly'
Only this class has a significant parameter with a high value for travel time, indicating that the elderly in this class are high sensitive for travel time. The willingness to pay is €1, 38 to shorten the travel time with 10 minutes. Next to that, the class is relatively high sensitive for travel costs. The willingness to pay for one transfer less is €0, 69. The distance to stop parameter did not become significant, indicating that this attribute is not important for the elderly in this class. The class membership parameter did not become significant, indicating that this class is not significant larger than class 1: price sensitive elderly. This also applies to the parameter for ability to cycle.

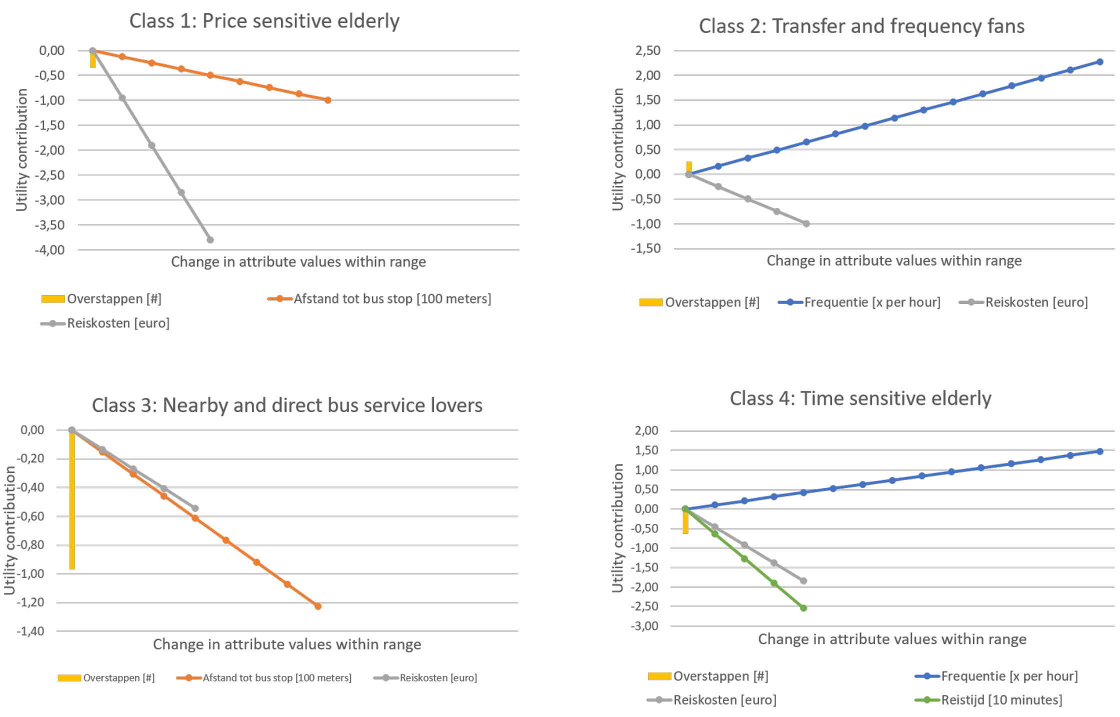


Figure 6.3: Changes in utilities for different attribute levels for each class

6.5. Model estimations with only bus user data

The models in section 6.4 capture all the data coming from the survey including bus users and non-bus users. It might be that bus users have different preferences than non-bus users. Therefore, a base MNL model and a latent class choice model without the non-bus users are estimated in this section. It is not possible to estimate the models for the non-bus users, since this sample is too small.

The same utility functions as in the MNL model in section 6.2 are used, since the quadratic component for 'frequency' became significant. The results of the MNL model including all data an the MNL model with only bus users data is presented in table 6.9. Comparing the parameter values of the two MNL models, shown in table 6.2 in section 6.2 and in appendix G.5.1, it can be seen that those parameters just have very little negligible differences. The relative importance of the parameters remained the same.

For estimating the Latent Class choice model, models with an increased number of classes are estimated with different starting values for the class membership parameters, similar to section 6.4. The model with 4 classes fits best, since it has the lowest BIC. Also in this model it is determined whether the classes can be interpreted by socio-demographic factors. All the socio-demographic factors from the survey are modeled in the LC choice model with 4 classes. However, none of the factors became statistically significant. This means that the elderly have a probability to be assigned to either class regardless of all their personal characteristics.

Table 6.9: Comparison model results including all data and including only bus user data

Model		# observations	# parameters	R^2	adjusted R^2	Null LL	Final LL	LRS	BIC
MNL model all data		3072	5	0,156	0,154	-2129,348	-1796,154	666,388	3632,459
MNL model only bus users		2400	5	0,164	0,161	-1663.553	-1391,188	544.730	2821,293
LC choice all data	**2**	3072	11	0,203	0,198	-2129,348	-1697,704	863,289	3483,739
	3	3072	17	0,234	0,226	-2129,348	-1630,466	997,763	3397,44
	4	3072	23	0,255	0,244	-2129,348	-1585,918	1086,86	3356,528
	4 able cycle	3072	26	0.259	0,246	-2129,348	-1578,492	1101,712	3365,766
	5	3072	29	0,264	0,25	-2129,348	-1566,986	1124,725	3366,844
LC choice only bus users	**2**	2400	11	0,21	0,203	-1663,55	-1314,838	697,43	2715,292
	3	2400	17	0,238	0,228	-1663,553	-1267,619	791,868	2667,554
	4	2400	23	0,257	0,243	-1663,553	-1236,772	853,563	2652,558
	5	2400	29	0,267	0,25	-1663,553	-1218,612	889,882	2662,938

6.6. Conclusion

This chapter described the model estimation and aimed to answer sub-questions 2 and 3. The influence of the five attributes 'travel time', 'travel costs', 'frequency', 'transfers' and 'distance to bus stop' on the bus choice was identified by estimation of a MNL model. The socio-demographic characteristics were included in the MNL model as interaction effects to test if these characteristics affect the attributes that influence the bus choice. To see if segments for the bus choice could be identified, and to test for heterogeneity in another way, a Latent Class Choice Model was estimated.

SQ2: "Which bus attributes are most important for the elderly, and to which extent?"

Results of the MNL model estimation show that all parameter values for the five attributes 'travel time', 'travel costs', 'frequency', 'transfers' and 'distance to bus stop' are significant. This means that the five attributes are of influence on elderly's choice for the bus. For the attribute level range used in this choice experiment, it turned out that 'travel costs' is the most important for choosing a bus service, followed by 'frequency' and 'travel time'. For the attribute level range used in this choice experiment, 'transfers' had the lowest relative importance followed by 'distance to the nearest bus stop'. The importance of 'travel costs' is about three times higher compared to those attributes. Also the willingness to pay indicates this differences in importances of the attributes. The willigness to pay for a bus stop 100 meters closer is €0,20, while the wtp for a 10 minutes reduction in travel time is €0,46.

SQ3: "To which extent does heterogeneity in preferences exist among elderly regarding the values of bus attributes, and to which socio-demographic characteristics can this unobserved heterogeneity be attributed?"

Results of the MNL model estimation on the interaction effects show heterogeneity in preferences exist. For the attribute 'travel time', the interactions with 'age' and 'walking tool' became significant. Higher age and having a walking tool reduce the sensitivity for travel time. For the attribute 'travel costs', the interactions with 'age', 'income', 'walking tool' and 'driving license' became significant. Higher age, higher income, having a walking tool and having a driving license reduce the sensitivity for travel costs. For the attribute 'transfers', the interaction with 'gender' became significant, suggesting that males are less sensitive for having a transfer during the trip. The interaction with 'bus usage' became significant for the attribute 'distance to bus stop'. However, this effect is very small and not considered. No interactions became significant for the attribute 'frequency'.

Results of the latent class choice model also show heterogeneity. The latent class model with 4 classes has the best model fit. Only the socio-demographic factor 'able to cycle' can explain the heterogeneity. The four classes 'price sensitive elderly', 'transfers and frequency fans', 'nearby and direct bus service lovers' and 'time sensitive elderly' were identified. However, the classes 'price sensitive elderly' and 'time sensitive elderly' are very small.

- The class 'transfers and frequency fans' contains 39% of the elderly. They are high sensitive for frequency and are positive about transfers, which is remarkable. It is more likely that elderly who can not cycle belong to this class.
- The largest class 'nearby and direct bus service lovers' contains 43% of the elderly. They do not consider the costs as important. These elderly have relatively high penalties for distance to bus stop and transfers. They are more likely to not be able to cycle.
- The class 'price sensitive elderly' is the smallest, with 7% of the elderly attributed to it. These elderly are high sensitive for travel costs and do not appreciate the distance to the bus stop. Price sensitive elderly are more likely to be able to cycle.
- Finally, the 'time sensitive elderly' has the largest dislike for travel time. Also the travel costs are relatively high penalized. The size of this class is comparable to the price sensitive elderly, since the class membership parameter did not become significant.

The MNL and LC choice models were also estimated for only bus user data to check whether these results are different. The differences for the MNL results are very small and therefore negligible. The LC choice model with 4 classes also had the best fit for this data. However, for this data, the heterogeneity can not be explained by the socio-demographic characteristics, since none of the characteristics became significant.

7

Theory versus practice: the elderly in Groningen

This chapter compares the results of the theory and models with findings in practice. Groningen is used to gain insights, because of the availability of public transport chip card data. Besides that, Groningen is an urban area with increasing ageing. The bus usage of elderly is compared with the bus usage of all bus users in Groningen, and compared with the model results from chapter 6. After this, a scenario analysis is done to test which bus network designs are preferred by the elderly. With the results from the scenario analysis, it is investigated whether a certain policy decision regarding the bus network in Groningen is beneficial or disadvantageous for the elderly.
The first section gives a description of the demographics and types of bus services in Groningen. Section 7.2 elaborates on the bus usage of elderly in Groningen including the usage of bus stops, bus lines and origin-destination pairs and compares this with the bus usage of all bus users. Besides that, the usage of the types of bus services by elderly in Groningen is compared with the model results from chapter 6. Scenarios are developed, and tested in sections 7.3 and 7.4 on the MNL model and LC choice model. One of the scenarios represents a policy choice for Groningen. The chapter ends with a conclusion in section 7.5.

7.1. Demographics and bus network of Groningen

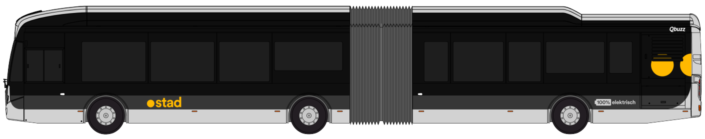
Groningen is one of the strong growing municipalities in The Netherlands. The municipality of Groningen is expected to grow from 203.000 to 250.000 inhabitants until 2030-2035 (Scheltes & Kwantes, 2019). Within the growing population the number of elderly is also increasing. The number of people aged 65 years and older in the city, villages and the countryside of Groningen is expected to double from 22.000 to 41.000 from now until 2040. At the moment, the share of elderly is 15% of the total population (CBS, 2019b).

The most popular transport mode for trips within the municipality is the bicycle. For longer trips between the municipality and beyond people mainly choose the car. About 11% of the total mobility from, to and within Groningen takes place with public transport (Scheltes & Kwantes, 2019). Four types of bus services can be distinguished, which are clearly different from each other. These types of bus services are shown in figure 7.1, and the differences are mentioned below.

- **City bus:** Stops en route at many stops, including the train station, shopping centers, hospitals, and living and working areas. Most city buses run twice an hour. City buses run more often on busier routes.
- **Regional bus:** Runs between the villages and towns in Groningen and Drenthe once or twice per hour on workdays. Regional buses less frequently in the evenings and at weekends.

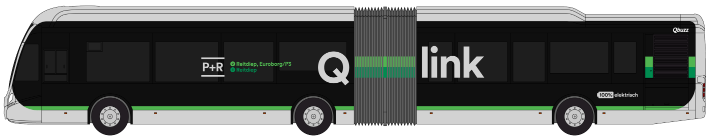
- **Q-link:** this is the fast bus network between Groningen City and the larger commuter areas around it. The network consists of seven lines. With this service, important destinations in the city such as the station, city center and hospital can be reached without transfers. Q-link is focused on short travel times by stretching lines and high frequency. The Q-link lines run every 10 minutes or more during rush hours.
- **Qliner:** Runs a direct, fast route between large villages and towns and stops at a limited number of stops. The Qliner also runs on a number of routes along the bus lane along the traffic jam, to reach destinations faster. Qliner drives more often during rush hours.

Q-link and Qliner are part of the high-quality public transport network (HOV-netwerk). This HOV-network has such characteristics that this transport is a serious alternative for many car trips from the origin or from transfer locations in the travel chain (OV bureau Groningen Drenthe, 2019a). An area-wide basic network connects and opens up larger villages and towns.

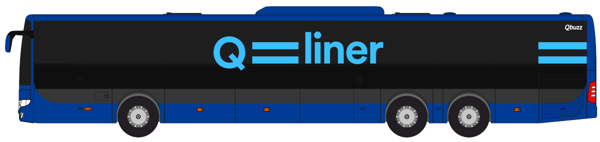


(a) City bus Groningen

(b) Regional bus Groningen



(c) Q-link bus Groningen



(d) Qliner bus Groningen

Figure 7.1: Types of bus services Groningen (OV bureau Groningen Drenthe, 2019b)

7.2. Bus usage Groningen and comparison to model results

Based on Public transport chip card data from March 2019 with a 65+ discount product, the bus usage of people aged 65 and over in Groningen is analysed. The bus usage data of these elderly is compared to the the model results of chapter 6. Besides that, the bus usage data of the elderly is compared to the public transport chip card data from 2018 of all bus users. The comparison between bus usage of the elderly and all bus users is made based on the average number of travelers boarding, the average distance per trip, the travel time during the day, the bus line usage, the bus stop usage and the most used origin-destination pairs.

7.2.1. Bus usage characteristics elderly

In March 2019, the number of elderly travelers boarding was 570.687. The average distance the elderly traveled by bus was 8 kilometers. From the data it appears that the elderly used the bus the most during the afternoon, at off peak hours. This bus usage during the day is shown in figure 7.2.

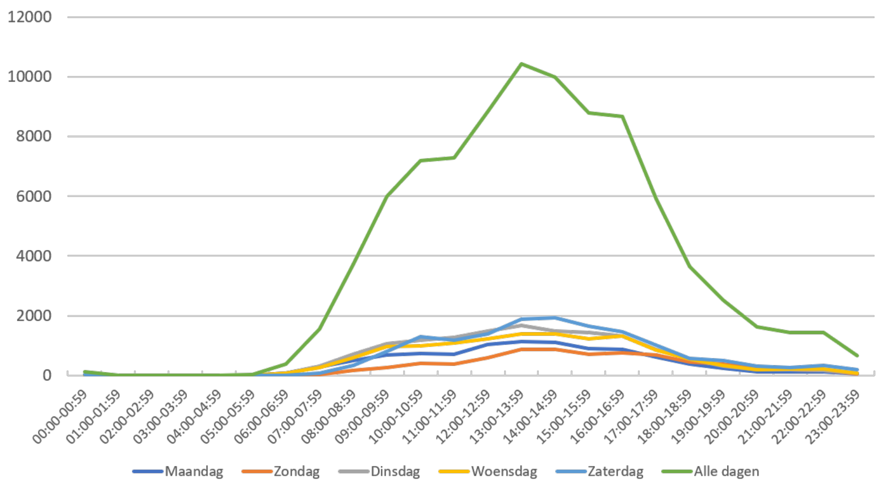


Figure 7.2: Number of times checked in by elderly during different days of the week and in total (own work)

Bus line usage elderly

There are many bus lines in Groningen. Some of the lines are used more frequent by the elderly than others. Figure H.1 in appendix H shows per bus line the number of times checked in by elderly in March 2019. This figure shows that 70% of the number of times checked in are at the first nine lines. Table 7.1 presents these nine bus lines with the number of times that elderly checked in and the line frequency. The most used types of lines are city lines and Q-link lines, specifically city line 10 and Q-link lines 4 and 3 are used intensively, with 11,4%, 11,3% and 10,8% respectively. As shown in the table, these lines have high frequencies during the day.
The bus lines which are part of Q-link or City lines, and its usage in % of the total usage are presented in Appendix G table H.1. This table shows that 40,3% of the number of times elderly checked-in in March 2019 were at Q-link lines and 29,8% at city lines.

Table 7.1: Busline usage elderly Groningen march 2019

Busline	Type of service	# check-ins	% of total	% cumulative	Freq spits	Freq dal	Freq weekend
10	City	10348	11,4%	11,4%	4	4	2-4
4	Q-link	10198	11,3%	22,7%	6	2-6	2-4
3	Q-link	9738	10,8%	33,5%	3-6	2-6	2-4
5	Q-link	8045	8,9%	42,4%	6	2-6	2-4
9	City	7227	8,0%	50,4%	2-4	2-4	2-4
7	City	4770	5,3%	55,6%	4	4	2-4
8	City	4301	4,8%	60,4%	2	2	0-2
6	Q-link	4160	4,6%	65,0%	2-6	2-4	0-2
50	Regional	3818	4,2%	69,2%	2-5	2-3	1-2

Bus stop usage elderly

The ten most used bus stops by elderly for boarding (march 2019) are shown in table 7.2. There is a big difference between the usage of the bus stops, even within the top 10 most used stops. The usage of the bus stop 'Groningen, Hoofdstation' comes out on top with 19,7% of the boardings, followed by 'Groningen, Grote markt' with only 6,8% of the boardings.
The stops in the table are nearby important facilities such as the train station, the city center, the hospital, the shopping mall, residential care centers and park and ride places. The bus stops with high amount of boardings are visualised in figure 7.3. The larger the dot, the higher the number of boardings. The red dots are in the top ten of most used bus stops.

Table 7.2: Most used stops for boarding among elderly in Groningen, march 2019

Bus stop	# times checked-in by elderly march 2019	% of total check-ins elderly (65+) march 2019
Groningen, Hoofdstation	17836	19,7%
Groningen, Grote markt	6174	6,8%
Groningen, Zuiderdiep	5614	6,2%
Groningen, UMCG Hoofdingang	2258	2,5%
Haren, P+R Haren / A28	1841	2,0%
Groningen, Westerhaven,	1647	1,8%
Hoogkerk, P+R Hoogkerk	1646	1,8%
Groningen, De Trefkoel	1458	1,6%
Groningen, MartiniZKH Hoofdingang	1290	1,4%
Emmen, Station	1153	1,3%

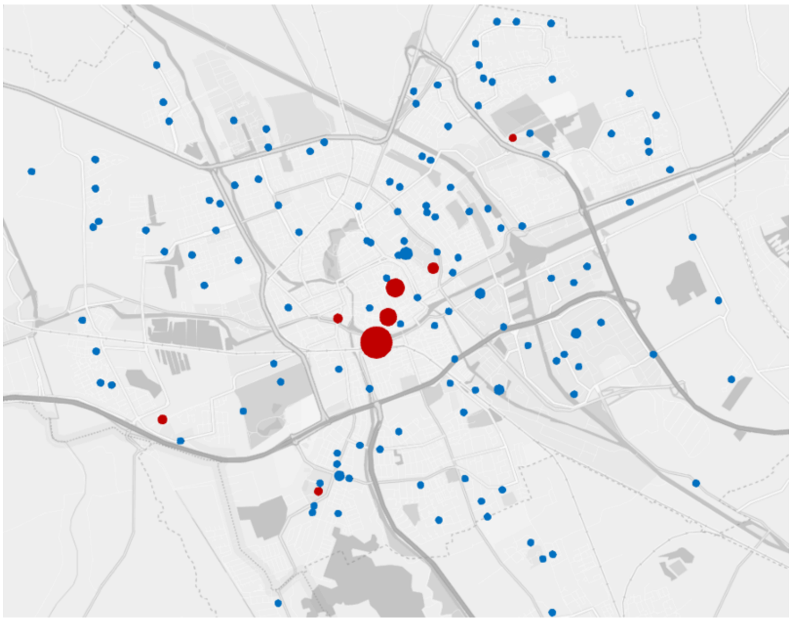


Figure 7.3: Stops in Groningen most used for elderly boarding, March 2019 (own work)

Most used origin-destination pairs elderly

The ten most used origin-destination pairs by elderly in Groningen are shown in table 7.3. The largest share of elderly travels from 'Groningen, Hoofdstation' to 'Groningen, Grote Markt'. This OD-pair has 881 boardings one way, and 825 boardings the way back. The most used OD pairs are all departing from or arriving at the most used stops already mentioned in table 7.2. Overall, the most used OD pairs are within the city center, between the city center and a park and ride location, or between the city center and the hospital.

Table 7.3: Most used origin - destination pairs by elderly, march 2019

Origin	Destination	# times checked-in by elderly
Groningen, Hoofdstation	Groningen, Grote Markt	881
Groningen, Grote Markt	Haren, P+R Haren/A28	825
Groningen, Grote Markt	Groningen, Hoofdstation	815
Haren, P+R Haren/A28	Groningen, Grote Markt	672
Groningen, Zuiderdiep	Haren, P+R Haren/A28	629
Hoogkerk, P+R	Groningen, Hoofdstation	557
Groningen, Hoofdstation	Groningen, UMCG Hoofdingang	535
Groningen, Hoofdstation	Groningen, Martini Ziekenhuis Hoofdingang	465
Groningen, Martini Ziekenhuis Hoofdingang	Groningen, Hoofdstation	434

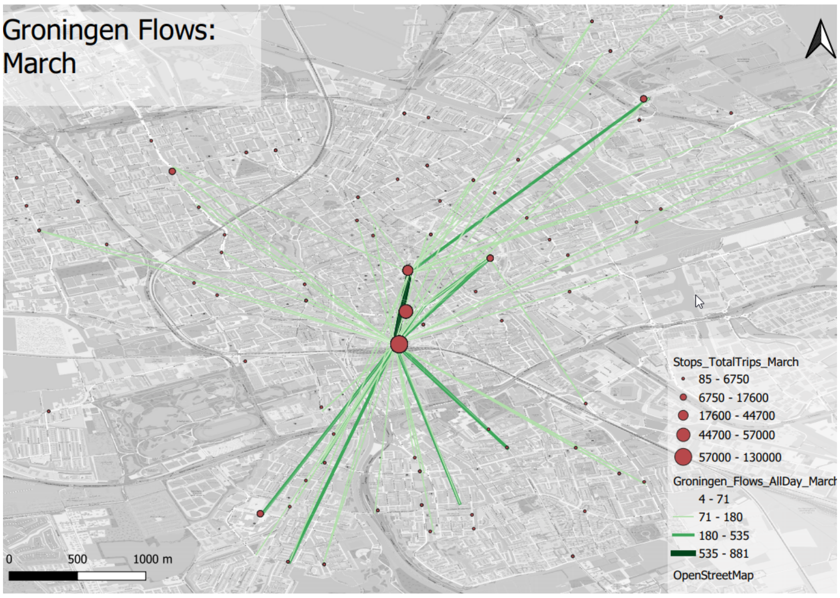


Figure 7.4: Origin-Destination flows Groningen, march 2019 (own work)

7.2.2. Comparison model results with bus usage elderly in Groningen

According to the results of the MNL model, elderly prefer a high-frequent bus service with low travel costs. Also the LC choice model results indicate that most of the elderly (50%) prefer a high-frequent bus service with low travel costs. However, another big group (43%) prefers a bus service without transfers and a low distance to the nearest bus stop. The findings of the bus usage of the elderly in Groningen showed that most of the check-ins at buses (40%) were at the fast and high-frequent Q-link buses. This indicates that most elderly prefer this bus option. Besides that in second place, 30% of the check-ins at buses were at the city bus lines with many stops and lower frequency. Therefore, it can be concluded that the results from the models are in line with findings in practice.

7.2.3. Bus usage characteristics all users compared to elderly

This section elaborates on the bus usage of all the bus users in Groningen in 2018, based on public transport chipcard data, and compares this with the bus usage of the elderly. In 2018, the total number of times checked-in at the bus during the year was 21.969.843. Comparing this with the data of the elderly indicates that 31% of the bus usage is by the elderly. The average distance of all travelers by bus was 10,3 kilometers. The average distance the elderly travel is a little lower. According to Zijlstra et al. (2017), the overall bus usage is the highest during peak hours in the morning and evening. However, the bus usage of the elderly is highest during off peak hours as shown in figure 7.2.

Bus line usage

An overview of the most used bus lines by all users is presented in figure 7.4. 70% of the total number of times checked-in was at these lines. The most used types of lines are again the Q-link and city lines. However, The Qliner lines and regional lines became also more important. The most used line is Q-link line 3 with 9,4%, followed by lines 4 and 15 with 9,2% and 7,1%, respectively.

Based on the tables 7.1 and 7.4 it can be concluded that the bus line usage of all users is more spread over the lines compared to the bus line use of elderly, since 15 lines served 70% of the boardings of all users compared to 9 lines serving 70% of the boardings of elderly users.

Table 7.4: Busline usage all bus users Groningen 2018

Bus line	Type of service	# times checked-in	% of total	% cumulative
3	Q-link	2092464	9,4%	9,4%
4	Q-link	2054499	9,2%	18,6%
15	Q-link	1575478	7,1%	25,7%
5	Q-link	1225277	5,5%	31,2%
10	City	1162519	5,2%	36,5%
9	City	1077555	4,8%	41,3%
7	City	937424	4,2%	45,5%
6	Q-link	856911	3,9%	49,4%
300	Qliner	786248	3,5%	52,9%
1	Q-link	768451	3,5%	56,4%
309	Qliner	674614	3,0%	59,4%
2	Qlink	666068	3,0%	62,4%
50	Regional	616407	2,8%	65,2%
61	Regional	480735	2,2%	67,3%
65	Regional	470749	2,1%	69,4%

Bus stop usage
The ten most used bus stops for boarding by all bus users in Groningen are shown in table 7.5. Again the bus stop 'Groningen, Hoofdstation' has the highest percentage number of times checked-in, with 22,2%, followed by 'Emmen, Station' with 3,2%. There is a big difference in usage between the stops in the table.
Many of the bus stops which are most used by all users, are also used a lot by the elderly. However, the bus stop 'Groningen, Zernikeplein' is used very little by elderly and very popular according to all users. This can be explained by the fact that this bus stop is at Groningen campus, which is relevant for students and employees and not for elderly. The bus stop with high amount of boardings by elderly and all users are visualised in figure 7.5. The larger the dot, the higher the number of boardings. The orange dots are the bus stops in the top ten most used bus stops by all bus users. The red dots are the bus stops in the top ten most used bus stops by elderly.

Table 7.5: Most used bus stops for boarding among all users in Groningen, year 2018

Bus stop	users boarding year 2018	% of total users boarding 2018
Groningen, Hoofdstation	4931294	22,2%
Emmen, Station	715437	3,2%
Groningen, Zuiderdiep	713512	3,2%
Groningen, Grote Markt	683947	3,1%
Groningen, Zernikeplein	669226	3,0%
Groningen, UMCG Hoofdingang	436624	2,0%
Groningen, UMCG Noord	416029	1,9%
Groningen, Westerhaven	364911	1,6%
Assen, Station	296655	1,3%
Groningen, P+R Kardinge	283698	1,3%
Hoogkerk, P+R Hoogkerk	282349	1,3%

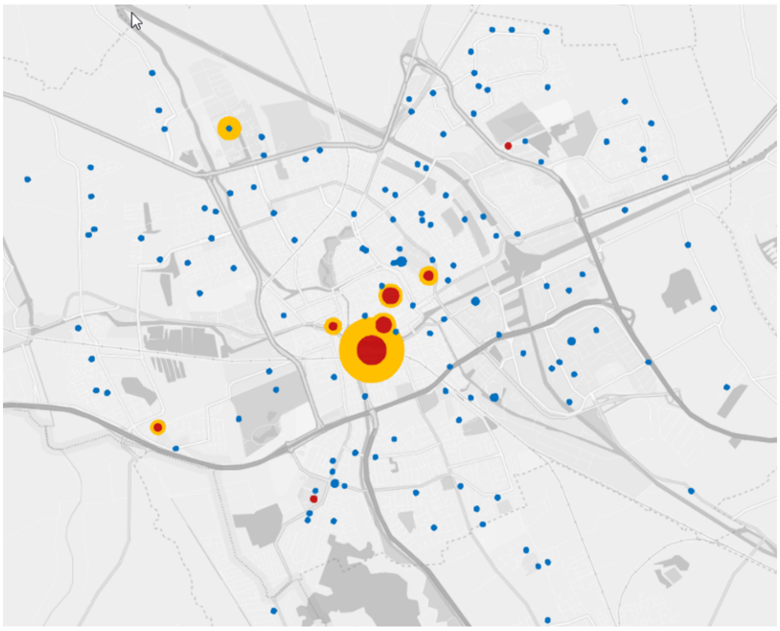


Figure 7.5: Stops in Groningen most used by elderly and all users (own work)

Bus stops with high share of boardings by elderly
In addition to the differences in usage of bus stops between elderly and all users, the proportion of number of times checked-in by elderly to the number of times checked-in by all bus users is also different per stop. At some bus stops, the share of checked-ins by elderly is relatively high compared to those of all users. Figure 7.6 shows the stops at which the share of check-ins by elderly is at least 15%. Details are shown in table H.2 in appendix H.
As shown in table H.2, 39,1% of the boardings at bus stop 'Groningen, W. Dreesstraat' are done by elderly. A possible explanation for this high percentage is the existence of the Willem Dreesflat nearby the bus stop. This flat contains rental apartments for elderly. The other bus stops in the table are also in neighbourhoods important for elderly, since they are nearby service flats with homes for the elderly, nearby a residential care center or nearby the hospital.

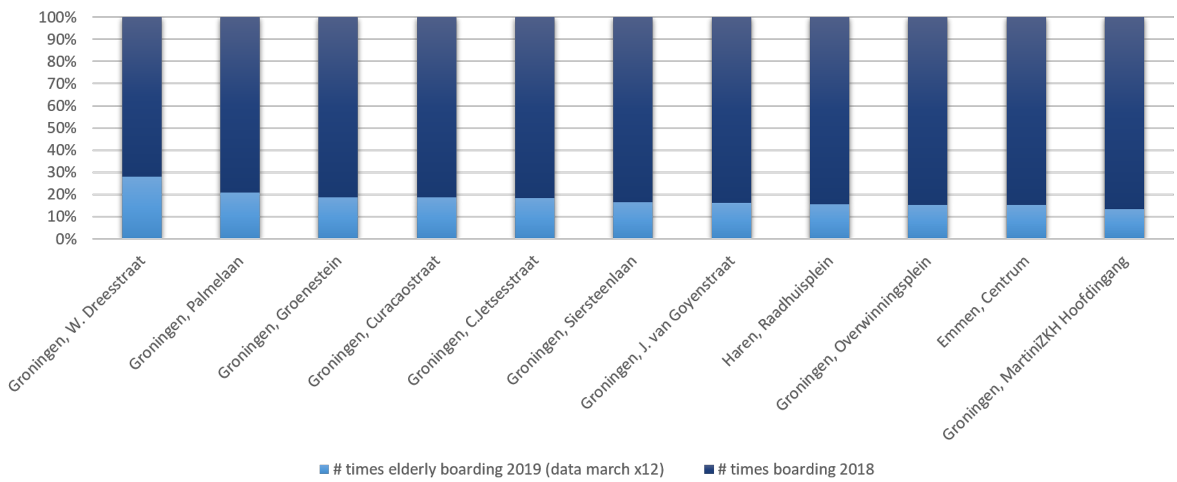


Figure 7.6: Stops with relative high amount of elderly boarding

Most used origin-destination pairs

The ten most used origin-destination pairs by all bus users are shown in table 7.6. The largest share of the bus users travels from 'Groningen, Zernikeplein' towards 'Groningen, Hoofdstation' or the other way around. Also here, OD pairs within the city center and between the city center and hospital are in the top ten most used OD pairs. However, the Park and Ride locations are not in the top 10. Instead of this, Zernikeplein and Nijenborgh, which are nearby the campus of Groningen, are now popular. Besides that, Also OD pairs starting or ending outside Groningen, such as Assen and Emmen, are popular.

Table 7.6: Most used origin - destination pairs by all bus users, 2018

Origin	Destination	#travelers boarding year
Groningen, Zernikeplein	Groningen, Hoofdstation	326846
Groningen, Hoofdstation	Groningen, Zernikeplein	279512
Groningen, Hoofdstation	Groningen, Grote Markt	156483
Groningen, Grote Markt	Groningen, Hoofdstation	129040
Groningen, Hoofdstation	Assen, M.L. Kingweg	128584
Groningen, Hoofdstation	Groningen, UMCG Noord	118665
Groningen, Hoofdstation	Groningen, Nijenborgh	115334
Groningen, Zuiderdiep	Groningen, Hoofdstation	113732
Emmen, Station	Groningen, Hoofdstation	112430

7.3. Scenario analysis on MNL model

In the following sections, three scenarios are developed to test which scenarios are beneficial or disadvantageous for the elderly and to help operators choose a strategy for the network design of the bus. The impact of all the attributes used in the survey are analysed: 'travel time', 'travel cost', 'frequency', 'distance to bus stop', and 'transfers'. To create different scenarios, the design dilemmas from section 3.3 are used as policy and design measures. One of the scenarios represents a public transport vision choice regarding the bus network in Groningen.

7.3.1. Estimating choice probabilities

To perform the scenario analysis, the MNL model without interaction effects with the estimated parameter is used. The multinomial logit probability function, presented in equation 2.4 , is used to compute the choice probabilities of the alternatives. The utility function is provided in equation 7.1.

$$V_i = -0.0316*TT_i+-0.580*TC_i+0.357*FREQ_i+-0.0269*FREQ_i^2+-0.364*TF_i+-0.00114*SD_i \quad (7.1)$$

Where:

V_i = utility of scenario i
TT_i = value of the variable 'Travel Time' (TT) of scenario i
TC_i = value of the variable 'Travel Cost' (TC) of scenario i
$FREQ_i$ = value of the variable 'Frequency' (FREQ) of scenario i
TF_i = value of the variable 'Transfers' (TF) of scenario i
SD_i = value of the variable 'Distance to bus stop' (SD) of scenario i

7.3.2. Reference scenario

A reference scenario is used, see table 7.7. Average values for the attributes of this scenario are defined based on the averages calculated in section 4.1. For determining the travel cost, it is assumed that the elderly use a public transport card with elderly discount of 34%.

Table 7.7: Reference scenario

Attribute	Reference scenario
Travel time [min]	30
Travel costs [euro]	1,70
Frequency [veh/h]	4
Transfers [transf/trip]	0
Distance to nearest bus stop [meter]	400

7.3.3. Scenarios

Three scenarios are developed and tested and will be explained in the following paragraphs. The results of the scenarios including the attribute values, utility and probability to be chosen are presented in table 7.8. Two probabilities are estimated. The first percentage indicates the probability of elderly choosing the scenario when they have to choose between the reference scenario and this scenario. The second percentage between brackets indicates the probability that this scenario will be chosen out of all four scenarios.

Table 7.8: Scenarios and their utility and probability

	Reference	Scenario 1: High frequent bus	Scenario 2: Dense network & high travel time	Scenario 3: Combination of both
Travel time [min]	30	20	35	27
Travel costs [euro]	1,70	1,50	2,00	1,70
Frequency [veh/h]	4	6	2	4
Transfers [transf/trip]	0	0	0	1
Distance to nearest bus stop [meter]	400	600	200	300
Utility	-1,3924	-1,0124	-1,8876	-1,5476
Probability when compared to reference*		59%	38%	46%
% of total**	25%	37%	16%	22%

** probability of elderly choosing the scenario when they have to choose between the reference scenario and this scenario*

*** probability of elderly choosing the scenario when they have to choose between the reference scenario and the 3 other scenarios*

Scenario 1: High frequent bus

This first scenario represents a public transport vision choice regarding the bus network in Groningen. In Groningen, the pressure on the public transport system gets higher, since the number of public transport users increases and the public transport usage per person gets higher due to a mobility transition (Scheltes & Kwantes, 2019). The municipality of Groningen wants to develop and improve their public transport network to secure affordable and future-proof high-quality public transport for the long term. Therefore, the public transport vision Groningen 2040 is composed, which describes the headlines of the public transport choices until 2040 and forms the basis for future public transport policy. One choice in the public transport vision is to improve the bus network and reduce the travel time of the city buses by stretching and straightening routes (Scheltes & Kwantes, 2019). The design dilemma short in-vehcile times versus short access times needs to be considered here, since stretching lines leads to a larger distance to the nearest bus stop. This choice is translated into a scenario.

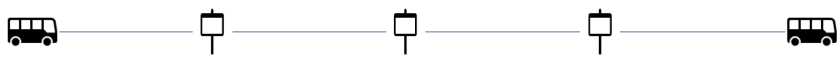


Figure 7.7: Scenario 1 (own work)

In this scenario the travel time is short, 20 minutes, and the distance to the nearest bus stop is large, 600 meters. The frequency is high, with 6 buses departing per hour (one bus per 10 minutes). The costs of the trip are €1,50. The attribute values of this scenario are shown in table 7.8.

Offering a bus option with higher frequency, low travel time and less travel cost will attract elderly, even if the distance to the nearest bus stop is high. To increase the frequency and decrease the travel time, the bus can not stop at too many places. Besides that, more vehicles are needed and operational costs are higher. However, when travel time decreases, less vehicles are needed again.

Scenario 2: Dense network with higher travel time

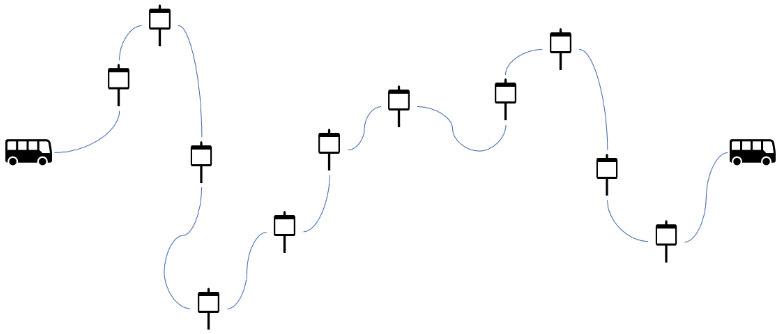


Figure 7.8: Scenario 2 (own work)

In this scenario, the network density is increased. The distance to the nearest bus stop is very short, 200 meters. However, the travel time is higher now, since the bus needs to stop at many places and is not driving in a straight line. This leads to an lower frequency as well. The costs increased because of the higher travel time (in-vehicle time).

Table 7.8 shows the values of the attributes. Offering a bus option with a very small distance to a bus stop, but higher travel time, costs and lower frequency is less attractive for the elderly. This scenario is not only less attractive compared to the reference scenario, but also compared to the two other scenarios.

Scenario 3: Combination of both

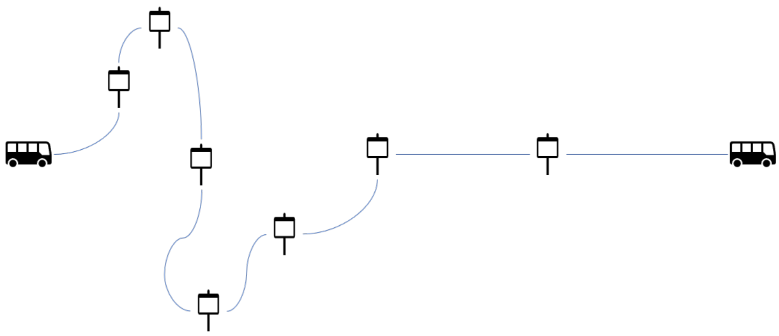


Figure 7.9: Scenario 3 (own work)

This scenario is a mix between scenario 1 and 2, between a dense and coarse bus network. The design dilemma short-in vehicle times versus short access times and minimization of transfers versus short waiting times is considered here. The travel time is higher compared to a coarse network, but lower compared to a dense network, since there are less stops. Because of this, the frequency is higher compared to the dense network scenario. However, this leads to a larger distance to the nearest bus stop for a part of the people compared to the dense network scenario. One transfer has to be made during the trip, to switch from the bus on a dense network to a bus on a coarse network. The values of the attributes of this scenario are shown in table 7.8.

Offering a bus option which combines lower distance to the bus stop and lower travel time compared to the reference scenario, but having a transfer is a little less attractive for the elderly. However, this scenario is more attractive compared to scenario 2.

7.4. Scenario analysis on LC choice model

The three developed scenarios are also tested on the classes of the Latent Class choice model, which is estimated in in section 6.4. Where the MNL model is used to test which scenarios are beneficial or disadvantageous for the elderly as a whole, the LC choice model is used to test which scenarios are beneficial or disadvantageous for each of the four classes among the elderly. The results of the estimated Latent class model are presented again in table 7.9.

Table 7.9: Class membership probabilities

Probabilities		**Class 1**	**Class 2**	**Class 3**	**Class 4**
Class membership probability (πns)		7,2%	38,8%	43,3%	10,8%
Ability to cycle (Ablecycle)	Probability that an individual who cannot cycle belongs to a class	2%	41%	54%	3%
	Probability that an individual who can cycle belongs to a class	15%	27%	25%	33%

To compute the choice probabilities of the different scenarios for the classes, again the multinomial logit probability function is used. The utility functions of the classes are provided in equations 7.2 to 7.5, where i represents the scenario. Only the significant parameters of each class are used in the utility function.

$$V_{class1i} = -1.9 * TC_i + -0.345 * TF_i + -0.0025 * SD_i \tag{7.2}$$

$$V_{class2i} = -0.498 * TC_i + 0.324 * FREQ_i + 0.251 * TF_i \tag{7.3}$$

$$V_{class3i} = -0.271 * TC_i + -0.968 * TF_i + -0.0031 * SD_i \tag{7.4}$$

$$V_{class4i} = -0.92 * TC_i + 0.211 * FREQ_i + -0.637 * TF_i + -0.127 * TT_i \tag{7.5}$$

The results of the scenarios in terms of utility and probability are presented in table 7.10. Again two probabilities are estimated. The first percentage indicates the probability of elderly choosing the scenario when they have to choose between the reference scenario and this scenario. The second percentage indicates the probability that this scenario will be chosen out of all four scenarios. The four classes with their preferences regarding the scenarios are discusses below.

Class 1
The elderly in the first class do not have a clear preference for one scenario. The probability that elderly in this class will choose a certain scenario is about 25% for all scenarios. An explanation for this is that this class is most sensitive for 'travel costs' and 'distance to the nearest bus stop'. For each scenario, a decrease in distance to the nearest bus stop also means an increase in travel costs, and vice versa. Therefore, this class judges the scenarios almost equally.

Class 2
The elderly in class 2 prefer scenario 1: 'high frequent bus'. The least favorite scenario is scenario 2: 'dense network and high travel time'. This can be explained by the fact that this class does not consider distance to bus stop and prefers high frequency and low travel costs.

Class 3
The elderly in class 3 prefer scenario 2: 'dense network & high travel time'. They prefer scenario 3: combination of both and scenario 1: 'high frequent bus' the least. This can be explained by the fact that this class only considers frequency, travel costs and transfers.

Table 7.10: Scenario results of the four classes: utility and probability

	Reference	Scenario 1: High frequent bus	Scenario 2: Dense network & high travel time	Scenario 3: Combination of both
Class 1				
Utility	-4,222	-4,338	-4,296	-4,319
Probability when compared to reference*		47%	48%	48%
% of total**	27%	24%	25%	24%
Class 2				
Utility	0,4494	1,197	-0,348	0,7004
Probability when compared to reference*		68%	31%	56%
and % of total**	21%	44%	9%	27%
Class 3				
Utility	-1,6847	-2,2425	-1,154	-2,3467
Probability when compared to reference*		36%	63%	34%
% of total**	21%	15%	45%	14%
Class 4				
Utility	-4,53	-2,654	-5,863	-4,786
Probability when compared to reference*		87%	21%	44%
% of total**	12%	76%	3%	9%

** probability of elderly choosing the scenario when they have to choose between the reference scenario and this scenario*

*** probability of elderly choosing the scenario when they have to choose between the reference scenario and the 3 other scenarios*

Scenario 2 has the lowest distance to the nearest bus stop and no transfers and thus the favourite scenario. On the other hand, scenario 1 has a very high distance to the nearest bus stop, and scenario 2 has a medium distance to the nearest bus stop and a transfer. Therefore, these scenarios are preferred the least.

Class 4
In this class, the elderly clearly prefer scenario 1: 'high frequent bus' with a choice probability of 76% out of all scenarios. The scenarios 2: 'dense network high travel time' and 3: 'combination of both' are by far preferred the least. This becomes clear when looking at the utility function of this class, indicating that for the elderly in this class lower travel costs and travel time, high frequency and no transfers are very important. The scenarios 2 and 3 have a lower distance to the nearest bus stop, but this is not important for the elderly in class 4.

7.5. Conclusion

This chapter analysed the bus usage of elderly in Groningen and compared it to the model results of chapter 6. Besides that, the bus usage of elderly is compared to all bus users in Groningen. Next, several scenarios are developed and tested. One of the scenarios represented the choice of the municipality of Groningen to stretch and straighten the bus lines. The results of these scenarios provided insights in preferences of elderly regarding the network design of the bus.

Based on the data from Groningen it can be concluded that elderly use the fast and high-frequent Q-link lines the most, with 40% followed by the dense and low-frequent city bus lines with 30%. This is in line with both the MNL and LC choice model results that most elderly prefer fast and high-frequent bus services.

Practice shows differences between the bus usage of elderly and all bus users. First of all, 30% of the number of check-ins at the buses are by elderly. Secondly, on average, elderly travel less distances. Thirdly, the bus usage of elderly is highest during off-peak hours, while that of all users is highest during peak hours. Fourth, the bus line usage of all users is more spread over the different bus lines, including Qliner buses and regional buses.

The analysis of the bus stop usage shows similarities between the elderly and all bus users. The most used bus stops by elderly and the most used bus stops by all users have much overlap. These stops are all nearby important facilities such as hospitals, stations, shopping malls, residential care centers, park and ride places, and the city center. The bus stop which stands out the most for both the elderly and all users is 'Groningen, Hoofdstation'. The only stop which is used extensively by all users and used very little by elderly is the bus stop 'Groningen, Zernikeplein', which is located next to Campus Groningen. Some bus stops are more used by elderly, such as 'Groningen, W. Dreesstraat'. These stops are located in areas nearby rental appartments for elderly, service flats, residential car centers or nearby the hospital.

Also the most used origin-destination pairs show similarities between the OD-pairs used by eldery and those used by all bus users. Only the OD pairs departing from or arriving at 'Groningen, Zernikeplein' or 'Groningen, Nijenborgh' are not popular to the elderly. As mentioned before, these stops are nearby Campus Groningen. Therefore, these stops are used intensively by students and employees, and not by elderly.

Three scenarios are tested on the MNL model and LC choice model.

According to the MNL model, the elderly prefer the scenario representing a public transport policy choice of the municipality of Groningen to stretch the bus lines. This scenario has a low travel time, high frequency, and high distance to the nearest bus stop. Although the distance to the nearest bus stop is high, this scenario is preffered the most by the elderly.

According to the LC choice model, the four classes have different preferences. The elderly in the first class do not have a preference for one of the scenarios. The probabilities of choosing one of the scenarios is equally distributed. The elderly in class 2 have the same preferences as resulting from the MNL model. This class might use the HOV network including Q-link and Qliner buses the most. On the other hand, class 3 prefers the scenario with the dense bus network the most. This class might use the city bus lines the most. The elderly in class 4 clearly prefer scenario 2. This class might use the HOV network including Q-link and Qliner buses the most, like class 2.

8
Conclusions, discussion and recommendations

This research investigated the mode attributes and socio-demographic factors influencing the bus usage and preferences of elderly in urban areas. This chapter first describes the conclusion in section 8.1, by answering the sub research questions and main research question. Section 8.2 contains a discussion of the results of this research. After that, the chapter ends with the recommendations for practice and future research.

8.1. Conclusions

The objective of this research was to find important socio-demographic characteristics and mode attributes that influence the bus service preferences and bus usage of elderly in urban areas in the Netherlands. Insight in individuals' preferences and trade-offs was obtained based on the choices made by respondents in the choice experiment. The presented results and guidelines could be used in future research on mobility options for an ageing population. At the same time, it could be used by governments to develop their bus network policy to make it more attractive for elderly to stimulate their bus usage in order to keep them mobile and participating in social and daily activities. This section answers the sub questions and main research question of this research.

The first sub research question is formulated as folllows:

SQ 1: "Which socio-demographic characteristics influence the bus usage of the elderly?"

Based on literature research and interviews with public transport and behaviour experts different socio-demographic characteristics were selected, as shown in table 8.1. It can be concluded based on cross-tables and the chi-square test that the socio-demographic characteristics 'walking tool', 'physically able to cycle', 'car ownership', 'driving license', 'public transport subscription', and 'ability to reach nearest bus stop without help' have a significant influence on the bus usage of elderly with the sign as expected from literature and expert interviews. It was observed that elderly with a walking tool make use of the bus more often. However, elderly who are not able to reach the bus stop without help, make less use of the bus. Furthermore, it was observed that the bus usage is higher for elderly without a car, elderly without a driving license and elderly having a transport subscription. Lastly, elderly who are able to cycle make more use of the bus as well. However, this last result needs to be taken with care, because the chi-square assumption for this socio-demographic characteristic is violated. The socio-demographic characteristic 'taken to or from destination by family or friends sometimes' turned out to have a significant influence on the bus usage of elderly, however, the direction of the sign is opposite to the direction expected from expert interviews. It was observed that elderly who are taken to or from a destination sometimes by friends or family are also using the bus more compared to the other elderly.

Table 8.1: Comparison results of this research with expectations of literature and expert interviews

Socio-demographic characteristics	Expected influence on bus usage (literature, expert interviews)	Influence on bus usage results from research
Age	-	no
Gender (man use less)	-	no
Household situation	-/+	no
Income	-	no
Walking tool	+	+
Physically able to cycle	+	+
Bicycle usage	-	no
Car ownership	-	-
Driving license	-	-
Taken to or from destination by family or friends sometimes	-	+
Valys usage	-	no
Public transport subscription	+	+
Ability to reach nearest bus stop without help	+	+
Distance to nearest bus stop in meters	-	no
Distance to nearest bus stop in minutes walking	-	no
Mobile phone possession	+	no
Internet access mobile phone	+	no
Internet usage mobile phone	+	no
Usage of trip planner via mobile phone	+	no

SQ 2: "Which bus attributes are most important for the elderly, and to which extent?"

In the choice experiment the generic attributes 'travel time', 'travel costs', 'frequency', 'transfers' and 'distance to nearest stop' were included that apply to both alternatives. Results of the MNL model estimation showed that all mode attributes have a negative effect on utility, except from frequency. This indicates that for the elderly a higher travel time, higher travel costs, having transfers, and a higher distance to the nearest bus stop are experienced as negative. Frequency has a positive effect on the utility of a bus option, which indicates that for the elderly a higher frequency is experienced as positive.

As can be seen in figure 8.1, travel costs has the largest influence on utility per unit change since the steepness of this line is the highest, followed by transfers and frequency. Looking at the impact on utility for the attribute level range used in the choice experiment, again travel costs has the largest impact. Based on these findings, it can be concluded that the travel costs are most important for the elderly followed by frequency, when looking at the elderly as one group. For the attribute level range used in this choice experiment, transfers had the lowest relative importance followed by distance to the nearest bus stop. The importance of travel costs is about three times higher compared to those attributes.

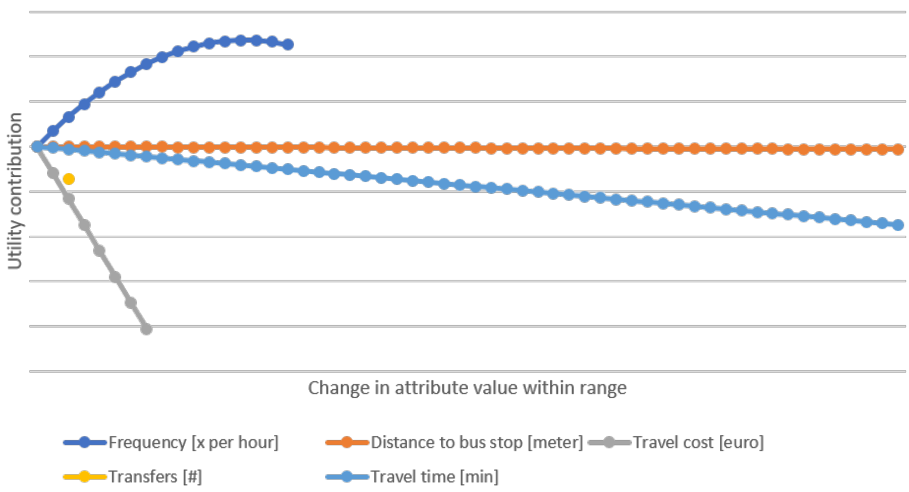


Figure 8.1: Attributes and the change in utility for the values within the range (own work)

SQ 3: "To which extent does heterogeneity in preferences exist among elderly regarding the values of bus attributes, and to which socio-demographic characteristics can this unobserved heterogeneity be attributed?"

It was examined if elderly with different socio-demographic characteristics are sensitive for different bus attributes in two ways. First, the socio-demographic variables obtained from the survey were included as interaction variables in the MNL model. Second, a Latent Class Choice model with a class membership function was estimated.

Results of the MNL model estimation on the interaction effects showed that only a few interactions are significant.

- Gender - transfers: Men are less sensitive to transfers than female.
- Age - travel costs: Elderly with higher age than 65-69 are less sensitive to travel cost.
- Age - travel time: Elderly aged 75-79 care also less about travel time than those aged 65-69.
- Income - travel costs: Elderly with higher (bruto) income are less sensitive to travel costs.
- Walking tool - travel costs: The elderly using a walking tool consider travel costs as less important than elderly without a walking tool.
- Driving license - travel costs: Elderly having a driving license consider travel costs as less important.
- Distance to the nearest bus stop in minutes walking - travel costs: Elderly who have to walk 6 minutes or more are less sensitive for travel costs than elderly who have to walk 0-2 minutes.

The heterogeneity in preferences has also been confirmed by the results of the estimation of the Latent Class Choice model. Four classes were distinguished: 7% of the elderly belong to class 1, 39% to class 2, 43% to class 3, and 11% to class 4 as visualised in figure 8.2. However, the class membership parameter of class 4 did not become significant, and should be interpreted as not being larger than class 1. Only the socio-demographic characteristic 'able to cycle' can significantly explain the membership of the classes.

- Elderly in the first class clearly prefer a cheap bus option without ransfers, having a low distance to the nearest bus stop. From the descriptive analysis it follows that this class mainly consists of elderly who are able to cycle.
- The second class mainly consists of elderly with a high preference for a frequent bus service. Remarkable in this class is the significant preference for transfers. There is

significant dis-utility for travel costs, however, much lower than in the first class. Elderly who are not able to cycle have a high chance to belong to this class. However, the absolute number of elderly who can cycle will be higher.

- The third class is the largest class and has a high preference for a bus service with low distance to the nearest bus stop and without transfers. Travel costs are less important compared to the other classes. Elderly who are not able to cycle have the highest chance to belong to this class. However, again, the absolute number of elderly who can cycle will be higher.
- Elderly in the fourth class prefer low travel time, low travel costs, no transfers and high frequency. The class membership parameter and ability to cycle parameter did not become significant. Therefore, it can be concluded that this class is not significant larger than class 1 and the probabilities being able to cycle are not significant larger than in class 1.

Based on these results, the design dilemmas mentioned in section 3.3 come up again. The first design dilemma 'short in-vehicle times versus short access times' is of interest, since the classes 1 and 3 prefer short access times, while the classes 2 and 4 prefer short in-vehicle times. Besides that, the third design dilemma 'minimisation of transfers versus short waiting times' is of interest, since the classes 1 and 3 prefer no transfers, while the classes 2 and 4 high frequency, and thus short waiting times. Following from the results of the scenario analysis, it can be concluded that the different classes have different preferences regarding the bus network. The first class does not have a clear preference for one of the types of bus networks. The classes 2 and 4, representing 50% of the elderly, prefer a network with fast and high-frequent network, but with a large distance to the nearest bus stop. Another large group, class 3 representing 43%, prefers a dense and low-frequent bus network, but with a bus stop nearby.

Also from the findings in practice in can be concluded that there is heterogeneity in preferences among the elderly. The use of the different bus lines differs per type of line. The fast and high-frequent Q-link lines are used the most, with 40%. The city bus lines with lower distance to the bus stop and lower frequency are used second most, with 30%.
To get back to the main research question:

"Which factors influence the preference and use of bus services among elderly people in urban areas of The Netherlands and what is the corresponding heterogeneity?"

The socio-demographic characteristics 'walking tool', 'able to reach the bus stop without help, 'car possession', 'driving license', 'transport subscription', 'taken/driven to or from destination by friends or family sometimes', and 'able to cycle' influence the bus usage of the elderly significantly.

Besides that, the values of the bus attributes influence the bus choice of the elderly. Travel costs has the largest negative effect on the bus preference per unit and frequency the largest and only positive effect.

The socio-demographic characteristics gender, age, income, walking tool, driving license and distance to the nearest bus stop in minutes walking influence the preferred value of the attributes and thus indicates heterogeneity in preferences among the elderly.

Four classes can be distinguished among the elderly having different preferences. The first class (7%) is very price sensitive and prefers a bus network without transfers and low distance to the nearest bus stop. The second class (39%) prefers high-frequent bus networks and are positive towards transfers. Class 3 (43%) highly prefers a bus stopping nearby and without transfers. Class four (11%) prefers a fast and high-frequent bus network without transfers. Only one the socio-demographic 'able to cycle' can explain the class membership significantly. The classes 1 and 4 consist of almost only elderly who are able to cycle. The elderly who are not able to cycle are spread over the classes 2 and 3. It can be concluded that elderly have opposite preferences regarding the values of bus attributes and opposite preferences regarding the bus network.

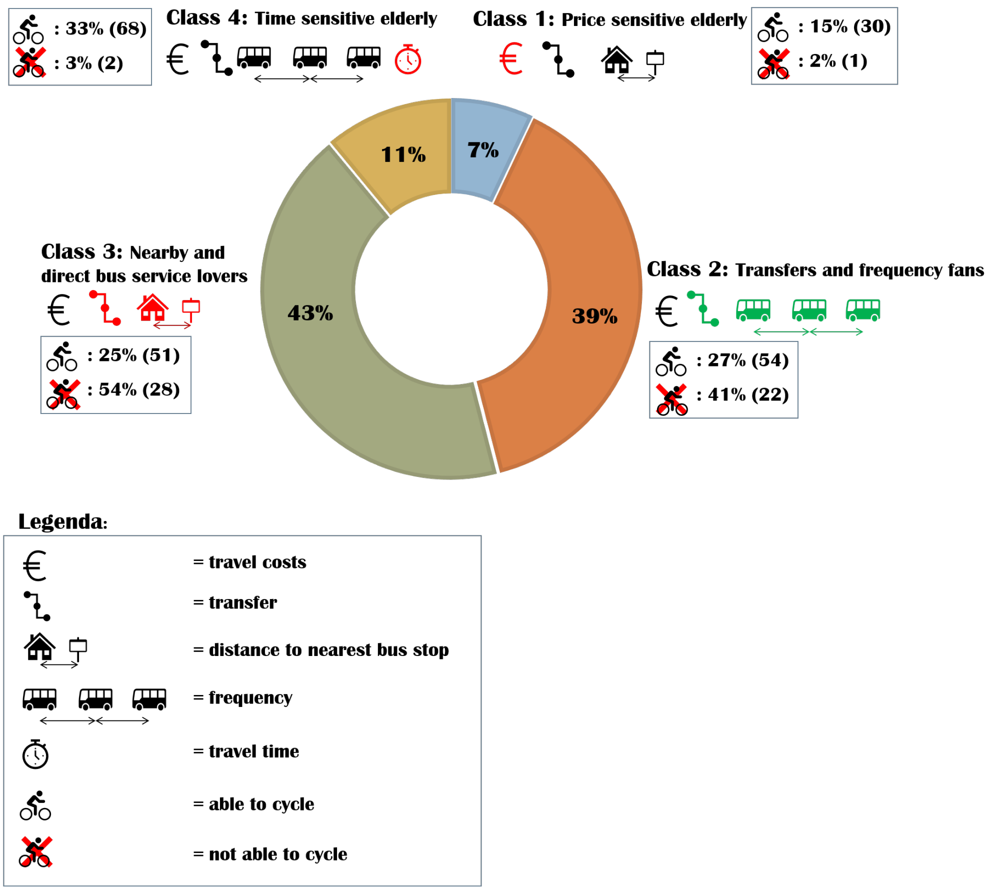


Figure 8.2: Classes of the LC choice model, size and important attributes per class (own work)

8.2. Discussion

This section discusses the methodology and results of this research. First, the results of the research are compared with results of previous studies. Second, the results of the models are compared with results from literature and findings from practice. The findings from practice result from data analysis of data from Groningen. Third, aspects related to the online survey and respondents are discussed. Fourth, the remarkable findings are discussed. Last, the limitations of this research are presented.

8.2.1. Comparison with previous research

The results of the research are compared with findings from previous studies. To the best of the author's knowledge, this study is unique, since no study has been conducted in order to determine the socio-demographic factors and mode attributes that influence the choice for bus specifically, and in The Netherlands. However, research has already been done towards factors influencing mode choice and the choice for public transport specifically of elderly. Factors from the literature review were selected and used in a Stated Preference experiment. The factors obtained from literature studies and used in this research are compared, based on their sign and significance. The results are shown in table 8.2.

Table 8.2: Comparison results of this research with results found in literature

	Literature		This research	
Factors	**Sign**	**Significance**	**Sign**	**Significance**
Socio-demographic characteristics				
Age	-	yes		no
Gender (man use less)	-	yes		no
Income	-	yes		no
Household situation	-/+	yes		no
Driving license	-	yes	-	yes
Car available	-	yes	-	yes
Mobile phone possession	+	yes		no
Walking tool	+	no	+	yes
Pt card owner	+	yes	+	yes
Bicycle ownership	-	no		no
Attributes				
Distance to stop	-	yes	-	yes
Travel time	-	yes	-	yes
Travel costs	-	yes	-	yes
Frequency	+	no	+	yes
Transfers	-	no	-	yes

The table shows that bicycle ownership was not significant from results obtained from literature and resulting from this research. This means that bicycle ownership does not have an effect on the elderly's bus choice. It can be seen that driving license, car availability and Pt card possession are both significant in results found in literature and within this research. The same applies for distance to stop, travel time and travel costs. However, age, gender, income, household situation and mobile phone possession were significant in results found in literature, but not within this research. Next to that, walking tool, frequency and transfer were insignificant in results found in literature, but significant in results found within this research.

Zijlstra et al. (2017) did a choice experiment among bus users where respondents had to choose between two public transport alternatives. The alternatives were varying in type of service, costs, travel time, punctuality, frequency and presence of other passengers. It was found that costs was the most important attribute for choosing between the public transport solutions. This is in line with the results found in this study, that costs has a high impact on utility per unit. This is also in line with the results of the choice experiment from Bronsvoort

(2019), where bus users in rural areas had to choose alternative public transport. Also here, costs proved to be the most important attribute.

Yang et al. (2013) researched the heterogeneity in travel time among elderly. It was found that elderly do not differ that much from other age groups in terms of their activity-travel behaviour. The needs of the elderly do not differ that much from younger people. The results of the MNL model estimation in our study is in line with these results. However, the results of the estimated class choice model indicate differences in needs among the elderly, and thus differences in needs compared to other age groups.

Hildebrand (2003) researched the heterogeneity in travel behaviour among elderly by delineating the elderly into different lifestyle groups. It was found that the majority of elderly will be highly mobile, while a smaller part will have disabilities. This is in line with our research, since 79% of the respondents is still able to cycle, and 62% is still using the cycle. Only 20,7% of the respondents is using a walking tool.

8.2.2. Comparison model results with literature and findings in Groningen

Data analysis on public transport chip card data of elderly and all bus users in Groningen showed that the average travel distance of the elderly is a little lower than the travel distance of the average bus user. This is in line with literature, as mentioned by Cui et al. (2017), and findings from CBS (2018c). The bus usage of the elderly resulted to be the highest during the afternoon at off peak hours and the bus usage of all bus users resulted to be the highest during peak hours, which is also in line with literature (CBS, 2018c; Cui et al., 2017).

According to the scenario analysis on the MNL model, most elderly prefer a high frequent bus service. Findings from practice confirm this, since data analysis showed that 40,3% of the check-ins of elderly in Groningen were at the fast and high-frequent Q-link buses and 29,8% of the check-ins were at city bus lines with more stops and lower frequency. The other 30% were either Qliner buses or regional buses. That most elderly prefer a high frequent bus option is also in line with research from KiM Netherlands Institute for Transport Policy Analysis (2016), which showed that a fast and frequent public transport option is preferred by most passengers. This is also in line with the scenario analysis on the LC choice model with four classes, in which 7% of the elderly (class 1) do not have a specific preference, 50% of the elderly (class 2 and 4) prefer a high-frequent bus, and 43% of the elderly (class 3) prefer a dense network with low distance to the nearest bus stop.

8.2.3. Online survey and respondents

An online panel is used for data collection, which means that respondents received some money for filling in the questionnaire. There is a risk that respondents did not fill in the questionnaire seriously and only completed the questionnaire to receive the money. Furthermore, the respondents were asked to answer 12 choice situations, which might have been too many questions, resulting in fatigue to answer the last questions seriously. Besides that, the elderly who do not have access to or do not have the skills to use a computer or tablet with internet connection are not reached by using an online survey. According to CBS (2019c), in 2018, 10% of the people aged 65 to 75 had never used internet. This was 32% of the people aged 75 years and older. Together, this might reduce the quality of the data and influence the results regarding the bus preferences. Elderly who not have a computer or do not use internet might have other preferences regarding bus services. It might be preferable for them to have direct bus services, since it is harder for them to get information about the route without using internet.

The respondents include both bus users and non-bus users. It might be that non-bus users consider this choice situations as less important and just answer those questions without really thinking about their preferences according to bus attributes.

8.2.4. Remarkable findings

Our expectation was that a lot of elderly would prefer a bus service with a low distance to the nearest bus stop and no transfers. However, according to the results from the models and from practice, just a part of the elderly prefers this. Most of the elderly prefer a fast high-frequent bus service. Next to that, our expectation was that elderly would care less about travel costs and travel time compared to the younger bus users. According to the results though, travel costs has the highest impact on utility for the attribute range used in this research. However, the sensitivity for the travel costs decreases with higher age. An explanation for the importance of costs might be the high possession of car (80%) and ability to cycle (79%) within the sample, which indicates that those elderly are probably still self-sufficient in their transport, and choose for cheaper options.

The descriptive statistics of the sample showed that only 33% of the elderly owns a public transport card including 65+ discount and 52% of the elderly do not have a public transport card at all. The descriptive statistics also showed that 6,6% of the elderly uses the bus at least once a month without a public transport card and 6,3% of the elderly uses the bus at least once a month with a public transport card with other discount or without discount. This is remarkable, since the results showed that elderly in general are very sensitive to travel costs. It might be that those elderly do not know about the 65+ discount.

Remarkable interaction effects are those between gender and transfers, and walking tool and travel costs. Men are less sensitive to have a transfer compared to women. According to research of Derriks (2011) and Molengraaff (2016) women are generally more insecure and sensitive to the factors that influence the risk perception on the road than men. It is possible that this also applies for women travelling independently by public transport, where having a transfer makes women more insecure.

Elderly with a walking tool are less sensitive for travel costs than elderly without a walking tool. Research from Schmöcker et al. (2005) shows that people with walking difficulties make fewer trips. Possibly those elderly are willing to pay more if they finally make a trip.

Another remarkable interaction effect is the effect between the distance to the nearest bus stop in minutes walking and travel costs. Elderly who have to walk 6 minutes or more are less sensitive for travel costs than elderly who have to walk 0-2 minutes. Two possible explanations are that in this sample, elderly living closer to a bus stop have lower incomes, or that elderly living more than 6 minutes walk from a bus stop make less use of the bus, and therefore might not care about the price. However, cross-tables in appendix F.6 and F.7 disprove these explanations. It is unclear what another explanation might be.

According to the results of the Latent Class choice model with 4 classes, transfers contribute to utility in a positive way. This is remarkable since elderly in general and bus users in general dislike transfers. An explanation is that for most choice sets in the questionnaire the bus option with the highest frequency also contained a transfer. Elderly who always choose the bus option with the highest frequency most of the time choose the option with a transfer as well. As a result, those elderly will both prefer frequency and transfers.

Our expectation was that the classes resulting from the Latent Class choice model with 4 classes could be explained by socio-demographic characteristics. However, only the socio-demographic 'able to cycle' can explain the class membership significantly. This indicates that the elderly are all very different, and cannot be placed in boxes according to the socio-demographic characteristics used in this research, except from 'able to cycle'. The classes 1 and 4 consisted of almost only elderly who are able to cycle. The elderly who are not able to cycle are spread over the classes 2 and 3. This is remarkable, since we would expect that elderly who are not able to cycle are less mobile. Therefore, is was expected that those elderly would prefer a low distance to the nearest bus stop and thus would be member of class 3.

Another remarkable finding is the high bus usage of elderly in Groningen. Based on the data, the elderly accounted for 30% to the total number of check-ins at the bus. This share is very high compared to proportion of elderly in relation to the total population, which is 15%. Besides that, research from Zijlstra et al. (2017) showed that an estimated 5 to 8% of the bus passengers is 65 years or older. In Groningen, this appears to be much higher.

8.2.5. Limitations of the research

This paragraph discusses the limitations of this research.

Stated Preference Survey Design

First of all, a Stated Preference survey has been used for data collection. Respondents had to make choices for hypothetical choice situations based on their own preferences. It is unknown whether respondents would make this choice in reality. Besides that, no opt-out option was included in the choice experiment to prevent that respondents would avoid making difficult trade-offs. Respondents always had to choose between two bus options. There was no choice to not make the trip or use another mode of transport. This made it impossible to calculate thresholds for attribute levels corresponding with no longer willing to use one of the bus options. Instead of this, insight is obtained into the preferences of elderly regarding attribute values of the bus.

Second, a description of the weather at the time of the trip and the trip purpose were included in the context of the choice experiment. It was assumed that the temperature was 17 degrees Celsius and no rainfall. Other weather forecasts could have resulted in other choices and thus different parameter values. For example, rain or temperature might influence the importance of less transfers and lower distance to the nearest bus stop.

Third, this research did not consider all bus attributes mentioned in section 3.4. Including more attributes would make it too complex for respondents, especially for elderly, to answer the questions. Next to that, some attributes are left out because they are difficult to manage or research. The attributes which are not considered could have an impact. For example, access and egress and comfort might be important for elderly, such as availability of seats. It is expected that these factors are of great influence for the bus choice and preferences of the elderly.

Fourth, there are some limitations regarding the attribute levels in the choice experiment. The used ranges for the attributes are limited. No conclusions can be drawn outside this range. However, using another range might lead to other choices and results.

Data Groningen

The results of the model estimations in section 6 are compared with and applied to the bus network and bus usage of elderly in Groningen. The public transport card data of elderly having a public transport subscription including elderly discount is used for this comparison and application. However, there are elderly who make use of the bus without having a subscription with discount or without having a public transport subscription at all. These elderly are not considered and this is a limitation of the current findings.

Besides that, the bus usage of the elderly is compared with the bus usage of all bus users in Groningen. This comparison is made based on elderly data of March 2019 and the total bus use data of the year 2018. Since the data is not from the same period of time and same year, the results of this research may differ from results when a comparison is made based on data from the same year and same period.

8.3. Recommendations

This section presents the recommendations for science in, practice, and policy based on the conclusions and limitations of this research.

8.3.1. Recommendations for further scientific research

Include other attributes and attribute levels

As described in the discussion, this research only considered two bus options and five attributes varying within these bus options. For further research, it is interesting to include other alternatives, such as valys, wmo, customized transport, or if the elderly will use other means of transport or will not travel at all. When other alternatives are included, it is likely that the choice distribution will become different.

Only a limited amount of attributes is tested within the bus options in order to reduce the complexity of the choice situations. For further research, it is interesting to include other attributes related to this research, such as comfort and reliability of the bus service, to see whether these attributes have an impact on the preference of elderly.

In this research, the attribute 'travel costs' has an attribute level range between 1,50 euro and 3,50 euro. It is interesting to test how the bus choice of the elderly will change when the bus options are both for free, since the MNL model showed a high relative importance of travel costs and in several cities elderly can travel by bus for a very low price or for free.

Use different contexts for the choice sets

In this research, the context was similar for all choice situations and respondents. However, respondents might choose different options in a different context. For further research, the context should be varied among the choice situations to see whether this has an impact on the results.

Compare different samples and investigate if the research is also applicable for other types of cities

The number of respondents per municipality was too low to compare the results between the municipalities. For further research, it is interesting to research if there is a difference in bus usage and bus choice among the elderly living in different municipalities by using a larger sample from each municipality.

The respondents in this research were mainly bus users, only 51 of the respondents never uses the bus. It is interesting for further research to see if elderly that make no use of the bus at the moment have similar preferences compared to the bus users. Besides that, to get a more complete picture of the bus usage of bus users and non-users and whether this usage has changed, it is interesting to ask to what extent the elderly used the bus in the past.

The choice model in this research was estimated on a sample with respondents living in urban municipalities without tram and metro and can be applied to these cities. For further research, it is interesting to research if elderly living in less urban areas or urban areas with tram and metro are making the same choices.

Last, no research is done into the elderly who are not using a computer or internet. In this research, only insight is obtained from elderly who are able to fill in a questionnaire online. For policy making, it is important to also have information on the preferences and bus usage of those non-digital elderly, since it is likely that they have different preferences.

Further research on a remarkable finding

As shown in the results of the MNL model with interaction effects, elderly who have to walk 6 minutes or more to reach the nearest bus stop are less sensitive for travel costs than elderly who have to walk 0-2 minutes. Two possible explanations are that in this sample, elderly living closer to a bus stop have lower incomes, or that elderly living more than 6 minutes walk from a bus stop make less use of the bus, and therefore might not care about the price. However, cross-tables in appendix F.6 and F.7 disprove these explanations. To explain this finding, further research is required.

Research the preferences of elderly without a car

The descriptive statistics of the survey showed that the car possession and driving license possession was very high, with 80% and 81% respectively. Based on this, it can be assumed that many of the elderly are still self-sufficient regarding their transport. It is interesting for further research to investigate the preferences of elderly regarding transport when they do not have a car and/or driving license any more, since it is likely that those elderly have different preferences.

8.3.2. Recommendations for practice

Based on the parameter interpretation of the scenario analysis it can be concluded that the preferences of bus services based on travel costs, travel time, frequency, transfers and distance to nearest bus stop are divided among the elderly. On the one hand there is a group that prefers high-frequent and fast buses, like the average non-elderly bus users, and on the other hand there is a group that prefers low-frequent, low distance to bus stop bus services. However, it is not possible to explain the differences among those groups based on their socio-demographic variables. Further research can be done towards these groups regarding the socio-demographic characteristics to investigate the nature of the heterogeneity among the elderly. To do so, a questionnaire including more questions about socio-demographic characteristics is required.

Another recommendation for further research is to use a bigger sample which can be sorted into smaller groups based on similar observed socio-demographic characteristics. In this research, some groups needed to be merged since the groups were too small, for example the number of elderly who used the valys was 22, which is too little to draw reliable conclusions. Possibly using a bigger sample with larger and more subgroups can contribute to explain the heterogeneity in preferences among the elderly.

8.3.3. Recommendations for policy

Bus network design and public transport vision Groningen 2040

The research showed that the preferences of elderly regarding the use and type of bus service is divided among the elderly. On the one hand there is a big group that prefers fast and high-frequent bus services, like the average bus users, and on the other hand there is a big group that prefers low-frequent bus services with low distance to the nearest bus stop. The preferences are so heterogeneous that it is difficult to create an optimal network for the elderly. Therefore, to meet the preferences of the different groups of elderly, it is advisable to offer different types of bus services: fast and high-frequent bus services, and dense low-frequent bus services.

One of the choices of the public transport vision Groningen 2040 is to stretch and straighten the routes of city bus services to reduce travel time. Since a big group of elderly prefer the low-frequent bus services with a low distance to the nearest bus stop, which are the characteristics of the city bus service in Groningen, it is advisable to not stretch and straighten all the city bus services.

Bus price

Results of the MNL model showed that travel costs are the most important attribute for the elderly when choosing a bus option. Therefore, it is advisable to offer bus services for lower price or for free to stimulate the elderly to use the bus. A number of cities, such as Nijmegen en Eindhoven, already experimented with offering (almost) free bus transportation, which led to an increase of bus trips made by elderly. However, many of the cities are going to terminate or already terminated the free bus transport, because of high costs. For many elderly this means that they will stay at home more often. An option to reduce these high costs of offering free public transport is to rise the age limit to which elderly are entitled to use the bus for a reduced price or for free. Currently, the age limit is 65 years and older. However, the life expectation of the current elderly is higher and they are more mobile compared to previous elderly generations. For example, the age limit can be raised to the AOW pension age, which raised as well, or to 70/75 years and older. Further research is required to examine if free bus also stimulates the non- bus users to travel.

In the current situation, elderly can already travel by bus with 34% discount. However, the research showed that not all bus users use this discount and an explanation for this is not clear. It is advisable to advertise more among the elderly that travelling with discount is possible, since this might stimulate the elderly to use the bus.

Lower the threshold to use public transport

Not only the bus usage of the elderly is low, but also the usage of all other public transport modes. This research shows that most of the elderly prefer a fast high-frequent bus service and another important part of the elderly prefer a bus service without transfers and low distance to the nearest bus stop. Currently, these types of bus services are already available in The Netherlands, such as Q-link and city bus services in Groningen. Nevertheless, this appears not to be sufficient for most elderly to use the bus. Probably, most elderly are not used to travel by public transport, among other things due to the increase in car use. When elderly are no longer able to use the car, it is a challenge to start using public transport. Using public transport can be complicated, such as buying tickets and checking-in, especially if you are disabled. According to SPoorPro (2018), 32% of the elderly has difficulties with travelling by public transport. It is advisable to investigate how to make the switch from using the car to using public transport easier. For example, in Zeeland ambassadors to make trips with elderly to teach them how to use public transport. However, this is only being carried out at local level. Further research could be done into this how to make it applicable throughout the Netherlands.

Further research to other types of transport

The choice experiment used in this research can also be applied to choices between tram, metro and train options. Since bus, tram, metro, and train are the same category public transport, it is possible and likely that this would result in similar preferences in attribute values. As mentioned before, the switch from car usage to public transport usage is difficult, which might be a cause of the low public transport usage of elderly. Therefore, it is advisable to do further research to transportation options which are easy to use, also for the elderly who have no experience in usage.

References

9292ov (2019). Hoeveel kost het reizen met de bus met de OV-chipkaart? - Ervaar het OV. URL https://www.ervaarhetov.nl/vraag-en-antwoord/categorie-b/hoeveel-kost-het-reizen-met-de-bus-met-de-ov-chipkaart.html

Aguiar, B., & Macário, R. (2017). The need for an elderly centred mobility policy. In *Transportation Research Procedia*, vol. 25.

Amaya-Amaya, M., Gerard, K., & Ryan, M. (2008). Discrete Choice Experiments in a nutshell . Tech. rep., The Economics of Non-Market Goods and Resources.
URL https://link.springer.com/content/pdf/10.1007{%}2F978-1-4020-5753-3{_}1.pdf

Asadoorian, M. O., & Kantarelis, D. (2005). *Essentials of Inferential Statistics*. Lanham, Maryland: University Press of America, fourth ed.

Athira, I., Muneera, C., Krishnamurthy, K., & Anjaneyulu, M. (2016). Estimation of Value of Travel Time for Work Trips. *Transportation Research Procedia*, *17*, 116–123. doi: 10.1016/J.TRPRO.2016.11.067.
URL https://www.sciencedirect.com/science/article/pii/S2352146516306810

Bakker, W., Hu, M., & Wittkamper, L. (2018). Ouderenmonitor 2018. Tech. rep., RIGO Research, Wetenschappelijk Bureau 50PLUS, Amsterdam.
URL https://www.rigo.nl/wp-content/uploads/2018/05/Ouderenmonitor2018{_}RIGO.pdf

Beelaerts van Blokland, R. (2008). Designing Stated Choice Experiments: An Analysis of the Effect of Airport Location on Air Passenger's Travel Choice.
URL https://repository.tudelft.nl/islandora/object/uuid{%}3Ae5079cc4-6ae9-44cf-9bd8-ad1dc706e64f?collection=education

Ben-Akiva, M., & Morikawa, T. (2002). Comparing ridership attraction of rail and bus. *Transport Policy*, *9*(2), 107–116. doi: 10.1016/S0967-070X(02)00009-4.
URL https://www.sciencedirect.com/science/article/pii/S0967070X02000094

Ben-Akiva, M., Morikawa, T., & Shiroishi, F. (1992). Analysis of the reliability of preference ranking data. In *Journal of Business Research*, vol. 24, (pp. 149–164). Elsevier.
URL https://www.sciencedirect.com/science/article/pii/014829639290058J

Bliemer, M. C., & Collins, A. T. (2016). On determining priors for the generation of efficient stated choice experimental designs. *Journal of Choice Modelling*, *21*, 10–14. doi: 10.1016/J.JOCM.2016.03.001.
URL https://www.sciencedirect.com/science/article/pii/S1755534515300877

Böcker, L., van Amen, P., & Helbich, M. (2017). Elderly travel frequencies and transport mode choices in Greater Rotterdam, the Netherlands. *Transportation*, *44*(4), 831–852. doi: 10.1007/s11116-016-9680-z.

Boschmann, E. E., & Brady, S. A. (2013). Travel behaviors, sustainable mobility, and transit-oriented developments: a travel counts analysis of older adults in the Denver, Colorado metropolitan area. *Journal of Transport Geography*, *33*, 1–11. doi: 10.1016/J.JTRANGEO.2013.09.001.
URL https://www.sciencedirect.com/science/article/pii/S0966692313001701

Bourguignon, V. (2015). Traveller choice behaviour at the passport control at airports. URL https://repository.tudelft.nl/islandora/object/uuid{%}3Ad3599ef6-a99f-42c0-b02c-bb2f439e39c7

Bouwknegt, H. (2019). Personal interview Public transport Goudappel Coffeng.

Bronsvoort, K. A. (2019). Exploring alternative public transport in rural areas. Tech. rep., Delft University of Technology, Delft.

Broome, K., Worrall, L., Fleming, J., & Boldy, D. (2012). Evaluation of flexible route bus transport for older people. *Transport Policy*. doi: 10.1016/j.tranpol.2012.02.005.

Buys, L., Snow, S., van Megen, K., & Miller, E. (2012). Transportation behaviours of older adults: An investigation into car dependency in urban Australia. *Australasian Journal on Ageing*, *31*(3), 181–186. doi: 10.1111/j.1741-6612.2011.00567.x.
URL http://doi.wiley.com/10.1111/j.1741-6612.2011.00567.x

Campbell, D., & Erdem, S. (2019). Including Opt-Out Options in Discrete Choice Experiments: Issues to Consider. *The Patient - Patient-Centered Outcomes Research*, *12*(1), 1–14. doi: 10.1007/s40271-018-0324-6.
URL http://www.ncbi.nlm.nih.gov/pubmed/30073482http://link.springer.com/10.1007/s40271-018-0324-6

CBS (2016). Bijna helft 75-plussers heeft autorijbewijs.
URL https://www.cbs.nl/nl-nl/nieuws/2016/40/bijna-helft-75-plussers-\heeft-autorijbewijs

CBS (2018a). Prognose: 18 miljoen inwoners in 2029.
URL https://www.cbs.nl/nl-nl/nieuws/2018/51/prognose-18-miljoen-inwoners-\in-2029

CBS (2018b). StatLine - Personenmobiliteit in Nederland; persoonskenmerken en vervoerwijzen, regio.
URL https://opendata.cbs.nl/statline/{#}/CBS/nl/dataset/83499NED/table?ts=1557219517748

CBS (2018c). StatLine - Personenmobiliteit in Nederland; persoonskenmerken en vervoerwijzen, regio.
URL https://opendata.cbs.nl/statline/{#}/CBS/nl/dataset/83499NED/table?ts=1554814242233

CBS (2018d). Statline - regionale kerncijfers nederland.
URL https://opendata.cbs.nl/statline/{#}/CBS/nl/dataset/70072ned/table?ts=1562769744192

CBS (2018e). Steeds langer leven zonder beperkingen.
URL https://www.cbs.nl/nl-nl/nieuws/2018/12/steeds-langer-leven-zonder-\beperkingen

CBS (2018f). Zie Nederland vergrijzen deel 1.
URL https://www.cbs.nl/nl-nl/achtergrond/2018/43/zie-nederland-vergrijzen-\deel-1

CBS (2019a). Rijbewijzen.
URL https://www.cbs.nl/nl-nl/maatschappij/verkeer-en-vervoer/transport-en-mobiliteit/mobiliteit/personenmobiliteit/categorie-personenmobiliteit/rijbewijzen{#}id=undefined

CBS (2019b). StatLine - Regionale kerncijfers Nederland.
URL https://opendata.cbs.nl/statline/{#}/CBS/nl/dataset/70072NED/table?fromstatweb

CBS (2019c). Zes procent nooit op internet.
URL https://www.cbs.nl/nl-nl/nieuws/2019/01/zes-procent-nooit-op-internet

Chintakayala, P. K., Hess, S., & Rose, J. (2009). Using second preference choices in pivot surveys as a means of dealing with inertia. Tech. rep.
URL http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.679.3879{&}rep=rep1{&}type=pdf

ChoiceMetrics (2018). Ngene 1.2 USER MANUAL & REFERENCE GUIDE The Cutting Edge in Experimental Design. Tech. rep.
URL www.choice-metrics.com

Choo, S., Sohn, D., & Park, M. (2016). Mobility characteristics of the elderly: A case for Seoul Metropolitan Area. *KSCE Journal of Civil Engineering*. doi: 10.1007/s12205-016-0651-x.

Chorus, C. G. (2018a). SEN1221 Lecture 1 - Statistical Analysis of Choice Behaviour: Discrete choice modeling and the MNL model.

Chorus, C. G. (2018b). SEN1221 Lecture 2 - Statistical Analysis of Choice Behaviour: Mixed Logit.

Cui, J., Loo, B. P., & Lin, D. (2017). Travel behaviour and mobility needs of older adults in an ageing and car-dependent society.

Davey, J. A. (2019). Older people and transport : coping without a car. doi: 10.1017/S0144686X06005332.
URL https://doi.org/10.1017/S0144686X06005332

de Haas, M., Bakker, P., & Harsm, L. (2018). Mobiliteitsarmoede: vaag begrip of concreet probleem? Tech. rep., Kennisinstituut voor Mobiliteitsbeleid (KiM), Den Haag.
URL https://www.kimnet.nl/publicaties/rapporten/2018/10/31/mobiliteitsarmoede-vaag-begrip-of-concreet-probleem

Derriks, H. (2011). Kennisinstituut voor Mobiliteitsbeleid. Tech. rep.

Dogterom, N. (2019). Personal interview Research & Behaviour Goudappel Coffeng.

Eck, G. V. (2010). Ontwerp van stedelijke openbaar vervoer netwerken; Herontwerp van het Utrechtse buslijnennet met behulp van een genetisch algoritme. In *Bijdrage aan het Colloquium Vervoersplanologisch Speurwerk*, november.

Fiedler, M. (2007). Older people and public transport: Challenges and chances of an ageing society. Tech. rep., European Metropolitan Transport Authorities.
URL www.rupprecht-consult.eu

Figueroa, M. J., Nielsen, T. A., & Siren, A. (2014). Comparing urban form correlations of the travel patterns of older and younger adults. *Transport Policy*. doi: 10.1016/j.tranpol.2014.05.007.

Goldenbeld, C. (2015). Effecten van vergrijzing op verkeersgedrag en mobiliteit : een literatuurstudie. Tech. rep., Stichting Wetenschapelijk Onderzoek Verkeersveiligheid SWOV.
URL https://www.narcis.nl/publication/RecordID/oai:library.swov.nl:131094

GVB (2019). Saldo.
URL https://www.gvb.nl/saldo

Harms, L., Jorritsma, P., & Kalfs, N. (2007). Beleving en beeldvorming van mobiliteit. Tech. rep., Kennisinstituut voor Mobiliteitsbeleid (KiM), Den Haag.

Hausman, J. A., & McFadden, D. (1981). Specification tests for the multinomial logit model.
URL https://dspace.mit.edu/bitstream/handle/1721.1/64213/specificationtes00haus2.pdf

Haustein, S. (2011). Mobility behavior of the elderly: an attitude-based segmentation approach for a heterogeneous target group. doi: 10.1007/s11116-011-9380-7.
URL https://link.springer.com/content/pdf/10.1007{%}2Fs11116-011-9380-7.pdf

Hensher, D. A. (2010). Hypothetical bias, choice experiments and willingness to pay. *Transportation Research Part B: Methodological*, *44*(6), 735–752. doi: 10.1016/J.TRB.2009.12.012.
URL https://www.sciencedirect.com/science/article/pii/S0191261509001477

Hensher, D. A., & Greene, W. H. (2003). The mixed logit model: The state of practice. *Transportation*, *30*(2), 133–176. doi: 10.1023/A:1022558715350.
URL https://link.springer.com/content/pdf/10.1023{%}2FA{%}3A1022558715350.pdf

Hess, D. B. (2012). Walking to the bus: perceived versus actual walking distance to bus stops for older adults. *Transportation*, *39*(2), 247–266. doi: 10.1007/s11116-011-9341-1.
URL http://link.springer.com/10.1007/s11116-011-9341-1

Hildebrand, E. D. (2003). Dimensions in elderly travel behaviour: A simplified activity-based model using lifestyle clusters. *Transportation*. doi: 10.1023/A:1023949330747.

Hinton, R. H. (2014). *Statistics Explained*. New York: Routledge, third ed.

Hjorthol, R. J., Levin, L., & Sirén, A. (2010). Mobility in different generations of older persons. The development of daily travel in different cohorts in Denmark, Norway and Sweden. *Journal of Transport Geography*. doi: 10.1016/j.jtrangeo.2010.03.011.

HTM (2019). Reizen met de OV-chipkaart.
URL https://www.htm.nl/vervoerbewijzen/ov-chipkaart/reizen-met-de-ov-chipkaart/

Johnson, R., Shaw, J., Berding, J., Gather, M., & Rebstock, M. (2017). European national government approaches to older people's transport system needs. *Transport Policy*, *59*. doi: 10.1016/j.tranpol.2017.06.005.

Kim, S. (2011). Assessing mobility in an aging society: Personal and built environment factors associated with older people's subjective transportation deficiency in the US. *Transportation Research Part F: Traffic Psychology and Behaviour*, *14*(5), 422–429. doi: 10.1016/J.TRF.2011.04.011.
URL https://www.sciencedirect.com/science/article/pii/S1369847811000507

Kim, S., & Ulfarsson, G. (2013). Transportation in an Aging Society: Linkage between Transportation and Quality of Life. *Transportation Research Record: Journal of the Transportation Research Board*. doi: 10.3141/2357-13.

Kim, S., & Ulfarsson, G. F. (2004). Travel Mode Choice of the Elderly: Effects of Personal, Household, Neighborhood, and Trip Characteristics. *Transportation Research Record: Journal of the Transportation Research Board*, *1894*(1), 117–126. doi: 10.3141/1894-13.
URL http://journals.sagepub.com/doi/10.3141/1894-13

KiM Netherlands Institute for Transport Policy Analysis (2016). The choice of the passenger.
URL https://english.kimnet.nl/publications/videos/2016/06/09/the-choice-of-the-passenger

Kløjgaard, M. E., Bech, M., & Søgaard, R. (2012). Designing a stated choice experiment: The value of a qualitative process. *Journal of Choice Modelling*, *5*(2), 1–18. doi: 10.1016/S1755-5345(13)70050-2.
URL http://dx.doi.org/10.1016/S1755-5345(13)70050-2

Koot, A. (2019). Personal interview Public transport Goudappel Coffeng.

Kroesen, M. (2018). Sen1721 lecture 6 - latent class (cluster) models.

Lucas, T. Y. I., Archilla, A. R., & Papacostas, C. S. (2007). Mode Choice Behavior of Elderly Travelers in Honolulu, Hawaii. *Transport Research Record: Journal of the Transportation Research Board*, *2013*, 71–79. doi: 10.3141/2013-10.
URL `https://journals.sagepub.com/doi/pdf/10.3141/2013-10`

Mackett, R. (2015). Improving accessibility for older people - investing in a valuable asset. *Journal of Transport and Health*. doi: 10.1016/j.jth.2014.10.004.

Mangham, L. J., Hanson, K., & McPake, B. (2009). How to do (or not to do) ... Designing a discrete choice experiment for application in a low-income country. *Health Policy and Planning*, *24*(2), 151–158. doi: 10.1093/heapol/czn047.
URL `https://academic.oup.com/heapol/article-lookup/doi/10.1093/heapol/czn047`

McHugh, M. L. (2013). The chi-square test of independence. *Biochemia medica*, *23*(2), 143–9. doi: 10.11613/BM.2013.018.
URL `http://www.ncbi.nlm.nih.gov/pubmed/23894860http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC3900058`

Molengraaff, A. (2016). Verwachtingen over mobiliteit: Een proefonderzoek onder oudere automobilisten. Tech. rep., Universiteit Leiden, Leiden.

Molin, E. (2018a). Sen1221 lecture 1 part ii - introduction to experimental designs.

Molin, E. (2018b). Sen1221 lecture 3 part ii - efficient designs.

Molin, E. (2019). representativiteit - TB232B Onderzoek en data-analyse (2018/19 Q4).
URL `https://brightspace.tudelft.nl/d2l/le/content/132797/viewContent/1334133/View`

Molin, E., & Maat, K. (2015). Bicycle parking demand at railway stations: Capturing price-walking trade offs. *Research in Transportation Economics*, *53*, 3–12. doi: 10.1016/J.RETREC.2015.10.014.
URL `https://www.sciencedirect.com/science/article/pii/S073988591500058X`

Molin, E. J., & Timmermans, H. J. (2010). Context Dependent Stated Choice Experiments: The Case of Train Egress Mode Choice. *Journal of Choice Modelling*, *3*(3), 39–56. doi: 10.1016/S1755-5345(13)70013-7.
URL `https://www.sciencedirect.com/science/article/pii/S1755534513700137`

Moniruzzaman, M., Páez, A., Nurul Habib, K. M., & Morency, C. (2013). Mode use and trip length of seniors in Montreal. *Journal of Transport Geography*, *30*, 89–99. doi: 10.1016/J.JTRANGEO.2013.03.007.
URL `https://www.sciencedirect.com/science/article/pii/S096669231300063X`

OV bureau Groningen Drenthe (2019a). Ontwerp hoofdlijnen busdienstregeling Groningen Drenthe 2020.
URL `https://www.ovbureau.nl/actueel/2019/definitieve/`

OV bureau Groningen Drenthe (2019b). OV-bureau | De toekomst is groen.
URL `https://www.ovbureau.nl/ambitie2030/nl`

PanelClix (2019). Over PanelClix.
URL `https://www.panelclix.nl/over/index.htm`

Patuelli, R., Ponce Dentinho, T., Geurs, K. T., Geurs, K., & Paix, L. L. (2016). Train station access and train use: a joint stated and revealed preference choice modelling study. *Accessibility, Equity and Efficiency. Challenges for transport and public services*, (pp. 144–166). doi: 10.4337/9781784717896.00017.

Phanikumar, C., & Maitra, B. (2007). Willingness-to-Pay and Preference Heterogeneity for Rural Bus Attributes. *Journal of Transportation Engineering*, *133*(1), 62–69.
URL https://ascelibrary.org/doi/pdf/10.1061/{%}28ASCE{%}290733-947X{%}\282007{%}29133{%}3A1{%}2862{%}29

Rahman, M. M., Strawderman, L., Adams-Price, C., & Turner, J. J. (2016). Transportation alternative preferences of the aging population. *Travel Behaviour and Society*, *4*, 22–28. doi: 10.1016/J.TBS.2015.12.003.
URL https://www.sciencedirect.com/science/article/pii/S2214367X15000447?via{%}3Dihub

Rosenbloom, S., & Smiley, A. (1999). Transportation in an Aging Society: A Decade of Experience. Technical Papers and Reports from a Conference. In *Transportation Research Board Conference Proceedings 27*, (p. 325). Transportation Research Board of the National Academies.

Savelberg, F., & Kansen, M. (2019). De bus over de grens: grensoverschrijdende busverbindingen in Nederland | Document (onderzoekspublicatie) | Kennisinstituut voor Mobiliteitsbeleid. Tech. rep., Kennisinstituut voor Mobiliteitsbeleid (KiM).
URL https://www.kimnet.nl/publicaties/rapporten/2019/06/20/de-bus-over-de-grens-grensoverschrijdende-busverbindingen-in-nederland

Scheltes, A. (2019). Personal interview Public transport Goudappel Coffeng.

Scheltes, A., & Kwantes, C. (2019). OV-visie Groningen 2040. Tech. rep., Goudappel Coffeng.

Schmöcker, J.-D., Quddus, M. A., Noland, R. B., & Bell, M. G. (2008). Mode choice of older and disabled people: a case study of shopping trips in London. *Journal of Transport Geography*, *16*(4), 257–267. doi: 10.1016/J.JTRANGEO.2007.07.002.
URL https://www.sciencedirect.com/science/article/pii/S0966692307000749

Schmöcker, J.-D., Quddus, M. A., Noland, R. B., & Bell, M. G. H. (2005). Estimating Trip Generation of Elderly and Disabled People. *Transportation Research Record: Journal of the Transportation Research Board*, *1924*(1), 9–18. doi: 10.1177/0361198105192400102.

Shen, J., Sakata, Y., & Hashimoto, Y. (2006). A Comparison between Latent Class Model and Mixed Logit Model for Transport Mode Choice: Evidences from Two Datasets of Japan. Tech. rep., Graduate School of Economics and Osaka School of International Public Policy (OSIPP).
URL http://www2.econ.osaka-u.ac.jp/library/global/dp/0605.pdf

Shrestha, B. P., Millonig, A., Hounsell, N. B., & McDonald, M. (2017). Review of Public Transport Needs of Older People in European Context. *Journal of Population Ageing*, *10*(4), 343–361. doi: 10.1007/s12062-016-9168-9.
URL http://link.springer.com/10.1007/s12062-016-9168-9

Siren, A., & Haustein, S. (2019). How do baby boomers' mobility patterns change with retirement? doi: 10.1017/S0144686X15000100.
URL https://doi.org/10.1017/S0144686X15000100

Siren, A., Kristiina, ., & Haustein, S. (2013). Baby boomers' mobility patterns and preferences: What are the implications for future transport? *Transport Policy*, (29), 136–144. doi: 10.1016/j.tranpol.2013.05.001.
URL http://dx.

Snap (2019). Snap Surveys | Survey Software, Feedback Tools, Research Services.
URL https://www.snapsurveys.com/

Snowball, J. D. (2008). The Choice Experiment Method and Use. In *Measuring the Value of Culture*. Springer, Berlin, Heidelberg.
URL https://link.springer.com/content/pdf/10.1007{%}2F978-3-540-74360-6{_}7.pdf

SPoorPro (2018). Eén op drie ouderen heeft moeite om te reizen met OV | SpoorPro.nl.
URL https://www.spoorpro.nl/spoorbouw/2018/05/23/een-op-drie-ouderen-heeft-moeite-om-te-

Su, F., & Bell, M. G. (2009). Transport for older people: Characteristics and solutions. *Research in Transportation Economics*. doi: 10.1016/j.retrec.2009.08.006.

SWOV (2019). Verkeersdoden in Nederland | SWOV. Tech. rep., SWOV, Den Haag.
URL https://www.swov.nl/feiten-cijfers/factsheet/verkeersdoden-nederland

Szeto, W., Yang, L., Wong, R., Li, Y., & Wong, S. (2017). Spatio-temporal travel characteristics of the elderly in an ageing society. *Travel Behaviour and Society*, *9*, 10–20. doi: 10.1016/j.tbs.2017.07.005.
URL https://linkinghub.elsevier.com/retrieve/pii/S2214367X16301430

The Department of Economic and Social Affairs (2017). World population prospects the 2017 revision.
URL https://esa.un.org/unpd/wpp/Publications/Files/WPP2017{_}KeyFindings.pdf

Train, K. (2002). Discrete Choice Methods with Simulation. Tech. rep., University of California, Berkeley.
URL https://eml.berkeley.edu/books/train1201.pdf

Transport, P. (2002). Transport and Ageing : Extending Quality of Life for Older People Via Public and Private Transport. *44*.
URL https://bura.brunel.ac.uk/bitstream/2438/1312/1/PDFESRCTransportFinalReport.pdf

Truong, L. T., & Somenahalli, S. V. (2015). Exploring frequency of public transport use among older adults: A study in Adelaide, Australia. *Travel Behaviour and Society*, *2*(3), 148–155. doi: 10.1016/J.TBS.2014.12.004.
URL https://www.sciencedirect.com/science/article/pii/S2214367X14000465

Tseng, Y.-Y., Knockaert, J., & Verhoef, E. T. (2013). A revealed-preference study of behavioural impacts of real-time traffic information. *Transportation Research Part C: Emerging Technologies*, *30*, 196–209. doi: 10.1016/J.TRC.2011.11.006.
URL https://www.sciencedirect.com/science/article/pii/S0968090X11001586

Valys (2019). Over Valys.
URL https://www.valys.nl/wat-is-valys

Van Cranenburgh, S. (2018). SEN1721 Latent class discrete choice models for travel behaviour research.

Van Dam, F., & Hilbers, H. (2013). PBL-notitie VERGRIJZING, verplaatsingsgedrag en mobiliteit. Tech. rep., Planbureau voor de Leefomgeving.
URL https://www.pbl.nl/sites/default/files/cms/publicaties/PBL{_}2013{_}Vergrijzing-verplaatsingsgedrag-en-mobiliteit.pdf

van den Berg, P., Arentze, T., & Timmermans, H. (2011). Estimating social travel demand of senior citizens in the Netherlands. *Journal of Transport Geography*, *19*(2), 323–331. doi: 10.1016/J.JTRANGEO.2010.03.018.
URL https://www.sciencedirect.com/science/article/pii/S0966692310000505

van Nes, R. (2015). Syllabus public transport service network design. Tech. rep., Delft University of Technology, Delft.
URL https://brightspace.tudelft.nl/content/enforced/125824-CIE4811-18+2018+1/PTSND/Publictransportnetworkdesign2015{_}{_}xid-9404662{_}2.pdf?{_}{&}d2lSessionVal=Iaop1Rtzw3d4JmGK8bnISYdAy{&}ou=125824

Van Oort, N., & Van Nes, R. (2009). Line length vs. reliability: Network design dilemma in urban public transport. Tech. rep.
URL http://nielsvanoort.weblog.tudelft.nl/files/2014/01/5-TRR-2009-Van{_}Oort{_}Line{_}Length.pdf

van Wijk, K. (2015). De drempel voor ouderen is hoog | OV-Magazine.
URL https://www.ovmagazine.nl/2015/06/de-drempel-voor-ouderen-is-hoog-1603/

Wardman, M. (1988). A comparison of Revealed Preference and Stated Preference models of travel behaviour. *Journal of Transport Economics and Policy*, (pp. 71–91).
URL http://www.bath.ac.uk/e-journals/jtep/pdf/Volume{_}XX11{_}No{_}1{_}71-91.pdf

Wen, C.-H., & Lai, S.-C. (2010). Latent class models of international air carrier choice. *Transportation Research Part E: Logistics and Transportation Review*, *46*(2), 211–221. doi: 10.1016/J.TRE.2009.08.004.
URL https://www.sciencedirect.com/science/article/pii/S1366554509001100

Wien, J. (2017). An assessment of the willingness to choose a self- driving bus for an urban trip.

Wittink, L. (2011). Choice modelling: an overview of theory and development in individual choice behaviour modelling. Tech. rep., Vrije Universiteit Amsterdam.
URL https://beta.vu.nl/nl/Images/werkstuk-wittink{_}tcm235-237206.pdf

Wong, R., Szeto, W., Yang, L., Li, Y., & Wong, S. (2018). Public transport policy measures for improving elderly mobility. *Transport Policy*, *63*, 73–79. doi: 10.1016/J.TRANPOL.2017.12.015.
URL https://www.sciencedirect.com/science/article/pii/S0967070X16306953?via{%}3Dihub

Yang, C., & Mesbah, M. (2013). Route Choice Behaviour of Cyclists by Stated Preference and Revealed Preference. Tech. rep., Australasian Transport Research Forum 2013 Proceedings.
URL http://www.patrec.org/atrf.aspx

Yang, D., Timmermans, H., & Grigolon, A. (2013). Exploring heterogeneity in travel time expenditure of aging populations in the Netherlands: results of a CHAID analysis. *Journal of Transport Geography*, *33*, 170–179. doi: 10.1016/J.JTRANGEO.2013.10.002.
URL https://www.sciencedirect.com/science/article/pii/S0966692313001890?via{%}3Dihub

Yang, Y., Xu, Y., Rodriguez, D. A., Michael, Y., & Zhang, H. (2018). Active travel, public transportation use, and daily transport among older adults: The association of built environment. *Journal of Transport & Health*, *9*, 288–298. doi: 10.1016/J.JTH.2018.01.012.
URL https://www.sciencedirect.com/science/article/pii/S2214140517301123?via{%}3Dihub

Zeitler, E., Buys, L., Aird, R., & Miller, E. (2012). Mobility and Active Ageing in Suburban Environments: Findings from In-Depth Interviews and Person-Based GPS Tracking. *Current gerontology and geriatrics research*, *2012*, 257186. doi: 10.1155/2012/257186.
URL http://www.ncbi.nlm.nih.gov/pubmed/23346108http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC3533602

Zijlstra, T., Bakker, P., & Harms, L. (2017). Reizigers in de haarvaten van het openbaar vervoersysteem | Paper | Kennisinstituut voor Mobiliteitsbeleid. Tech. rep., Kennisinstituut voor Mobiliteitsbeleid (KiM).
URL https://www.kimnet.nl/publicaties/papers/2017/11/23/reizigers-in-de-haarvaten-van-het-openbaar-vervoersysteem

Zijlstra, T., Bakker, P., Harms, L., Durand, A., & Wüst, H. (2018). Busgebruikers door dik en dun. Tech. rep., Kennisinstituut voor Mobiliteitsbeleid (KiM), Den Haag.

A

Scientific paper

Bus preferences and usage amongst elderly in urban areas of The Netherlands

E.M. van Gorp
Transport, Infrastructure and Logistics
Delft University of Technology

Abstract – **The population is ageing worldwide. The current and future generation of elderly is more mobile, but there is also a group with disabilities which is increasing. There is often a lack of suitable transport, which leads to loneliness and health problems. Since the bus network is extensive, with 1800 lines and having the highest density of the public transport network, this could be a suitable transport option for the elderly. However, the usage of the bus by elderly is very low. In this study, a stated preference survey is designed and implemented in order to identify the usage and preferences regarding bus services of elderly in urban areas of The Netherlands. In this survey, respondents chose between two bus options, that varied in travel costs, travel time, frequency, transfers, and distance to the nearest bus stop. Based on the observed choices in the experiment, a four-class latent class choice model was estimated that provides insight in the heterogeneity of the preferences of the elderly. The results from the choice model show that travel costs has the largest influence on the bus choice, followed by frequency. Also, the results show heterogeneity and opposite preferences among the elderly.**

Keywords – Latent class choice model, Ageing society, Discrete choice modelling, Elderly, Bus usage

1. Introduction

Currently, 19% of the Dutch population is 65 years and older. It is expected that that this will be about 25% in 2030 [1]. The elderly these days are more mobile, prosperous and vital compared to previous generations, and are travelling more. They grew up in a period in which travelling became more common as part of an active, mobile and independent lifestyle. The ageing of the population also leads to more people with disabilities, for who it is problematic to meet their own transport needs [2]. Those elderly experience loneliness and a decline in the quality of life, due to a lack of suitable transportation options [2,3].

Different transportation options are already researched to make travelling easier for the elderly, such as self-driving cars, customized transport, and ambassadors making trips with elderly [4,5,6]. Nevertheless, those options are often futuristic, expensive, complex to organize or only applicable locally. Since the bus network in The Netherlands is extensive, having the highest density compared to other public transport modes with 1800 lines, it could be a suitable transport option for the elderly [7]. However, the public transport usage, and thus bus usage, by elderly is very low, with 10% [8].

In this research, the factors influencing the preferences and bus usage of the elderly, and the corresponding heterogeneity are explored. The results of this study could be used to guide policymakers to design bus networks which are more attractive for the different groups of elderly in The Netherlands. This could keep the elderly mobile and facilitates a way to stimulate participating in social and daily activities.

The research question corresponding to the research problem stated above is formulated as follows:

"Which factors influence the preference and use of bus service among elderly people in urban areas of The Netherlands and what is the corresponding heterogeneity?"

This paper is structured as follows. First, the stated preference survey design and data collection. Then, the MNL and LC choice models and the model estimation procedure will be presented. The subsequent section will present the results. In addition, the model will be applied to explore the predicted choice behavior of elderly under various scenarios of bus networks. The final sections presents the conclusions and provides a discussion on the results.

2. Methodology

2.1 Stated Preference survey design

To gain insight into the preferences and bus usage of the elderly in urban areas, a stated preference survey was developed and conducted. The stated choice experiment designed in this study included two bus options A and B. Each option contained attributes with different values. The following attributes were included in the experiment: travel time, travel costs, frequency, transfers, and distance to the nearest bus stop. Table I provides an overview of the attributes and attribute levels used for the bus options. The bus options had generic parameters.

A Bayesian efficient fractional factorial design was used to construct the stated choice experiment and prior parameters were estimated. For this particular experiment an efficient fractional factorial design resulted in 12 choice sets.

***Table 1:** Attribute levels used in the choice experiment*

Attribute	Attribute levels		
Travel time [min]	20	30	40
Travel costs [euro]	1,50	2,50	3,50
Frequency [headway]	60	15	7,5
Transfers [#]	0	1	
Distance to bus stop [meter]	200	400	600

From the experimental design, the stated choice part of the questionnaire was constructed. Each row in the experimental design contained the attribute levels for a choice situation. An example of a choice situation presented to the respondents is shown in figure 1. In addition to the data related to the respondents' preferences, socio-demographic data was collected.

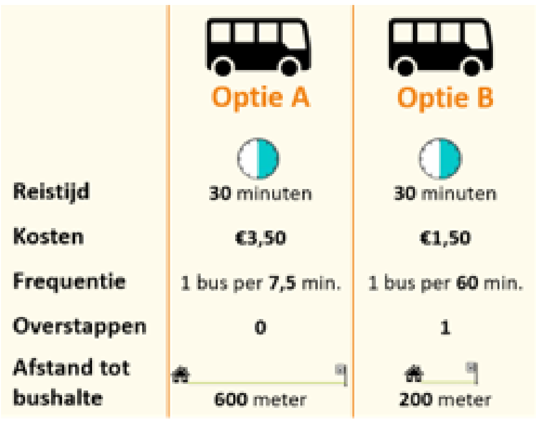


***Figure 1:** Example of a choice set*

2.2. Data collection and sample

The data was collected with the online panel Panelclix between the 26th and 28th of June 2019. To participate in the survey, the respondent needed to be 65 years or older and living in one of the urban municipalities Groningen, Eindhoven, Tilburg, Breda, Nijmegen, Apeldoorn, Haarlem, Arnhem, Enschede, Amersfoort, Zaanstad, Den Bosch, Haarlemmermeer, Zwolle, Leiden, Leeuwarden, Maastricht, Dordrecht, Alphen aan de Rijn, Alkmaar or Venlo. In total, 256 suitable responses were collected. The sample was found to be representative for the bus user population in urban areas in The Netherlands.

Table 2 shows the distribution of some socio-demographic characteristics of the respondents. Males are slightly overrepresented, and the respondents have a high car and driving license possession. The bus usage is varying, 11% of the respondents uses the bus 1 day per week or more, and 22% makes never use of the bus.

***Table 2:** Distribution of respondent characteristics (N=256)*

Socio-demographic variable	Number of respondents	Sample share
Gender		
Male	141	55,1%
Female	115	44,9%
Age		
65-69	72	28,1%
70-74	73	28,5%
75-79	75	29,3%
80+	36	14,1%
Income (Bruto)		
less than 20.000 euro	64	25,0%
20.000 - 30.000 euro	50	19,5%
30.000 - 40.000 euro	46	18,0%
40.000 or more	45	17,6%
I don't know	51	19,9%
Walking tool		
Yes	53	20,7%
No	203	79,3%
Bus usage		
1 day per week or more	29	11,3%
1 - 3 days per month	49	19,1%
6 - 11 days per year	47	18,4%
5 days or less per year	75	29,3%
Never	56	21,9%
Car ownership household		
Yes	204	79,7%
No	52	20,3%
Driving license		
Yes	207	80,9%
No	49	19,1%

2.3 Data analysis and model estimation

The data gathered from the survey is analysed using cross-tables. Besides that, discrete choice modelling is used for model estimation. Two models are estimated: a multinomial logit (MNL) model, and a latent class choice model (LC) model.

Cross tables

To test if respondents with a certain bus usage have socio-demographic characteristics in common, cross-tables are used in the program SPSS. The chi-square test is used for each socio-demographic variable to check the significance of the relation with bus usage [9].

MNL model

The most widely used and easiest model in discrete choice modelling is the multinomial logit (MNL) model [10]. Based on the observed choices in the survey and assuming that the respondents chose the option from which they would derive the highest utility, a utility function can be estimated. The utility U_i of alternative i has a systematic component V_i and a random component ε_i, which captures the unobserved factors and randomness in choices: $U_i = V_i + \varepsilon_i$ [10]. The structural utility V_i is typically modelled as a linear in the parameters function and was assumed to have the following form: $Ui = \sum_{k=1}^{K} \beta_m * x_{im}$, where β_m are parameters to be estimated, which expresses the value or weight regarding attributes m; x_{im}, is the value of attribute m for alternative i. However, other types of relationships, different from linear, may also be specified [11]. For example, in this study, we a quadratic relationship between utility and frequency is specified, since it was expected that the utility would rise less rapidly if frequency increased.

The structural utility for model estimation, which can be used by both choice alternatives, is specified as follows:

$$Vi = \beta_{TT} * TT + \beta_{TC} * TC + \beta_{FREQl} * FREQ + \beta_{FREQq} * FREQ^2 + \beta_{TF} * TF + \beta_{SD} * SD$$

Where V_i is the utility derived from alternative i; β_{TT}, β_{TC}, β_{FREQl}, β_{TF}, and β_{SD} are generic parameters to be estimated for the linear components of travel time (TT), travel costs (TC), transfers (TF), frequency (FREQ), and distance to the nearest bus stop (SD); β_{FREQq} is the parameter estimated for the quadratic component of frequency ($FREQ^2$).

LC choice model

To test for heterogeneity, a LC choice model is estimated, which is based on the assumption that the population can be separated into several classes with homogeneous preferences [12]. Across these classes, the preferences are different. For each class, a set of parameters is estimated by applying the latent class choice model. The classes are not directly observable, and thus latent [11]. The number of classes is not know beforehand and therefore multiple models with different numbers of classes will be estimated. Based on the model fit of the models, the optimal number of classes can be determined. To select the optimum number of classes, the Bayesian Information Criterion (BIC) is used: $BIC = -2 * LL + k * ln(N)$ [13]. Where LL is the final log-likelihood, k is the number of parameters to be estimated and N is the number of respondents. The lower the BIC value, the better the model.

Simultaneously with the estimation of the parameters, a class membership model is estimated, modelling the probability of an individual belonging to a class based on the socio-demographic characteristics [12]. By weighting the choice probabilities for each class by the estimated share of each segment, the choice probabilities for each choice alternative can be predicted, which indicates the relative size of each class in the population. The utility function for modeling the latent class choice model is similar to the MNL model, except from the quadratic parameter for frequency, since this parameter appeared to be insignificant.

To determine the number of classes which fits the data the best, different models are estimated with increasing the number of classes from 2 to 5. Table 3 presents the fit measures of the latent class choice models with different numbers of classes. As shown, the model with 4 classes has the lowest BIC value. With every addition of an extra class, the Rho square index increased and thus improved and was equal to 0.255 for the four-classes model.

Table 3: *Fit measures LC choice models with different numbers of classes*

Classes	LL	BIC	R^2
Basic RUM model	-1796,2	3632,5	0,156
2	-1697,7	3483,7	0,203
3	-1630,5	3397,4	0,234
4	-1585,9	3356,5	0,255
5	-1567,0	3366,8	0,264

In addition, the class membership parameters and corresponding probabilities were added to determine if the classes could be interpreted by socio-demographic variables. Only 'able to cycle' appeared to be statistically significant.

3. Results

3.1 Cross tables and Chi-square tests

The results of the chi-square tests, which checks the significance of the relation between a socio-demographic with bus usage, are shown in table 4. The seven socio-demographic characteristics using a walking tool, physically able to cycle, car ownership household, driving license, taken by friends/family to or from destination, public transport subscription, and able to reach bus stop have significant results, since their p-values are lower than 0.05. Elderly with a walking tool, who are able to cycle, who are taken by friends/family sometimes, who have public transport subscription or who are able to reach the bus stop without help make more use of the bus. Elderly who posses a car and/or a driving license make less use of the bus.

Table 4: *Results X^2-tests*

Socio-demographic variable	Chi-square	p-value
Gender	6.436	0.169
Age	7.487	0.824
Household situation	7.813	0.800
Income	9.038	0.700
Walking tool	10.468	0.033*
Physically able to cycle	11.906	0.018*
Cycle usage	0.977	0.913
Car ownership household	23.391	0.000*
Driving license	12.405	0.001*
Taken by friends/family	14.557	0.006*
Valys usage	2.746	0.601
Public transport subscription	85.24	0.000*
Able to reach bus stop without help	17.155	0.002*
Distance to nearest bus stop	21.545	0.158
Walking time to nearest bus stop	22.901	0.116
Mobile phone posession	2.451	0.653
Internet access mobile phone	1.682	0.794
Internet usage mobile phone	7.123	0.971
Trip planner usage mobile phone	8.503	0.075

* Significant on a 95% confidence interval ($p < 0.05$)

3.2 MNL model

The results of the MNL model estimation are shown in table 5 and 6. All parameters are significant and have the expected sign: Distance to bus stop, travel costs, transfers and travel time have negative signs, which means that if these attributes increase in value, utility decreases. Frequency has a positive sign, indicating that if frequency increases, utility increases. The quadratic negative component of frequency suggests that utility increases less rapidly if frequency increases.

Table 5: *Parameter estimates MNL model estimation*

Parameter name	Parameter	Parameter estimate	p-value
Frequency	β_{FREQl}	0.357	0.00*
	β_{FREQq}	-0.0269	0.01*
Distance to bus stop	β_{SD}	-0.00114	0.00*
Travel costs	β_{TC}	-0.580	0.00*
Transfers	β_{TF}	-0.364	0.00*
Travel time	β_{TT}	-0.0316	0.00*

The table shows that travel costs has the highest impact on utility for the attribute level range used. Frequency has the highest positive impact on utility.

Table 6: *Contribution to utility per attribute*

Parameter estimate	Value	Relative importance
β_{FREQl}	0.357	2.50
β_{FREQq}	-0.0269	-1.69
$\beta_{FREQl} + \beta_{FREQq}$		0.80
β_{SD}	-0.00114	-0.46
β_{TC}	-0.58	-1.16
β_{TF}	-0.364	-0.36
β_{TT}	-0.0316	-0.63

3.3 LC choice model

The results of the LC choice model estimation are shown in tables 7 and 8.

Table 7: *Parameter estimates LC choice model with 4 classes*

Parameter	Class 1	Class 2	Class 3	Class 4
Frequency	0,0355	0,324	0,0507	0,211
Distance to stop	-0,0025	0,0003	-0,003	-0,0006
Travel costs	-1,9	-0,498	-0,271	-0,92
Transfers	-0,345	0,251	-0,968	-0,637
Travel Time	-0,027	0,0039	-0,009	-0,127
Class membership parameter (δ)	0	1,69	1,8	0,41
Able to cycle	0	-1,12	-1,29	0,39

Significant values are marked in green

The parameter signs are as expected, except from the parameter 'transfers' in class 2: This parameter is statistically significant and positive, which means that if the number of transfers increases, the utility increases. This is remarkable, since elderly dislike transfers in general. For the other classes 'transfers' has a negative sign. The parameter 'travel costs' is negative and significant in all classes, which means that if travel costs increase, utility decreases. The 'frequency' parameter is positive in all classes, but only significant in classes 2 and 4, suggesting that in the other classes this parameter is not of importance. The 'distance to stop' parameter is only significant, and thus only of importance, in

Table 8: Class membership probabilities

Probabilities		Class 1	Class 2	Class 3	Class 4
Class membership probability (πns)		7,2%	38,8%	43,3%	10,8%
Ability to cycle (Ablecycle)	Probability that an individual who cannot cycle belongs to a class	2%	41%	54%	3%
	Probability that an individual who can cycle belongs to a class	15%	27%	25%	33%

classes 1 and 3. The parameter 'travel time' was only significant in class 4, suggesting it is only of importance in class 4.

3.3.1 The four classes

Class 1: 'Price sensitive elderly'

This class is the smallest, with 7% of the elderly assigned to it. The acceptance of travel costs is very low. The penalty for the distance to the nearest bus stop is relatively high. The transfer parameter does not have an extreme value compared to the other classes, and has the lowest willingness to pay for having one transfer less (€0,18). The frequency and travel time parameters are not significant, suggesting these attributes are not important for the elderly in this class. Elderly who are able to cycle have a chance of 15% to be assigned to this class. Elderly who are not able to cycle have a minimum chance to be assigned to this class. On average, people who are able to cycle have a lower acceptance of travel costs.

Class 2: 'Transfers and frequency fans'

This second class is most positive towards frequency. A remarkable characteristic of elderly in this class is the positive parameter for transfers, indicating that this class prefers transfers. This can be explained by the fact that for most choice sets the bus option with higher frequency is associated with having a transfer. The respondents choosing for higher frequency will automatically choose for a transfer. The travel costs parameter does not have an extreme value. The distance to stop and travel time parameters are not significant, suggesting these attributes are not important for the elderly in this class. About 39% of the elderly belongs to this class. Elderly who are able to cycle have a high chance (41%) to be assigned to this class.

Class 3: 'Nearby and direct bus service lovers'

The elderly in this class are least sensitive to travel costs and the highest sensitive for distance to stop and transfers. This suggests that the elderly in this class are willing to pay more to shorten the distance to the nearest bus stop (€1, 11 for 100 meter less) and to have less transfers (€3, 57 for a transfer less). The frequency and travel time parameters are not significant, suggesting these attributes are not important for the elderly in this class. This class is the largest with about 43% of the elderly assigned to it. The probability of elderly able to cycle being assigned to this class is high, with 54%. For the elderly who are not able to cycle is this chance 25%.

Class 4: 'Time sensitive elderly'

Only this class has a significant parameter with a high value for travel time, indicating that the elderly in this class are high sensitive for travel time. The willingness to pay is €1, 38 to shorten the travel time with 10 minutes. Next to that, the class is relatively high sensitive for travel costs. The willingness to pay for one transfer less is €0,69. The distance to stop parameter did not become significant, indicating that this attribute is not important for the elderly in this class. The class membership parameter did not become significant, indicating that this class is not significant larger than class 1. This also applies to the parameter for ability to cycle.

3.4 Scenario analysis

To explore the choice behavior of elderly regarding the bus choice, the estimated LC choice model was used to predict the stated choices for three bus scenarios. The scenarios are shown in table 9. The stated choice indicates what the elderly would choose if the scenario were existing in real life. The measured choice probabilities are presented in table 10, for each of the four classes individually, as well as for the population of elderly as a whole in table 9.

The first scenario is a stretched and straightened bus line with short travel time, low price, high frequency and high distance to the nearest bus stop. Offering a bus option with higher

Table 9: Scenarios and their utility and probability

	Reference	Scenario 1: High frequent bus	Scenario 2: Dense network & high travel time	Scenario 3: Combination of both
Travel time [min]	30	20	35	27
Travel costs [euro]	1,70	1,50	2,00	1,70
Frequency [veh/h]	4	6	2	4
Transfers [transf/trip]	0	0	0	1
Distance to nearest bus stop [meter]	400	600	200	300
Utility	-1,3924	-1,0124	-1,8876	-1,5476
Probability when compared to reference*		59%	38%	46%
% of total**	25%	37%	16%	22%

* probability of elderly choosing the scenario when they have to choose between the reference scenario and this scenario

** probability of elderly choosing the scenario when they have to choose between the reference scenario and the 3 other scenarios

Table 10: Scenario results of the four classes: utility and probability

	Reference	Scenario 1: High frequent bus	Scenario 2: Dense network & high travel time	Scenario 3: Combination of both
Class 1				
Utility	-4,222	-4,338	-4,296	-4,319
Probability when compared to reference*		47%	48%	48%
% of total**	27%	24%	25%	24%
Class 2				
Utility	0,4494	1,197	-0,348	0,7004
Probability when compared to reference*		68%	31%	56%
and % of total**	21%	44%	9%	27%
Class 3				
Utility	-1,6847	-2,2425	-1,154	-2,3467
Probability when compared to reference*		36%	63%	34%
% of total**	21%	15%	45%	14%
Class 4				
Utility	-4,53	-2,654	-5,863	-4,786
Probability when compared to reference*		87%	21%	44%
% of total**	12%	76%	3%	9%

* probability of elderly choosing the scenario when they have to choose between the reference scenario and this scenario

** probability of elderly choosing the scenario when they have to choose between the reference scenario and the 3 other scenarios

frequency, lower travel time and less travel costs will attract elderly, even if the distance to the nearest bus stop is high. To increase the frequency and decrease the travel time, the bus can not stop at too many places. Besides that, more vehicles are needed and operational costs are higher. However, when travel time decreases, less vehicles are needed again.

In the second scenario, the network density is increased. The distance to the nearest bus stop is very short, 200 meters. However, the travel time is higher now, since the bus needs to stop at many places and is not driving in a straight line. This leads to an lower frequency as well. The costs increased because of the higher travel time (in-vehicle time). Offering a bus option with a very small distance to a bus stop, but higher travel time, costs and lower frequency is less attractive for the elderly. This scenario is less attractive compared to both reference scenario and scenarios 1 and 3.

The third scenario is a mix between scenario 1 and 2, between a dense and coarse bus network. The design dilemma short-in vehicle times versus short access times and minimization of transfers versus short waiting times is considered here. The travel time is higher compared to a coarse network, but lower compared to a dense network, since there are less stops. Because of this, the frequency is higher compared to the dense network scenario. However, this leads to a larger distance to the nearest bus stop for a part of the people compared to the dense network scenario. One transfer has to be made during the trip, to switch from the bus on a dense network to a bus on a coarse network. Offering a bus option which combines lower distance to the bus stop and lower travel time compared to the reference scenario, but having a transfer is a little less attractive for the elderly. However, this scenario is more attractive compared to scenario 2.

4. Conclusion and recommendations

This study aimed to find important socio-demographic characteristics and mode attributes that influence the bus service preferences and bus usage of elderly in urban areas in The Netherlands. From the research, it can be concluded that socio-demographic and bus attributes influence the preferences and bus usage of the elderly and that there is heterogeneity in preferences among the elderly.

It can be concluded based on cross-tables and the chi-square test that the socio-demographic characteristics 'walking tool', 'physically able to cycle', 'car ownership', 'driving license', 'public transport subscription', and 'ability to reach nearest bus stop without help' have a significant influence on the bus usage of elderly with the sign as expected from literature and expert interviews. It was observed that elderly with a walking tool make use of the bus more often. However, elderly who are not able to reach the bus stop without help, make less use of the bus. Furthermore, it was observed that the bus usage is higher for elderly without a car, elderly without a driving license and elderly having a transport subscription. Lastly, elderly who are able to cycle make more use of the bus as well. The socio-demographic characteristic 'taken to or from destination by family or friends sometimes' turned out to have a significant influence on the bus usage of elderly, however, the direction of the sign is opposite to the direction expected from expert interviews. It was observed that elderly who are taken to or from a destination sometimes by friends or family are also using the bus more compared to the other elderly.

Results of the MNL model estimation showed that all mode attributes have a negative effect on utility, except from frequency. This indicates that for the elderly a higher travel time, higher travel costs, having transfers, and a higher distance to the nearest bus stop are experienced as negative. Frequency has a positive effect on the utility of a bus option, which indicates that for the elderly a higher frequency is experienced as positive. Travel costs has the largest impact on utility for the attribute level range used. Based on these findings, it can be concluded that the travel costs are most important for the elderly followed by frequency, when looking at the elderly as one group. Transfers has the lowest relative importance followed by distance to the nearest bus stop. The importance of travel costs is about three times higher compared to those attributes.

The heterogeneity in preferences has been confirmed by the results of the estimation of the latent class choice model. Four classes turned out to fit the data best, indicating the existence of heterogeneity in bus preferences of elderly. The first class 'price sensitive elderly' consists of elderly who prefer a cheap bus option with low distance to the nearest bus stop and without transfers. The second class involves elderly with a high preference for a frequent bus service. Remarkable in this class is the significant preference for transfers. They have significant disutility for travel costs, however, much lower than in the first class. The third class is the largest class and has a high preference for a bus service with low distance to the nearest bus stop and without transfers. Travel costs are less important compared to the other classes. Elderly in the fourth class prefer low travel time, low travel costs, no transfers and high frequency. The class membership parameter and ability to cycle parameter did not become significant. Therefore, it can be concluded that this class is not significant larger than class 1 and the probabilities being able to cycle are not significant larger than in class 1.

The estimated membership function indicates that elderly who are able to cycle are more likely to belong to classes two or three.

In conclusion, the results of this study suggest that if elderly choose a bus option, the majority of the elderly would choose the fast and high-frequent bus service and do not mind the large distance to the nearest bus stop.

In order to meet the opposite preferences of the different groups of elderly, it is advised to offer different types of bus services: not only fast and high-frequent bus services, but also dense low-frequent bus service with a low distance to the nearest bus stop. Although the largest group of elderly prefer a high-frequent bus service, it is not advisable to stretch and straighten all the bus lines, since this could be disadvantageous for an important part of the elderly.

Travel costs has the largest negative effect on the bus choice of the elderly. Therefore, it is advised to offer bus services for lower prices or for free to attract the elderly to make more use of the bus. Currently, the elderly can travel by bus with a discount of 34%, but the sample in this research showed that not all the elderly use this discount when using the bus. It is advisable to promote the discount, since it is possible not all elderly know that they can get discount.

Further research is required to examine the influence of other socio-demographic and attributes on the preferences and choice for bus, such as the kind of walking tool and other types of special transport elderly use, comfort level of the bus and seat availability. Only two bus options were considered, while it is interesting to include other alternatives and to research whether elderly will use other means of transport, or will not travel at all.

Additionally, research is needed to look into the preferences and choices of elderly living in less urban areas or urban areas with tram and metro.

Another limitation is that only stated choices were investigated. Stated choice experiments examine choices between hypothetical alternatives, which was the reason for choosing this type of data collection. However, what people say they will do in the choice experiment is not always what they really would do if the situation is available in reality.

Not only the bus usage of elderly is low, but also the usage of other modes of public transport, such as tram, metro and bus. Insight into the trade-offs made by elderly between travel costs, travel time, frequency, transfers, and distance to the nearest bus stop is also important for those transportation options, to design transport networks that meet the preferences of the elderly. Providing transportation that make elderly happy may contribute to encouraging more elderly to use make trips. This could lead to deterioration in loneliness and social isolation. Examining preferences of the elderly regarding other types of transportation and other mode attributes is, therefore, an important topic for further research.

Lastly, elderly who are not using a computer or internet are not considered, while a large part of the elderly, 10% of the elderly aged 65 to 75 and 32% of the elderly aged 75 and over, has never used internet. For policy making, it is important to know the preferences and bus usage of the non-digital elderly.

References

[1] CBS (2018f). Zie Nederland vergrijzen deel 1.

[2] Goldenbeld, C. (2015). Effecten van vergrijzing op verkeersgedrag en mobiliteit : een literatuurstudie. Tech. rep., Stichting Wetenschapelijk Onderzoek Verkeersveiligheid SWOV

[3] Johnson, R., Shaw, J., Berding, J., Gather, M., & Rebstock, M. (2017). European national government approaches to older people's transport system needs. Transport Policy, 59. doi: 10.1016/j.tranpol.2017.06.005.

[4] van Wijk, K. (2015). De drempel voor ouderen is hoog | OV-Magazine.

[5] Su, F., & Bell, M. G. (2009). Transport for older people: Characteristics and solutions. Research in Transportation Economics. doi: 10.1016/j.retrec.2009.08.006.

[6] Broome, K., Worrall, L., Fleming, J., & Boldy, D. (2012). Evaluation of flexible route bus transport for older people. Transport Policy. doi: 10.1016/j.tranpol.2012.02.005.

[7] Zijlstra, T., Bakker, P., & Harms, L. (2017). Reizigers in de haarvaten van het openbaar vervoersysteem | Paper | Kennisinstituut voor Mobiliteitsbeleid. Tech. rep., Kennisinstituut voor Mobiliteitsbeleid (KiM).

[8] Szeto, W., Yang, L., Wong, R., Li, Y., & Wong, S. (2017). Spatio-temporal travel characteristics of the elderly in an ageing society. Travel Behaviour and Society, 9, 10–20. doi: 10.1016/j.tbs.2017.07.005.

[9] McHugh, M. L. (2013). The chi-square test of independence. Biochemia medica, 23(2), 143–9. doi: 10.11613/BM.2013.018.

[10] Hausman, J. A., & McFadden, D. (1981). Specification tests for the multinomial logit model.

[11] Train, K. (2002). Discrete Choice Methods with Simulation. Tech. rep., University of California, Berkeley.

[12] Molin, E., & Maat, K. (2015). Bicycle parking demand at railway stations: Capturing price-walking trade offs. Research in Transportation Economics, 53, 3–12. doi: 10.1016/J.RETREC.2015.10.014.

[13] Van Cranenburgh, S. (2018). SEN1721 Latent class discrete choice models for travel behaviour research.

B

Literature review

In table B.1 an overview of the reviewed studies is given with the location of the study, age group, study goals, type of factors, data source, and the used models.

Table B.1: Study goals, factor types, data and models used in the reviewed studies

Study	Location	Age group	Study goals	Type of factors	Data	Model
[1]	The Netherlands	60+	Investigating heterogeneity within ageing population to detect homogenous segments	- Personal characteristics - Travel purposes - Transport modes - Travel time expenditure	Dutch National Travel Survey 2009 (aged 60-64, n=2681, aged 65-74, n=3523, aged 75+, n=2123)	- Descriptive analysis - Chi-square automatic interaction detection analysis
[2]	Eindhoven, The Netherlands	Older adults relative to younger cohorts	Predicting the effect of age on number of trips, travel distance and mode choice for social trips	- Personal characteristics - Neighborhood information	Two days' social interaction diaries in 2008 (n=732)	- Descriptive analysis - Regression model analysis
[3]	Denver, Colorado, US	60+	Analysing trips, distances, mode choices, trip purposes, time of day travel characteristics	- Personal characteristics - Trip purpose - Trip characteristics	A 24-hour weekday travel activities survey during october 2009 and june 2010 by the Denver regional Council of Government (n=6966 households, 1 6,210 persons	- Descriptive analysis - Regression model
[4]	Denmark, Norway and Sweden	40-84	Analysing changes in travel and activity patterns during the life course and identifying period, age and cohort effects	- Personal characteristics	Aggregated data through National Travel Surveys of Denmark (1981 and 2006), Norway (1984/1985 and 2005) and Sweden (1984/1985 and 2005/2006), n=?	- Descriptive analysis - Cohort analysis
[5]	New Zealand	75+	Analysing the impacts of living without a car on on lifestyle and quality of life	- Personal characteristics	Face-to-face interviews by Office for Senior Citizens, New Zealand government (n=28 couple and 43 single)	- Descriptive analysis
[6]	Brisbane, Australia	56-87	Exploring if and how suburban environments impact older people's mobility and their use of different modes of transport	- Personal characteristics- Neighborhood information	Travel diary and GPS tracking data for seven consecutive days, Semi-structured interviews (n=13)	- Descriptive analysis
[7]	Rotterdam, The Netherlands	65+	Analysing effects of socio-demographic, health, trip, spatial and weather attributes on trip making and transport mode choice	- Personal characteristics - Neighborhood information - Natural environment - Trip attributes	Travel diary dataset of 2012 and 2013 (n=147)	- Zero-inflated negative binomial model - Multinomial logit regression model
[8]	Washington State	65+	Analysing travel patterns and travel mode choice	- Personal characteristics - Neighborhood information - Trip attributes - Activity purpose	2000 Puget Sound Transportation Panel (PSTP) data (n=421)	- Multinomial logit model
[9]	London, UK	65+	Understanding mode choice decisions	- Personal characteristics - Mode attributes / accessibility variables	LATS (London Area Travel Survey) 2001 (n=8012, and n=2427 younger than 65 with a longstanding health problem)	- Nested Logit model
[10]	Adelaide, Australia	65+	Exploring factors influencing the frequency of public transport use	- Personal characteristics - Mode attributes	Questionnaire 2010 (n=177)	- Descriptive analysis - Multinomial logistic regression model - Multiple correspondence analysis model
[11]	Montreal, Canada	55+	Investigating factors factors influencing mode choice and corresponding trip length	- Personal characteristics - Neighborhood information	Household travel survey of 2008 (n=31,631)	- Joint discrete-continuous model analysis - Spatial modelling
[12]	North Rhine-Westphalia, Germany	60+	Exploring factors influencing mobility behaviour and finding clusters with distinct mobility patterns	- Personal characteristics - Mode attributes/infrastructure - Mobility-related attitudes - Perceived danger	Computer-assisted telephone interviews 2009, (n=1500)	- Five regression analyses

Where: [1] (Yang & Mesbah, 2013); [2] (van den Berg et al., 2011); [3] (Boschmann & Brady, 2013); [4] (Hjorthol et al., 2010); [5] (Davey, 2019); [6] (Zeitler et al., 2012); [7] (Böcker et al., 2017); [8] (Kim & Ulfarsson, 2004); [9] (Schmöcker et al., 2008); [10] (Truong & Somenahalli, 2015); [11] (Moniruzzaman et al., 2013); [12] (Haustein, 2011)

C

Experimental Design

C.1. Efficient design in NGENE

EFFICIENT DESIGN

```
Design
;alts = alt1*, alt2*
;rows = 12
;eff = (mnl,d,mean)
;model:
U(alt1) = bTT[(u,-0.035,0)] * TT[20,30,40] + bTC[(u,-0.35,0)] * TC[1.5,2.5,3.5] + bF[(u,0,0.8)] *
F[1,4,8] + bTF[(u,-1.4,0)] * TF[0,1] + bSD[(u,-0.00225,0)] * SD[200,400,600]/
U(alt2) = bTT * TT + bTC * TC + bF * F + bTF * TF + bSD * SD
$
```

C.2. Pilot survey design

Table C.1: Choice situations for the pilot survey

Choice situation	Option A					Option B				
	TT	TC	F	TF	SD	TT	TC	F	TF	SD
1	30	1.5	1	0	400	30	3.5	8	1	400
2	30	3.5	8	0	200	30	1.5	4	1	600
3	30	3.5	8	0	600	30	1.5	1	1	200
4	20	1.5	4	1	600	40	3.5	4	0	200
5	20	2.5	1	0	400	40	2.5	8	1	400
6	30	2.5	4	1	600	30	2.5	1	0	200
7	20	3.5	1	1	200	40	1.5	8	0	600
8	40	2.5	8	0	400	20	2.5	1	1	400
9	40	2.5	1	0	600	20	2.5	8	1	200
10	40	3.5	4	1	200	20	1.5	4	0	600
11	40	1.5	4	1	200	20	3.5	4	0	600
12	20	1.5	8	1	400	40	3.5	1	0	400

C.3. Final survey design

Table C.2: Choice situations for the final survey

Choice situation	Option A					Option B				
	TT	TC	F	TF	SD	TT	TC	F	TF	SD
1	30	3.5	8	0	600	30	1.5	1	1	200
2	20	1.5	8	1	200	40	3.5	1	0	600
3	30	2.5	1	0	600	30	2.5	8	1	200
4	40	3.5	1	0	200	20	1.5	8	1	600
5	40	1.5	1	0	200	20	3.5	8	1	600
6	30	1.5	4	1	600	30	3.5	4	0	200
7	30	3.5	8	0	200	30	1.5	4	1	600
8	40	2.5	4	1	400	20	2.5	1	0	400
9	40	2.5	8	1	400	20	2.5	1	0	400
10	20	3.5	4	1	400	40	1.5	4	0	400
11	20	2.5	1	1	400	40	2.5	8	0	400
12	20	1.5	4	0	600	40	3.5	4	1	200

D

Final Stated Preference Survey Design

Onderzoek busgebruik van 65+'ers

Beste deelnemer,

Deze enquête is onderdeel van mijn afstudeeronderzoek voor de Master Transport, Infrastructuur en Logistiek aan de TU Delft in samenwerking met mobiliteits adviesbureau Goudappel Coffeng. Het doel van het onderzoek is om het busgebruik en bijbehorende voorkeuren van personen van 65 jaar of ouder in kaart te brengen.

De enquête bestaat uit 2 delen. In het eerste deel wordt u gevraagd in 12 keuzesituaties met 2 opties voor de bus uw voorkeur te selecteren. **Als u geen gebruik maakt van de bus, geef dan alsnog aan welke optie uw eerste keuze zou zijn.** In het tweede deel worden vragen over persoonlijke kenmerken gesteld.

Alle informatie wordt anoniem verzameld en wordt alleen gebruikt voor dit onderzoek.

De enquête duurt ongeveer 10 minuten en werkt het beste als deze wordt ingevuld op een computer of tablet.

Hartelijk bedankt voor uw deelname!

Ellis van Gorp
Bij vragen kunt u contact opnemen via:
evgorp@goudappel.nl

TU Delft

Volgende >>

Onderzoek busgebruik van 65+'ers

Onderdeel 1 - Keuzesituaties

In dit onderdeel krijgt u 12 keuzesituaties te zien met elk 2 opties voor de bus. De opties verschillen in '*reistijd*', '*kosten*', '*frequentie*', '*aantal overstappen*' en '*afstand tot bushalte*'. Aan u wordt gevraagd welke optie uw voorkeur heeft.

Allereerst wordt een voorbeeldvraag getoond en uitleg van de kenmerken gegeven, vervolgens wordt gevraagd uw voorkeuren te geven.

De omstandigheden zijn voor elke keuzesituatie als volgt:
Stel u reist in uw eentje met de bus vanaf uw huis naar familie of vrienden. Het is 17 graden en droog. U heeft geen (grote) bagage bij u.

Voorbeeld

Welke optie heeft uw voorkeur?
U maakt uw keuze door te klikken op optie A of B.

	Optie A	Optie B
Reistijd	20 minuten	40 minuten
Kosten	€3,50	€1,50
Frequentie	1 bus per 7,5 min.	1 bus per 60 min.
Overstappen	0	1
Afstand tot bushalte	400 meter	600 meter

Kenmerken	Uitleg
Reistijd	De reistijd in de bus in minuten.
Kosten	De kosten voor een buskaartje in euro's.
Frequentie	Tijd tussen het vertrek van twee opeenvolgende bussen (volgtijd) in minuten.
Aantal overstappen	Het aantal keer wisselen van bus om het beoogde reisdoel te bereiken.
Afstand tot bushalte	De afstand van huis tot aan de bushalte in meters.

Onderzoek busgebruik van 65+'ers

Stel u reist in uw eentje met de bus vanaf uw huis naar familie of vrienden. Het is 17 graden en droog. U heeft geen (grote) bagage bij u.

1. **Welke optie heeft uw voorkeur? [1/12]**
U maakt uw keuze door te klikken op optie A of B.

	Optie A	Optie B
Reistijd	30 minuten	30 minuten
Kosten	€3,50	€1,50
Frequentie	1 bus per 7,5 min.	1 bus per 60 min.
Overstappen	0	1
Afstand tot bushalte	600 meter	200 meter

<< Vorige | Volgende >>

Onderzoek busgebruik van 65+'ers

Stel u reist in uw eentje met de bus vanaf uw huis naar familie of vrienden. Het is 17 graden en droog. U heeft geen (grote) bagage bij u.

2. **Welke optie heeft uw voorkeur? [2/12]**
U maakt uw keuze door te klikken op optie A of B.

	Optie A	Optie B
Reistijd	20 minuten	40 minuten
Kosten	€1,50	€3,50
Frequentie	1 bus per 7,5 min.	1 bus per 60 min.
Overstappen	1	0
Afstand tot bushalte	200 meter	600 meter

<< Vorige | Volgende >>

Onderzoek busgebruik van 65+'ers

Stel u reist in uw eentje met de bus vanaf uw huis naar familie of vrienden. Het is 17 graden en droog. U heeft geen (grote) bagage bij u.

3. **Welke optie heeft uw voorkeur? [3/12]**
U maakt uw keuze door te klikken op optie A of B.

	Optie A	Optie B
Reistijd	30 minuten	30 minuten
Kosten	€2,50	€2,50
Frequentie	1 bus per 60 min.	1 bus per 7,5 min.
Overstappen	0	1
Afstand tot bushalte	600 meter	200 meter

<< Vorige | Volgende >>

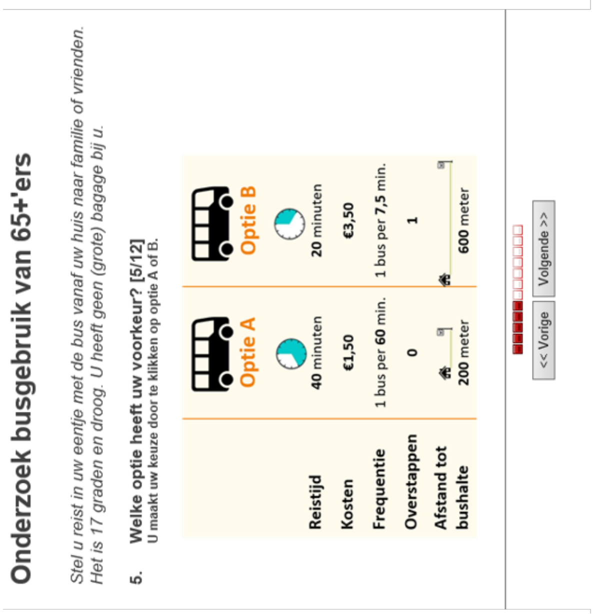
Onderzoek busgebruik van 65+'ers

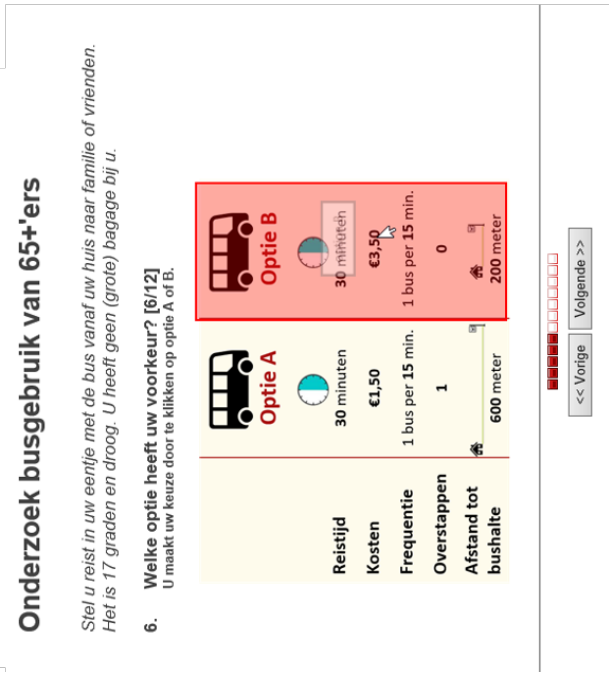
Stel u reist in uw eentje met de bus vanaf uw huis naar familie of vrienden. Het is 17 graden en droog. U heeft geen (grote) bagage bij u.

4. **Welke optie heeft uw voorkeur? [4/12]**
U maakt uw keuze door te klikken op optie A of B.

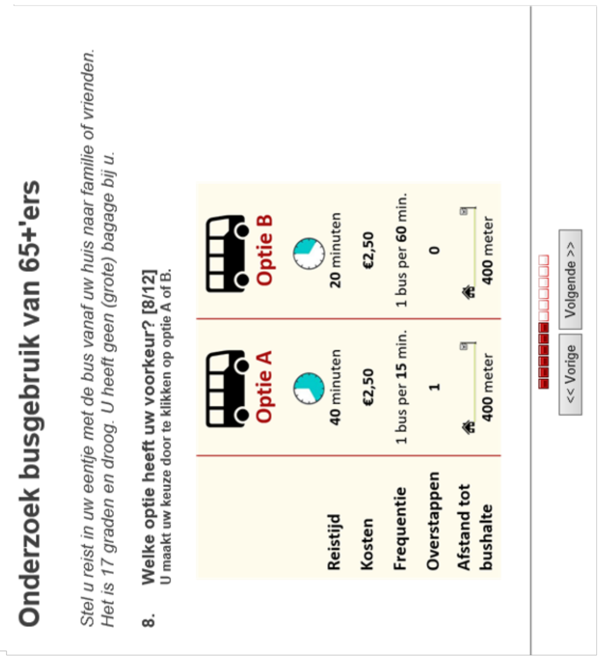
	Optie A	Optie B
Reistijd	40 minuten	20 minuten
Kosten	€3,50	€1,50
Frequentie	1 bus per 60 min.	1 bus per 7,5 min.
Overstappen	0	1
Afstand tot bushalte	200 meter	600 meter

<< Vorige | Volgende >>


Onderzoek busgebruik van 65+'ers
Stel u reist in uw eentje met de bus vanaf uw huis naar familie of vrienden.
Het is 17 graden en droog. U heeft geen (grote) bagage bij u.
5. Welke optie heeft uw voorkeur? [5/12]
U maakt uw keuze door te klikken op optie A of B.
Optie A
Optie B
Reistijd
40 minuten
20 minuten
Kosten
€1,50
€3,50
Frequentie
1 bus per 60 min.
1 bus per 7,5 min.
Overstappen
0
1
Afstand tot bushalte
200 meter
600 meter
<< Vorige
Volgende >>


Onderzoek busgebruik van 65+'ers
Stel u reist in uw eentje met de bus vanaf uw huis naar familie of vrienden.
Het is 17 graden en droog. U heeft geen (grote) bagage bij u.
6. Welke optie heeft uw voorkeur? [6/12]
U maakt uw keuze door te klikken op optie A of B.
Optie A
Optie B
Reistijd
30 minuten
30 minuten
Kosten
€1,50
€3,50
Frequentie
1 bus per 15 min.
1 bus per 15 min.
Overstappen
1
0
Afstand tot bushalte
600 meter
200 meter
<< Vorige
Volgende >>


Onderzoek busgebruik van 65+'ers
Stel u reist in uw eentje met de bus vanaf uw huis naar familie of vrienden.
Het is 17 graden en droog. U heeft geen (grote) bagage bij u.
7. Welke optie heeft uw voorkeur? [7/12]
U maakt uw keuze door te klikken op optie A of B.
Optie A
Optie B
Reistijd
30 minuten
30 minuten
Kosten
€3,50
€1,50
Frequentie
1 bus per 7,5 min.
1 bus per 15 min.
Overstappen
0
1
Afstand tot bushalte
200 meter
600 meter
<< Vorige
Volgende >>


Onderzoek busgebruik van 65+'ers
Stel u reist in uw eentje met de bus vanaf uw huis naar familie of vrienden.
Het is 17 graden en droog. U heeft geen (grote) bagage bij u.
8. Welke optie heeft uw voorkeur? [8/12]
U maakt uw keuze door te klikken op optie A of B.
Optie A
Optie B
Reistijd
40 minuten
20 minuten
Kosten
€2,50
€2,50
Frequentie
1 bus per 15 min.
1 bus per 60 min.
Overstappen
1
0
Afstand tot bushalte
400 meter
400 meter
<< Vorige
Volgende >>

Onderzoek busgebruik van 65+'ers

Stel u reist in uw eentje met de bus vanaf uw huis naar familie of vrienden. Het is 17 graden en droog. U heeft geen (grote) bagage bij u.

9. **Welke optie heeft uw voorkeur? [9/12]**
U maakt uw keuze door te klikken op optie A of B.

	Optie A	Optie B
Reistijd	40 minuten	20 minuten
Kosten	€2,50	€2,50
Frequentie	1 bus per 7,5 min.	1 bus per 60 min.
Overstappen	1	0
Afstand tot bushalte	400 meter	400 meter

<< Vorige | Volgende >>

Onderzoek busgebruik van 65+'ers

Stel u reist in uw eentje met de bus vanaf uw huis naar familie of vrienden. Het is 17 graden en droog. U heeft geen (grote) bagage bij u.

10. **Welke optie heeft uw voorkeur? [10/12]**
U maakt uw keuze door te klikken op optie A of B.

	Optie A	Optie B
Reistijd	20 minuten	40 minuten
Kosten	€3,50	€1,50
Frequentie	1 bus per 15 min.	1 bus per 15 min.
Overstappen	1	0
Afstand tot bushalte	400 meter	400 meter

<< Vorige | Volgende >>

Onderzoek busgebruik van 65+'ers

Stel u reist in uw eentje met de bus vanaf uw huis naar familie of vrienden. Het is 17 graden en droog. U heeft geen (grote) bagage bij u.

11. **Welke optie heeft uw voorkeur? [11/12]**
U maakt uw keuze door te klikken op optie A of B.

	Optie A	Optie B
Reistijd	20 minuten	40 minuten
Kosten	€2,50	€2,50
Frequentie	1 bus per 60 min.	1 bus per 7,5 min.
Overstappen	1	0
Afstand tot bushalte	400 meter	400 meter

<< Vorige | Volgende >>

Onderzoek busgebruik van 65+'ers

Stel u reist in uw eentje met de bus vanaf uw huis naar familie of vrienden. Het is 17 graden en droog. U heeft geen (grote) bagage bij u.

12. **Welke optie heeft uw voorkeur? [12/12]**
U maakt uw keuze door te klikken op optie A of B.

	Optie A	Optie B
Reistijd	20 minuten	40 minuten
Kosten	€1,50	€3,50
Frequentie	1 bus per 15 min.	1 bus per 15 min.
Overstappen	0	1
Afstand tot bushalte	600 meter	200 meter

Einde van het eerste onderdeel.

<< Vorige | Volgende >>

Onderzoek busgebruik van 65+'ers

Onderdeel 2 - Persoonlijke kenmerken

In dit onderdeel wordt gevraagd om antwoord te geven op vragen over persoonlijke informatie. Alle antwoorden worden vertrouwelijk en anoniem behandeld.

<< Vorige | Volgende >>

Onderzoek busgebruik van 65+'ers

13. Wat is uw geslacht?
    - ☐ Man
    - ☐ Vrouw
    - ☐ Zeg ik liever niet

14. In welk jaar bent u geboren? *(Voorbeeld: 1948)*

15. Wat zijn de eerste 4 cijfers van uw postcode? *(Voorbeeld: 1234)*

16. Welke van de volgende opties omschrijft uw thuissituatie het beste?
    - ○ Alleenstaand zonder kinderen
    - ○ Alleenstaand met kinderen die thuis wonen
    - ○ Alleenstaand met kinderen die niet thuis wonen
    - ○ Samenwonend met een partner zonder kinderen
    - ○ Samenwonend met een partner en kinderen die thuis wonen
    - ○ Samenwonend met een partner en kinderen die niet thuis wonen
    - ○ Anders

17. Wat is het totale bruto jaarinkomen van uw gehele huishouden? *(Alle inkomsten, van alle leden van uw huishouden)*
    - ○ Minder dan 10.000 euro
    - ○ 10.000 - 20.000 euro
    - ○ 20.000 - 30.000 euro
    - ○ 30.000 - 40.000 euro
    - ○ 40.000 - 50.000 euro
    - ○ 50.000 - 100.000 euro
    - ○ 100.000 - 200.000 euro
    - ○ 200.000 euro of meer
    - ○ Weet ik niet/wil ik niet zeggen

<< Vorige | Volgende >>

Onderzoek busgebruik van 65+'ers

18. Maakt u gebruik van een loophulpmiddel als u de deur uit gaat? *(U kunt meerdere opties selecteren)*
    - ☐ Nee
    - ☐ Ja, ik gebruik een rolstoel
    - ☐ Ja, ik gebruik een rollator
    - ☐ Ja, ik gebruik een wandelstok
    - ☐ Anders

19. Bent u lichamelijk in staat om te fietsen?
    - ◉ Ja
    - ○ Nee

20. Maakt u weleens gebruik van de fiets?
    - ○ Ja
    - ○ Nee

21. Is er een auto beschikbaar binnen uw huishouden?
    - ○ Ja
    - ○ Nee

22. Heeft u een (geldig) autorijbewijs?
    - ○ Ja
    - ○ Nee

23. Wordt u weleens gebracht of gehaald naar/van uw bestemming door anderen in uw omgeving, zoals vrienden of familie?
    - ○ Ja
    - ○ Nee

24. Maakt u gebruik van Valys? *(Valys = speciaal vervoer voor mensen met een mobiliteitsbeperking)*
    - ○ Ja
    - ○ Nee

<< Vorige | Volgende >>

Onderzoek busgebruik van 65+'ers

25. Hoe vaak reist u gemiddeld met de bus?
    - ○ 5 dagen per week of vaker
    - ○ 1-4 dagen per week
    - ○ 1-3 dagen per maand
    - ○ 6-11 dagen per jaar
    - ○ 5 of minder dagen per jaar
    - ○ Nooit

26. Bent u in het bezit van een abonnement/vervoersbewijs voor het openbaar vervoer?
    - ○ Ja, ik heb een abonnement/vervoersbewijs met korting voor 65+
    - ○ Ja, ik heb een abonnement/vervoersbewijs met andere soort korting
    - ○ Ja, ik heb een abonnement/vervoersbewijs zonder korting
    - ○ Nee, ik heb geen abonnement of vervoersbewijs

27. Bent u in staat om zelf bij de dichtsbijzijnde bushalte vanaf huis te komen? *(Bijvoorbeeld fietsend of lopend, zonder hulp van anderen)*
    - ○ Ja
    - ○ Nee

28. Wat is de afstand van uw huis tot de dichtstbijzijnde bushalte?
    - ○ 0 - 200 meter
    - ○ 200 - 400 meter
    - ○ 400 - 600 meter
    - ○ 600 - 800 meter
    - ○ 800 - 1000 meter
    - ○ Meer dan 1 kilometer
    - ○ Weet ik niet

29. Hoeveel minuten moet u lopen tot de dichtstbijzijnde bushalte?
    - ○ 0 - 2 minuten
    - ○ 2 - 4 minuten
    - ○ 4 - 6 minuten
    - ○ 8 - 10 minuten
    - ○ Meer dan 10 minuten
    - ○ Weet ik niet

Onderzoek busgebruik van 65+'ers

30. Bent u in het bezit van een mobiele telefoon?
    - ☑ Ja
    - ○ Nee

31. Heeft u toegang tot internet op uw mobiele telefoon?
    - ☑ Ja
    - ○ Nee

32. Hoe vaak maakt u gebruik van internet op uw telefoon?
    - ○ Een of meerdere keren per dag
    - ○ Enkele keren per week
    - ○ 1 keer per week
    - ○ 2 of 3 keer per maand
    - ○ 1 keer per maand of minder

33. Maakt u weleens gebruik van reisplanner via uw telefoon?
    - ○ Ja
    - ○ Nee

<< Vorige | Volgende >>

Onderzoek busgebruik van 65+'ers

34. Heeft u nog vragen of opmerkingen over deze enquête of zijn er nog andere dingen die u graag kwijt wilt?

Einde van de vragen.

Mocht u nog opmerkingen of vragen hebben naar aanleiding van deze enquête, dan kunt u mij ook bereiken via:
evgorp@goudappel.nl

Bedankt voor uw deelname aan dit onderzoek!

<< Vorige | Verzenden

E

Cities for sampling

In the figure below the municipalities are shown with the address density, degree of urbanity, province, surface, share of 65+, and the number of inhabitants. The municipalities in red are removed from the list.

Gemeente	adressendichtheid	stedelijkheid	Provincie	[km2]	65+ (%)	inwoners
Eindhoven	2.605	sterk	NB	88,87	16,7	229.126
Groningen	3.456	zeer sterk	GR	83,72	12,7	202.810
Tilburg	3.456	zeer sterk	NB	83,72	12,7	202.810
Almere	1584	sterk	FL	250,15	10,8	203.990
Breda	2.165	sterk	NB	128,68	17,9	183.448
Nijmegen	2.360	sterk	OV	57,6	15,4	175.948
Apeldoorn	1715	sterk	GE	341,1	20,4	161.156
Haarlem	3.500	zeer sterk	NH	32,09	17	159.709
Arnhem	2145	sterk	GE	101,54	14,9	157.223
Enschede	2.115	sterk	OV	142,8	17,5	158.261
Amersfoort	2.271	sterk	UT	63,86	14,4	155.226
Zaanstad	2.021	sterk	NH	83,24	17,9	154.865
Den Bosch	1.963	sterk	NB	118,07	17,5	153.434
Haarlemmermeer	1.556	sterk	NH	185,3	16,3	147.282
Zwolle	1.993	sterk	OV	119,3	15,3	126.116
Zoetermeer	2.507	sterk	ZH	37,06	17,9	124.695
Leiden	3.670	zeer sterk	ZH	23,16	14,8	124.306
Leeuwarden	2.071	sterk	FR	170,23	18	122.415
Maastricht	2.433	sterk	LI	60,06	20,7	122.723
Dordrecht	2.519	sterk	ZH	99,45	18,6	118.426
Ede	1.525	matig	GE	318,62	17,8	114.682
Alphen aan de Rijn	1.782	sterk	ZH	132,5	18,5	109.682
Alkmaar	2.243	sterk	NH	31,22	18,7	108.470
Westland	1.404	matig	ZH	90,58	18,8	107.492
Emmen	849	weinig	DR	346,26	22,1	107.192
Venlo	1.625	sterk	LI	86,41	21,1	101.192

Figure E.1: Cities used for sample

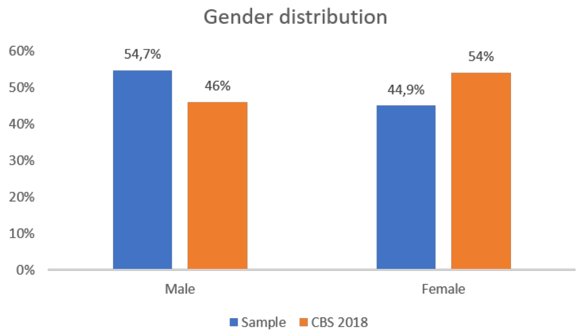
F

Results SP Final Survey

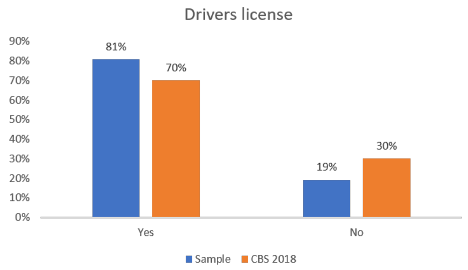
F.1. Descriptive statistics frequency distribution

Table F.1: Frequency distribution socio-demographic characteristics sample compared to population

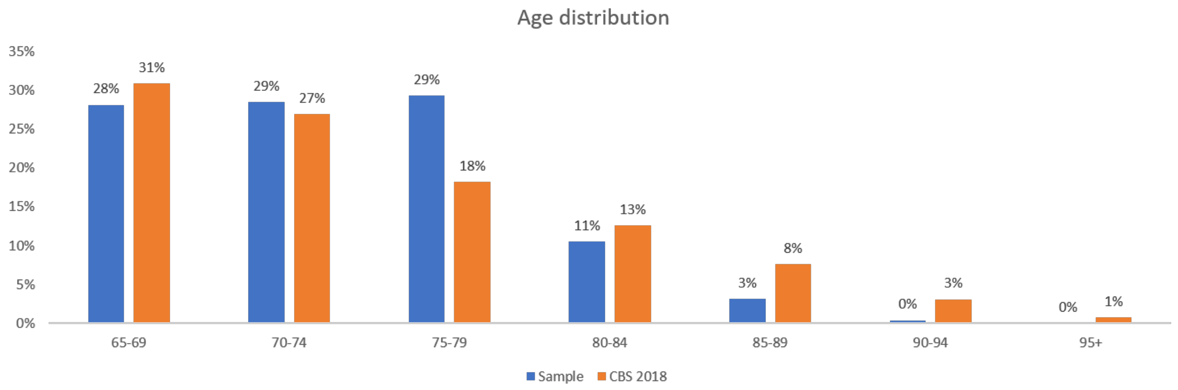
Socio-demographic variable	Number of respondents	Sample share		Share NL	Share municipalities together
Gender					
Male	141	55,1%		46%	45%
Female	115	44,9%		54%	54%
Age					
65-69	72	28,1%		30,9%	30,3%
70-74	73	28,5%		26,9%	27,3%
75-79	75	29,3%		18,2%	18,0%
80-84	27	10,5%		12,6%	12,7%
85-89	8	3,1%		7,6%	7,7%
90-94	1	0,4%		3,1%	3,2%
95+	0	0%		0,8%	0,8%
Income (Bruto)					
less than 10.000 euro	6	2,3%	(2,9%)	4%	
10.000 - 20.000 euro	58	22,7%	(28,3%)	50%	
20.000 - 30.000 euro	50	19,5%	(24,4%)	22%	
30.000 - 40.000 euro	46	18,0%	(22,4%)	11%	
40.000 - 50.000 euro	26	10,2%	(12,7%)	5%	
50.000 - 100.000 euro	18	7,0%	(8,8%)	6%	
100.000 - 200.000 euro	1	0,4%	(0,5%)	1%	
200.000 euro or more	0	0,0%	(0%)	0%	
I don't know/I don't wanna say	51	19,9%	(-)	-	
Driving license					
Yes	207	80,9%		70%	
No	49	19,1%		30%	
Residence					
Alkmaar	12	5%		4%	
Amersfoort	7	3%		5%	
Apeldoorn	14	5%		6%	
Arnhem	12	5%		5%	
Breda	16	6%		6%	
Dordrecht	8	3%		4%	
Eindhoven	18	7%		8%	
Enschede	23	9%		5%	
Groningen	12	5%		7%	
Haarlem	15	6%		5%	
Haarlemmermeer	12	5%		5%	
Leeuwarden	9	4%		4%	
Leiden	10	4%		4%	
Maastricht	18	7%		4%	
Nijmegen	15	6%		6%	
Tilburg	19	7%		7%	
Venlo	10	4%		3%	
Zaanstad	16	6%		5%	
Zwolle	10	4%		4%	



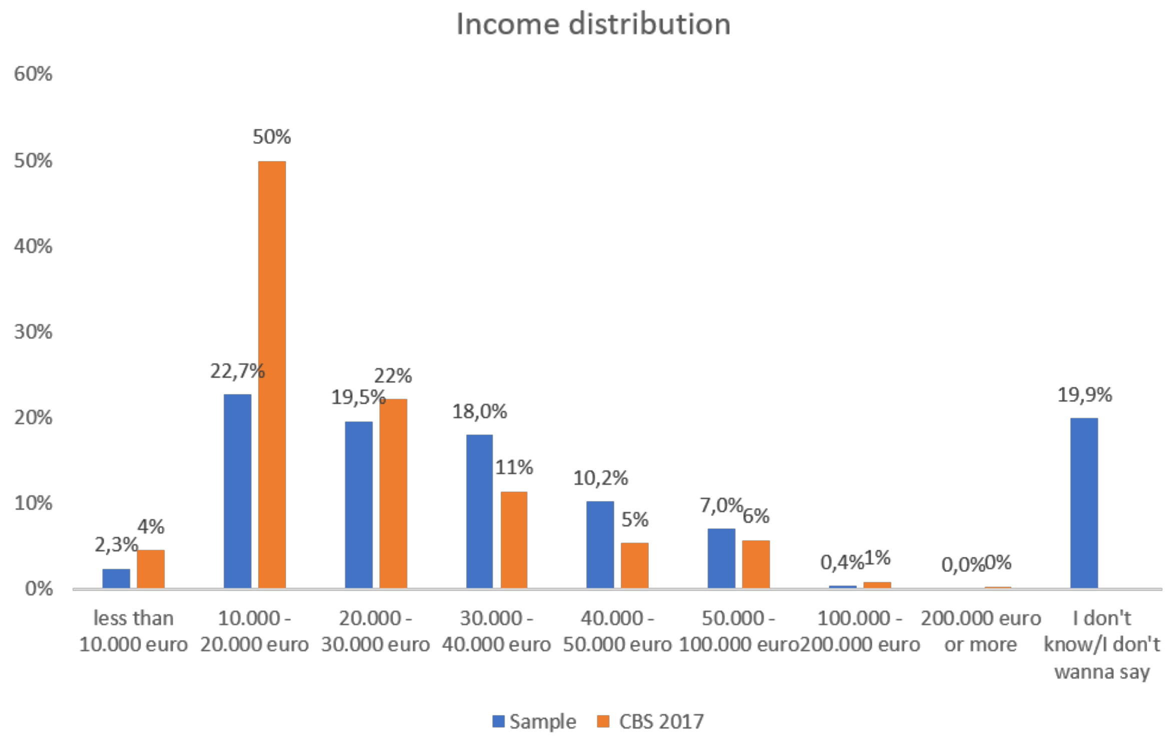
(a) Gender (own work, based on (CBS, 2018d))



(b) Drivers license (own work, based on (CBS, 2019a))

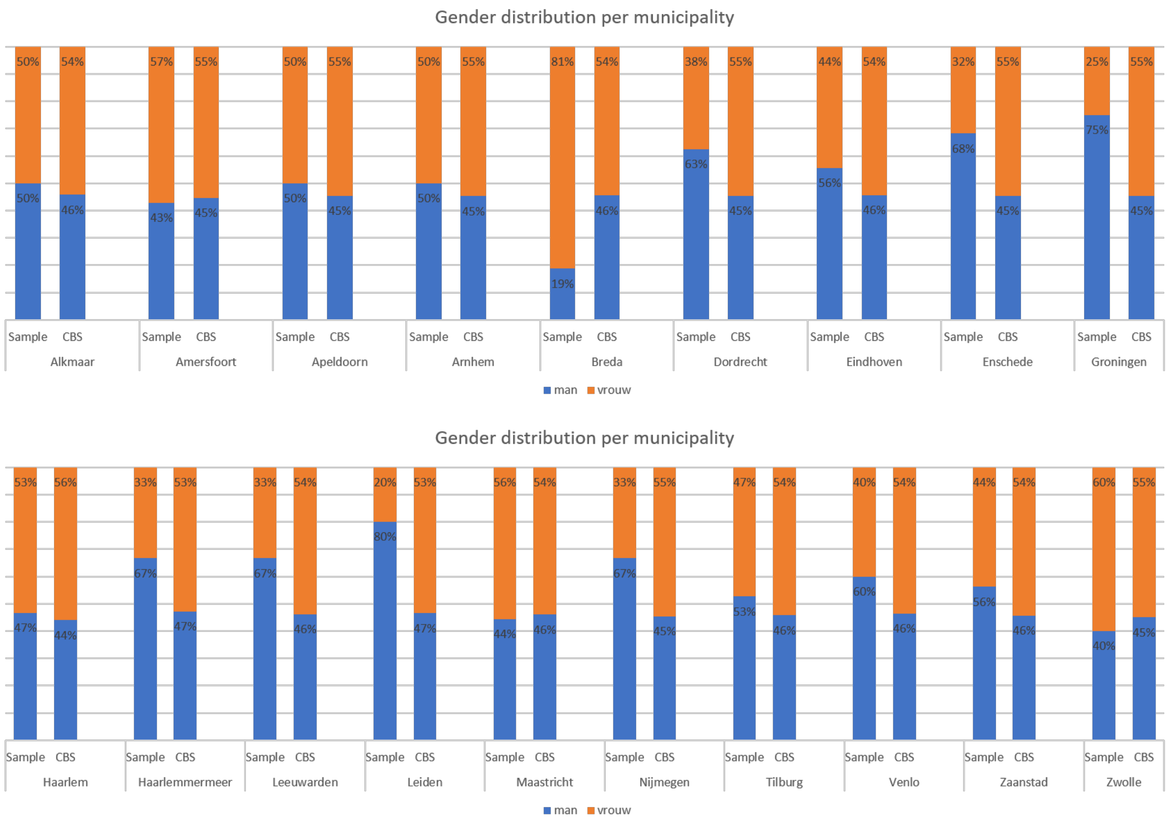


(c) Age (own work, based on(CBS, 2018d))



(d) Income (own work, based on (CBS, 2018d))

Figure F.2: Gender distribution municipalities: sample data compared with CBS data (own work, based on (CBS, 2018d))



F.2. Representativeness sample check

Table F.2: Results of representativeness test of sample socio-demographic characteristics

Socio-demographic variable	Chi-square	p-value
Gender	17,322	0.000
Age	29,584	0.000
Income	60,900	0.000
Residence	11,862	0.854

Table F.3: Crosstable results of socio-demographic variables with bus usage

Socio-demographic variable	sample mean	population estimator
Gender	3,31	3,29
Age	3,31	3,34
Income	3,33	3,25

F.3. Re-organizing segments and frequency distribution

- The age segments ’80-84 years’, ’85-89 years’, ’90-94 years’ and ’95+’ are taken together to one segment called ’80+’.
- The income segments ’less than 10.000’ and ’10.000-20.000’ are taken together in ’less than 20.000’. The last four segments are taken together into ’more than 40.000’.
- The bus usage segments ’1-4 days per week’ and ’5 days a week or more’ are taken together into ’1 day per week or more’.
- The household situation segments ’single with children’ and ’single with children living somewhere else’ are taken together into ’single with children (living at home or somewhere else)’. The same applies to ’together with a partner and children (living at home or somewhere else)’.
- The walking tool segments are reclassified in the segments walking tool ’yes’ or ’no’.
- The public transport subscription segments ’yes without discount’ and ’yes including different discount’ are taken together.
- The distance to nearest bus stop segments ’600-800 meters’, ’800-1000 meters’ and ’more than 1 km’ are taken together in the segment ’600 meters or more’.
- The walking distance in minutes to nearest bus stop segments ’8-10 minutes’ and ’more than 10 minutes’ are taken together in the segment ’6 minutes or more’.
- The internet usage mobile phone segments ’1 time per week’, ’2 or 3 times per month’, ’1 time per month or less’ are taken together to the segment ’1 time per week or less’.

Table F.4: Frequency distribution personal characteristics of respondents compared to population

Socio-demographic variable	Number of respondents	Sample share
Gender		
Male	141	55,1%
Female	115	44,9%
Age		
65-69	72	28,1%
70-74	73	28,5%
75-79	75	29,3%
80+	36	14,1%
Household situation		
Single without children	52	20,3%
Single with children living at home or somewhere else	42	16,4%
Together without children	76	29,7%
Together with children living at home orsomewhere else	86	33,6%
Income (Bruto)		
less than 20.000 euro	64	25,0%
20.000 - 30.000 euro	50	19,5%
30.000 - 40.000 euro	46	18,0%
40.000 or more	45	17,6%
I don’t know	51	19,9%
Walking tool		
Yes	53	20,7%
No	203	79,3%
Physically albe to cycle		
Yes	203	79,3%
No	53	20,7%
Cycle usage		
Yes	159	62,1%
No	24	9,4%
Car ownership household		
Yes	204	79,7%
No	52	20,3%
Driving license		
Yes	207	80,9%
No	49	19,1%

Table F.5: Frequency distribution personal characteristics of respondents

Socio-demographic variable	Number of respondents	Sample share
Taken by friends/family		
Yes	114	44,5%
No	142	55,5%
Valys usage		
Yes	22	8,6%
No	234	91,4%
Bus usage		
1 day per week or more	29	11,3%
1 - 3 days per month	49	19,1%
6 - 11 days per year	47	18,4%
5 days or less per year	75	29,3%
Never	56	21,9%
Public transport subscription		
Yes, including 65+ discount	85	33,2%
Yes, without discount or other discount	39	15,2%
No	132	51,6%
Able to reach bus stop without help		
Yes	239	19,1%
No	17	80,9%
Distance to nearest bus stop		
0 - 200 meters	90	55,5%
200 - 400 meters	68	26,6%
400 - 600 meters	56	21,9%
600 meters or more	36	14,1%
I don’t know	56	21,9%
Walking distance in minutes to nearest bus stop		
0 - 2 minutes	60	2,3%
2 - 4 minutes	66	25,8%
4 - 6 minutes	76	29,7%
6 minutes or more	47	18,4%
I don’t know	7	2,7%
Mobile phone possession		
Yes	248	96,9%
No	8	3,1%
Internet access mobile phone		
Yes	178	71,8%
No	70	28,2%
Internet usage mobile phone		
One or several times per day	103	56%
A few times per week	34	19%
1 time per week or less	41	17%
Trip planner usage mobile phone		
Yes	93	52%
No	85	48%

F.4. Cross-tables

Table F.6: Cross-table Walking distance in minutes to nearest bus stop with bus usage

Walking distance in minutes to nearest bus stop		Bus usage					Total
		1 day per week or more	1 - 3 days per month	6 - 11 days per year	5 days or less per year	Never	
0 - 2 minutes	Count	5	9	13	17	16	60
	% min distance	8,3%	15,0%	21,7%	28,3%	26,7%	100%
2 - 4 minutes	Count	11	13	14	17	11	66
	% min distance	16,7%	19,7%	21,2%	25,8%	16,7%	100%
4 - 6 minutes	Count	8	15	15	27	11	76
	% min distance	10,5%	19,7%	19,7%	35,5%	14,5%	100%
6 minutes or more	Count	5	12	5	12	13	47
	% min distance	10,6%	25,5%	10,6%	25,5%	27,7%	100%
I don't know	Count	0	0	0	2	5	7
	% min distance	0,0%	0,0%	0,0%	28,6%	71,4%	100%
Total	Count	29	49	47	75	56	256
	% min distance	11,3%	19,1%	18,4%	29,3%	21,9%	100%

Table F.7: Cross-table Walking distance in minutes to nearest bus stop with income

Walking distance in minutes to nearest bus stop		Income (Bruto)					Total
		less than 20.000	20.000 - 30.000	30.000 - 40.000	40.000 or more	I don't know	
0 - 2 minutes	Count	16	12	8	14	10	60
	% min distance	26,7%	20,0%	13,3%	23,3%	16,7%	100%
2 - 4 minutes	Count	15	17	8	9	17	66
	% min distance	22,7%	25,8%	12,1%	13,6%	25,8%	100%
4 - 6 minutes	Count	13	15	21	13	14	76
	% min distance	17,1%	19,7%	27,6%	17,1%	18,4%	100%
6 minutes or more	Count	18	6	8	8	7	47
	% min distance	38,3%	12,8%	17,0%	17,0%	14,9%	100%
I don't know	Count	2	0	1	1	3	7
	% min distance	28,6%	0,0%	14,3%	14,3%	42,9%	100%
Total	Count	64	50	46	45	51	256
	% min distance	25,0%	19,5%	18,0%	17,6%	19,9%	100%

F.5. Chi-square tests socio-demographic characteristics

Table F.8: Chi-square test results for socio-demographic characteristics significant related to bus usage

Socio-demographic variable			Bus usage One day per week or more (1)	1-3 days per month (2)	6-11 days per year (3)	5 days or less per year (4)	Never (5)	
Walking tool	**Yes**	(O)	6	13	8	8	18	Pearson chi-square = 10,468 df = 4 p-value = 0,033 0 cells (0,0%) have expected count less than 5.
		(E)	6,0	10,1	9,7	15,5	11,6	
		(%)	11,3%	24,5%	15,1%	15,1%	34,0%	
	No	(O)	23	36	39	67	38	
		(E)	23,0	38,9	37,3	59,5	44,4	
		(%)	11,3%	17,7%	19,2%	33,0%	18,7%	
Able to cycle	**Yes**	(O)	22	40	39	66	36	Pearson chi-square = 11,906 df = 4 p-value = 0,018 0 cells (0,0%) have expected count less than 5.
		(E)	23,0	38,9	37,3	59,5	44,4	
		(%)	10,8%	19,7%	19,2%	32,5%	17,7%	
	No	(O)	7	9	8	9	20	
		(E)	6,0	10,1	9,7	15,5	11,6	
		(%)	13,2%	17,0%	15,1%	17,0%	37,7%	
Car possession	**Yes**	(O)	17	31	40	67	49	Pearson chi-square = 23,391 df = 4 p-value = 0,000 0 cells (0,0%) have expected c ount less than 5.
		(E)	23,1	39,0	37,5	59,8	44,6	
		(%)	8,3%	15,2%	19,6%	32,8%	24,0%	
	No	(O)	12	18	7	8	7	
		(E)	5,9	10,0	9,5	15,2	11,4	
		(%)	23,1%	34,6%	13,5%	15,4%	13,5%	
Driving license	**Yes**	(O)	19	35	37	66	50	Pearson chi-square = 12,405 df = 4 p-value = 0,015 0 cells (0,0%) have expected count less than 5.
		(E)	23,4	39,6	38,0	60,6	45,3	
		(%)	9,2%	16,9%	17,9%	31,9%	24,2%	
	No	(O)	10	14	10	9	6	
		(E)	5,6	9,4	9,0	14,4	10,7	
		(%)	20,4%	28,6%	20,4%	18,4%	12,2%	
Taken by friends/family	**Yes**	(O)	19	29	20	28	18	Pearson chi-square = 14,557 df = 4 p-value = 0,006 0 cells (0,0%) have expected count less than 5.
		(E)	12,9	21,8	20,9	33,4	24,9	
		(%)	16,7%	25,4%	17,5%	24,6%	15,8%	
	No	(O)	10	20	27	47	38	
		(E)	16,1	27,2	26,1	41,6	31,1	
		(%)	7,0%	14,1%	19,0%	33,1%	26,8%	
Transport subscription	**Yes, incl 65+ discount**	(O)	20	25	23	15	2	Pearson chi-square = 85,240 df = 8 p-value = 0,000 1 cells (6,7%) have expected count less than 5.
		(E)	9,6	16,3	15,6	24,9	18,6	
		(%)	23,5%	29,4%	27,1%	17,6%	2,4%	
	Yes, other/no discount	(O)	4	12	11	8	4	
		(E)	4,4	7,5	7,2	11,4	8,5	
		(%)	10,3%	30,8%	28,2%	20,5%	10,3%	
	No	(O)	5	12	13	52	50	
		(E)	15,0	25,3	24,2	38,7	28,9	
		(%)	3,8%	9,1%	9,8%	39,4%	37,9%	
Able to reach bus stop without help	**Yes**	(O)	27	46	45	75	46	Pearson chi-square = 17,155 df = 4 p-value = 0,002 5 cells (50,0%) have expected count less than 5.
		(E)	27,1	45,7	43,9	70,0	52,3	
		(%)	11,3%	19,2%	18,8%	31,4%	19,2%	
	No	(O)	2	3	2	0	10	
		(E)	1,9	3,3	3,1	5,0	3,7	
		(%)	11,8%	17,6%	11,8%	0,0%	58,8%	
Total number of respondents			29	49	47	75	56	

G
Model estimation

G.1. Dummy coding

Table G.1: Dummy coding scheme for the personal characteristics

Gender	**GENDER**			
Male	1			
Female	0			
Age	**AGE1**	**AGE2**	**AGE3**	
80+	1	0	0	
75-79	0	1	0	
70-74	0	0	1	
65-69	0	0	0	
Household situation	**HH1**	**HH2**	**HH3**	
Together with children living at home or somewhere else	1	0	0	
Together without children	0	1	0	
Single with children living at home or somewhere else	0	0	1	
Single without children	0	0	0	
Income (Bruto)	**INC1**	**INC2**	**INC3**	
40.000 or more	1	0	0	
30.000 - 40.000 euro	0	1	0	
20.000 - 30.000 euro	0	0	1	
less than 20.000	0	0	0	
Walking tool	**TOOL**			
Yes	1			
No	0			
Physically able to cycle	**ABLECYCLE**			
Yes	1			
No	0			
Cycle usage	**CYCLEUSE**			
Yes	1			
No	0			
Car ownership	**CAR**			
Yes	1			
No	0			
Driving license	**LICENSE**			
Yes	1			
No	0			
Taken to or from destination by friends/family sometimes	**TAKEN**			
Yes	1			
No	0			
Valys usage	**VALYS**			
Yes	1			
No	0			
Bus usage	**BUSU1**	**BUSU2**	**BUSU3**	**BUSU4**
1 day per week or more	1	0	0	0
1-3 days per month	0	1	0	0
6-11 days per year	0	0	1	0
5 days or less per year	0	0	0	1
Never	0	0	0	0
Public transport subscription/ticket	**PTCARD1**	**PTCARD2**		
Yes, including 65+ discount	1	0		
Yes, without discount or other discount	0	1		
No	0	0		
Able to get to nearest bus stop without help	**REACHBUS**			
Yes	1			
No	0			

Table G.2: Dummy coding scheme for the personal characteristics

Distance to nearest bus stop	**DISTBUS1**	**DISTBUS2**	**DISTBUS3**
600 meters or more	1	0	0
400 - 600 meters	0	1	0
200 - 400 meters	0	0	1
0 - 200 meters	0	0	0
Minutes to nearest bus stop	**DISTBUS1**	**DISTBUS2**	**DISTBUS3**
6 minutes or more	1	0	0
4-6 minutes	0	1	0
2-4 minutes	0	0	1
0-2 minutes	0	0	0
Mobile phone posession	**MOBILE**		
Yes	1		
No	0		
Internet access mobile phone	**MOBINTER**		
Yes	1		
No	0		
Internet usage mobile phone	**MOBUSE1**	**MOBUSE2**	
One or several times per day	1	0	
A few times per week	0	1	
1 time per week or less	0	0	
Trip planner usage mobile phone	**TRIPPLAN**		
Yes	1		
No	0		

G.2. MNL model estimation results

G.2.1. Results of five estimated MNL models

MNL	Final LL	Rho-square	Adjusted Rho-square	Number of parameters	% of parameters significant
[1]	-1796.154	0.156	0.154	5	100%
[2]	-1792.918	0.158	0.155	6	100%
[3]	-1796.154	0.156	0.154	6	67%
[4]	-1796.154	0.156	0.154	6	67%
[5]	-1796.154	0.156	0.154	6	67%

Where:
[1] =MNL model with all parameters, no quadratic parameter components.
[2] =MNL model with all parameters, quadratic parameter component for frequency.
[3] =MNL model with all parameters, quadratic parameter component for distance to stop.
[4] =MNL model with all parameters, quadratic parameter compontent for transfers.
[5] =MNL model with all parameters, quadratic parameter component for travel time.

G.2.2. Parameter estimates of five estimated MNL models

MNL		frequency	frequency^2	distance to bus stop	distance to bus stop^2	travel costs	transfers	transfers^2	travel time	travel time^2
[1]	parameter estimate	**0.109**		**-0.000958**		**-0.584**	**-0.290**		**-0.0271**	
	t-value	13.17		-6.89		-20.31	-6.73		-9.68	
	p-value	0.00*		0.00*		0.00*	0.00*		0.00*	
[2]	parameter estimate	**0.357**	**-0.0269**	**-0.00114**		**-0.580**	**-0.364**		**-0.0316**	
	t-value	3.65	-2.55	-7.22		-19.99	-6.99		-9.46	
	p-value	0.00*	0.01*	0.00*		0.00*	0.00*		0.00*	
[3]	parameter estimate	**0.109**		-4.99e-13	-1.20e-006	**-0.584**	**-0.290**		**-0.0271**	
	t-value	13.17		0.00	0.00	-20.31	-6.73		-9.68	
	p-value	0.00*		1.00	1.00	0.00*	0.00*		0.00*	
[4]	parameter estimate	**0.109**		**-0.000958**		**-0.584**	-0.145	-0.145	**-0.0271**	
	t-value	13.17		-6.89		-20.31	0.00	0.00	-9.68	
	p-value	0.00*		0.00*		0.00*	1.00	1.00	0.00*	
[5]	parameter estimate	**0.109**		**-0.000958**		**-0.584**	**-0.290**		-3.09e-014	-0.00045
	t-value	13.17		-6.89		-20.31	-6.73		0.00	0.00
	p-value	0.00*		0.00*		0.00*	0.00*		1.00	1.00

G.2.3. Biogeme syntax Multinomial Logit base model

```
from biogeme import *
from headers import *
from loglikelihood import *
from statistics import *

# Parameters to be estimated
BETA_TT         = Beta('BETA_TT',0,-1000,1000,0)
BETA_TC         = Beta('BETA_TC',0,-1000,1000,0)
BETA_FREQl      = Beta('BETA_FREQl',0,-1000,1000,0)
BETA_FREQq      = Beta('BETA_FREQq',0,-1000,1000,0)
BETA_TF         = Beta('BETA_TF',0,-1000,1000,0)
BETA_SD         = Beta('BETA_SD',0,-1000,1000,0)

V1 = TTA * BETA_TT + TCA * BETA_TC + FREQA * BETA_FREQl + FREQA * FREQA * BETA_FREQq + TFA * BETA_TF + SDA * BETA_SD
V2 = TTB * BETA_TT + TCB * BETA_TC + FREQB * BETA_FREQl + FREQB * FREQB * BETA_FREQq + TFB * BETA_TF + SDB * BETA_SD


# Associate utility functions with the numbering of alternatives
V = {1: V1,
   2: V2}

AV1 = 1
AV2 = 1

# Associate the availability conditions with the alternatives
av = {1: AV1,
    2: AV2}

# The choice model is a logit, with availability conditions
logprob = bioLogLogit(V,av,CHOICE)

# Defines an itertor on the data
rowIterator('obsIter')

# DEfine the likelihood function for the estimation
BIOGEME_OBJECT.ESTIMATE = Sum(logprob,'obsIter')

# Statistics

nullLoglikelihood(av,'obsIter')
choiceSet = [1,2]
cteLoglikelihood(choiceSet,CHOICE,'obsIter')
availabilityStatistics(av,'obsIter')
```

G.2.4. Summary statistics Multinomial Logit base model

Model:	Multinomial logit
Nr of estimated parameters:	6
Sample size:	3072
Number of individuals:	256
Null log-likelihood:	-2129.35
Cte log-likelihood:	-2122.44
Init log-likelihood:	-2129.348
Final log-likelihood:	-1792.918
Likelihood ratio test:	672.861
Rho-square:	0.158
Adjusted rho-square:	0.155
Iterations:	8

G.3. MNL models with interaction effects

G.3.1. Biogeme syntax MNL model with interaction of license

```
from biogeme import *
from headers import *
from loglikelihood import *
from statistics import *

# Parameters to be estimated
BETA_TT              = Beta('BETA_TT',0,-1000,1000,0)
BETA_TC              = Beta('BETA_TC',0,-1000,1000,0)
BETA_FREQl           = Beta('BETA_FREQl',0,-1000,1000,0)
BETA_FREQq           = Beta('BETA_FREQq',0,-1000,1000,0)
BETA_TF              = Beta('BETA_TF',0,-1000,1000,0)
BETA_SD              = Beta('BETA_SD',0,-1000,1000,0)
BETA_LICENSE         = Beta('BETA_LICENSE',0,-1000,1000,0)
BETA_LICENSEtt       = Beta('BETA_LICENSEtt',0,-1000,1000,0)
BETA_LICENSEtc       = Beta('BETA_LICENSEtc',0,-1000,1000,0)
BETA_LICENSEfreql = Beta('BETA_LICENSEfreql',0,-1000,1000,0)
BETA_LICENSEfreqq= Beta('BETA_LICENSEfreqq',0,-1000,1000,0)
BETA_LICENSEtf       = Beta('BETA_LICENSEtf',0,-1000,1000,0)
BETA_LICENSEsd       = Beta('BETA_LICENSEsd',0,-1000,1000,0)

V1 =      TTA * BETA_TT + TCA * BETA_TC + FREQA * BETA_FREQl + FREQA * FREQA * BETA_FREQq + TFA * BETA_TF +
          SDA * BETA_SD + LICENSE * BETA_LICENSE + BETA_LICENSEtt * TTA * LICENSE + BETA_LICENSEtc * TCA * LICENSE +
          BETA_LICENSEfreql * FREQA * LICENSE + BETA_LICENSEfreqq * FREQA * FREQA * LICENSE + BETA_LICENSEtf * TFA * LICENSE +
          BETA_LICENSEsd * SDA * LICENSE

V2 =      TTB * BETA_TT + TCB * BETA_TC + FREQB * BETA_FREQl + FREQB * FREQB * BETA_FREQq + TFB * BETA_TF +
          SDB * BETA_SD + LICENSE * BETA_LICENSE + BETA_LICENSEtt * TTB * LICENSE + BETA_LICENSEtc * TCB * LICENSE +
          BETA_LICENSEfreql * FREQB * LICENSE + BETA_LICENSEfreqq * FREQB * FREQB * LICENSE + BETA_LICENSEtf * TFB * LICENSE +
          BETA_LICENSEsd * SDB * LICENSE


# Associate utility functions with the numbering of alternatives
V = {1: V1,
    2: V2}

AV1 = 1
AV2 = 1

# Associate the availability conditions with the alternatives
av = {1: AV1,
     2: AV2}

# The choice model is a logit, with availability conditions
logprob = bioLogLogit(V,av,CHOICE)

# Defines an itertor on the data
rowIterator('obsIter')

# DEfine the likelihood function for the estimation
BIOGEME_OBJECT.ESTIMATE = Sum(logprob,'obsIter')

# Statistics

nullLoglikelihood(av,'obsIter')
choiceSet = [1,2]
cteLoglikelihood(choiceSet,CHOICE,'obsIter')
availabilityStatistics(av,'obsIter')
```

G.3.2. Estimation outcomes interaction effects

Socio-demographic variable	Travel Time				Travel Cost			
	Value	St error	t-test	p-value	Value	St error	t-test	p-value
Gender								
Male	-0,00143	0,00689	-0,21	0,84	-0,0595	0,0601	-0,99	0,32
Female	**-0,031**	0,005	-6,2	0*	**-0,55**	0,0434	-12,68	0*
Age								
80+	0,0157	0,0115	1,36	0,17	**0,21**	0,101	2,09	0,04*
75-79	**0,0186**	0,00919	2,02	0,04*	**0,248**	0,0821	3,02	0*
70-74	0,00319	0,00978	0,33	0,74	**0,193**	0,0864	2,23	0,03*
65-69	**-0,041**	0,00705	-5,82	0*	**-0,748**	0,0642	-11,65	0*
Household situation								
Together with children living at home or somewhere else	-0,019	0,00953	-1,99	0,05	-0,135	0,084	-1,61	0,11
Together without children	-0,00926	0,0096	-0,96	0,34	-0,0551	0,0834	-0,66	0,51
Single with children living at home or somewhere else	-0,00483	0,011	-0,44	0,66	-0,0669	0,0951	-0,7	0,48
Single without children	**-0,0224**	0,00722	-3,1	0*	**-0,515**	0,0629	-8,2	0*
Income (Bruto)								
40,000 or more	9,40E-05	0,0257	0	1	0,44	0,222	1,98	0,05
30,000 - 40,000 euro	0,0014	0,026	0,05	0,96	**0,54**	0,225	2,4	0,02*
20,000 - 30,000 euro	0,0146	0,0259	0,57	0,57	**0,455**	0,224	2,03	0,04*
less than 20,000	-0,0386	0,0249	-1,55	0,12	**-1,05**	0,216	-4,86	0*
Walking tool								
Yes	**0,0162**	0,008	2,02	0,04*	**0,175**	0,069	2,53	0,01*
No	**-0,0357**	0,004	-8,93	0*	**-0,624**	0,0351	-17,8	0*
Physically able to cycle								
Yes	**-0,0237**	0,00806	-2,94	0*	**-0,194**	0,0683	-2,84	0*
No	-0,0139	0,00697	-1,99	0,05	-0,438	0,00697	-1,99	0,05
Cycle usage								
Yes	0,0054	0,0138	0,39	0,7	0,0775	0,127	0,61	0,54
No[1]	**-0,0425**	0,0131	-3,24	0*	**-0,704**	0,122	-5,78	0*
Car ownership								
Yes	-0,00444	0,0087	-0,51	0,61	0,146	0,077	1,9	0,06
No	**-0,0281**	0,00781	-3,59	0*	**-0,699**	0,0694	-10,07	0*
Driving license								
Yes	0,00757	0,00986	0,77	0,44	**0,27**	0,0872	3,1	0*
No	**-0,0386**	0,00913	-4,22	0*	**-0,808**	0,081	-9,97	0*
Taken to or from destination by friends/family sometimes								
Yes	-0,00214	0,00694	-0,31	0,76	-0,0255	0,0606	-0,42	0,67
No	**-0,0308**	0,00456	-6,76	0*	**-0,571**	0,0395	-14,44	0*
Valys usage								
Yes[1]	0,017	0,0114	1,5	0,13	0,0798	0,0991	0,8	0,42
No	**-0,0332**	0,00363	-9,14	0*	**-0,588**	0,0316	-18,61	0*
Bus usage								
1 day per week or more	-0,0176	0,013	-1,36	0,17	-0,147	0,108	-1,36	0,17
1-3 days per month	0,0125	0,00976	1,28	0,2	0,0746	0,076	0,98	0,33
6-11 days per year	-0,00545	0,0105	-0,52	0,6	-0,0391	0,084	-0,46	0,64
5 days or less per year	-0,00544	0,00771	-0,71	0,48	-2,51E-15	3,35E+04	0	1
Never	**-0,0303**	0,00645	-4,7	0*	**-0,581**	0,0423	-13,73	0*
Public transport subscription/ticket								
Yes, including 65+ discount	7,62E-17	1,59E+03	0	1	7,62E-17	1,59E+03	0	1
Yes, without discount or other discount	-1,30E-16	1,80e+308	0	1	-1,30E-16	1,80e+308	0	1
No	**-0,0271**	0,00463	-5,86	0*	**-0,559**	0,0403	-13,86	0*
Able to get to nearest bus stop without help								
Yes	-0,0213	0,0136	-1,57	0,12	-0,174	0,115	-1,52	0,13
No[1]	-0,0121	0,0131	-0,92	0,36	**-0,421**	0,11	-3,82	0*
Distance to nearest bus stop								
600 meters or more	-0,00171	0,011	-0,16	0,88	-0,000589	0,0943	-0,01	1
400 - 600 meters	-0,0055	0,00922	-0,6	0,55	0,0265	0,0814	0,33	0,74
200 - 400 meters	-0,00525	0,00894	-0,59	0,56	-0,0148	0,0781	-0,19	0,85
0 - 200 meters	**-0,0287**	0,00574	-4,99	0*	**-0,588**	0,0502	-11,71	0*
Minutes to nearest bus stop								
6 minutes or more	0,0177	0,0101	1,76	0,08	**0,19**	0,0877	2,16	0,03*
4-6 minutes	-0,00601	0,00997	-0,6	0,55	-0,0485	0,0874	-0,56	0,58
2-4 minutes	-0,0119	0,00991	-1,2	0,23	0,0333	0,0874	0,38	0,7
0-2 minutes	**-0,0303**	0,00705	-4,3	0*	**-0,626**	0,062	-10,1	0*
Mobile phone posession								
Yes	0,00139	0,0225	0,06	0,95	0,227	0,199	1,14	0,26
No[1]	-0,0331	0,0222	-1,49	0,14	**-0,801**	0,197	-4,07	0*
Internet access mobile phone								
Yes	2,05E-17	5,98E+05	0	1	0,016	0,0606	0,26	0,79
No	**-0,0276**	0,00641	-4,31	0*	**-0,588**	0,0512	-11,49	0*
Internet usage mobile phone								
One or several times per day	-0,00345	0,0101	-0,34	0,73	0,141	0,0882	1,6	0,11
A few times per week	-0,0201	0,0146	-1,38	0,17	-0,226	0,131	-1,72	0,09
1 time per week or less	**-0,0285**	0,00867	-3,29	0*	**-0,623**	0,0757	-8,23	0*
Reisplanner usage mobile phone								
Yes	-0,00185	0,00833	-0,22	0,82	0,0115	0,0726	0,16	0,87
No	**-0,0325**	0,00577	-5,64	0*	**-0,581**	0,051	-11,41	0*

*Significant values are marked in green and with a * ($p < 0.05$)*

[1] = *N < 30*

Socio-demographic variable	Frequency				Frequency2			
	Value	St error	t-test	p-value	Value	St error	t-test	p-value
Gender								
Male	-0,00806	0,197	-0,04	0,97	0,000919	0,0212	0,04	0,97
Female	**0,363**	0,145	2,5	0,01*	-0,0275	0,0157	-1,75	0,08
Age								
80+	-0,0652	0,322	-0,2	0,84	0,00945	0,0346	0,27	0,78
75-79	-0,00106	0,258	0	1	0,000292	0,0278	0,01	0,99
70-74	0,0948	0,266	0,36	0,72	-0,00605	0,0285	-0,21	0,83
65-69	0,349	0,188	1,86	0,06	-0,0273	0,0202	-1,36	0,18
Household situation								
Together with children living at home or somewhere else	0,349	0,273	1,28	0,2	-0,0332	0,0294	-1,13	0,26
Together without children	0,156	0,28	0,56	0,58	-0,0122	0,0302	-0,41	0,68
Single with children living at home or somewhere else	0,101	0,323	0,31	0,75	-0,00824	0,0348	-0,24	0,81
Single without children	0,186	0,213	0,87	0,38	-0,0115	0,023	-0,5	0,62
Income (Bruto)								
40,000 or more	0,515	0,772	0,67	0,5	-0,0624	0,0827	-0,75	0,45
30,000 - 40,000 euro	0,508	0,786	0,65	0,52	-0,0658	0,0842	-0,78	0,43
20,000 - 30,000 euro	0,347	0,781	0,44	0,66	-0,0478	0,0837	-0,57	0,57
less than 20,000	-0,111	0,755	-0,15	0,88	0,0322	0,0808	0,4	0,69
Walking tool								
Yes	-0,223	0,239	-0,94	0,35	0,0212	0,0258	0,82	0,41
No	**0,412**	0,111	3,71	0*	**-0,032**	0,0119	-2,68	0,01*
Physically able to cycle								
Yes	-0,113	0,239	-0,47	0,64	0,0118	0,0258	0,46	0,65
No	**0,456**	0,212	2,16	0,03*	-0,037	0,0228	-1,62	0,11
Cycle usage								
Yes	-0,447	0,354	-1,26	0,21	0,0428	0,0379	1,13	0,26
No1	**0,739**	0,333	2,22	0,03*	-0,063	0,0357	-1,77	0,08
Car ownership								
Yes	0,0734	0,246	0,3	0,77	-0,0104	0,0265	-0,39	0,69
No	0,3	0,221	1,36	0,17	-0,0187	0,0237	-0,79	0,43
Driving license								
Yes	-0,248	0,259	-0,96	0,34	0,0197	0,0277	0,71	0,48
No	**0,568**	0,236	2,41	0,02*	-0,0436	0,0251	-1,74	0,08
Taken to or from destination by friends/family sometimes								
Yes	0,179	0,197	0,91	0,36	-0,0159	0,0212	-0,75	0,45
No	**0,279**	0,132	2,12	0,03*	-0,0199	0,0142	-1,4	0,16
Valys usage								
Yes1	0,1	0,342	0,29	0,77	-0,00958	0,0371	-0,26	0,8
No	**0,35**	0,103	3,4	0*	**-0,0262**	0,0111	-2,37	0,02*
Bus usage								
1 day per week or more	0,185	0,33	0,56	0,58	-0,0128	0,0353	-0,36	0,72
1-3 days per month	4,18E-05	0,259	0	1	0,00108	0,028	0,04	0,97
6-11 days per year	-0,102	0,269	-0,38	0,7	0,0146	0,029	0,51	0,61
5 days or less per year	3,23E-16	7,02E+04	0	1	0,00268	0,00235	1,14	0,25
Never	**0,366**	0,137	2,67	0,01*	**-0,03**	0,0148	-2,03	0,04*
Public transport subscription/ticket								
Yes, including 65+ discount	0,123	0,219	0,56	0,57	-0,00955	0,0236	-0,41	0,69
Yes, without discount or other discount	0,127	0,289	0,44	0,66	-0,0103	0,031	-0,33	0,74
No	**0,301**	0,135	2,23	0,03*	-0,0225	0,0145	-1,55	0,12
Able to get to nearest bus stop without help								
Yes	-0,376	0,401	-0,94	0,35	0,0348	0,043	0,81	0,42
No1	0,715	0,387	1,85	0,06	-0,06	0,0416	-1,44	0,15
Distance to nearest bus stop								
600 meters or more	0,197	0,312	0,63	0,53	-0,0226	0,0335	-0,68	0,5
400 - 600 meters	0,356	0,267	1,34	0,18	-0,0422	0,0288	-1,47	0,14
200 - 400 meters	-0,0662	0,254	-0,26	0,79	0,00383	0,0273	0,14	0,89
0 - 200 meters	0,268	0,165	1,62	0,1	-0,0153	0,0178	-0,86	0,39
Minutes to nearest bus stop								
6 minutes or more	0,213	0,302	0,71	0,48	-0,0263	0,0326	-0,81	0,42
4-6 minutes	0,337	0,276	1,22	0,22	-0,0364	0,0297	-1,23	0,22
2-4 minutes	0,264	0,281	0,94	0,35	-0,0296	0,0303	-0,98	0,33
0-2 minutes	0,151	0,204	0,74	0,46	-0,00338	0,022	-0,15	0,88
Mobile phone posession								
Yes	-0,637	0,612	-1,04	0,3	0,0635	0,0657	0,97	0,33
No1	0,977	0,604	1,62	0,11	-0,0886	0,0648	-1,37	0,17
Internet access mobile phone								
Yes	0,155	0,219	0,71	0,48	-0,0141	0,0236	-0,6	0,55
No	0,229	0,186	1,23	0,22	-0,015	0,0199	-0,75	0,45
Internet usage mobile phone								
One or several times per day	-0,113	0,29	-0,39	0,7	0,0132	0,0312	0,42	0,67
A few times per week	0,22	0,377	0,58	0,56	-0,0212	0,0403	-0,53	0,6
1 time per week or less	0,42	0,246	1,71	0,09	-0,0338	0,0265	-1,28	0,2
Reisplanner usage mobile phone								
Yes	-0,257	0,236	-1,09	0,28	0,0317	0,0254	1,25	0,21
No	**0,517**	0,168	3,08	0*	**-0,0455**	0,0181	-2,51	0,01*

*Significant values are marked in green and with a * ($p < 0.05$)*

[1] = N < 30

Socio-demographic variable	Transfers Value	St error	t-test	p-value	Distance to busstop Value	St error	t-test	p-value
Gender								
Male	**0,245**	0,105	2,34	0,02*	-5,06E-05	0,000319	-0,16	0,87
Female	**-0,498**	0,0772	-6,45	0*	**-0,00112**	0,000233	-4,81	0*
Age								
80+	0,112	0,173	0,65	0,52	2,32E-05	0,000526	0,04	0,96
75-79	0,0406	0,139	0,29	0,77	-0,000172	0,000417	-0,41	0,68
70-74	-0,269	0,144	-1,87	0,06	0,00019	0,000433	0,44	0,66
65-69	**-0,322**	0,104	-3,09	0*	**-0,00116**	0,000304	-3,82	0*
Household situation								
Together with children living at home or somewhere else	-0,0652	0,146	-0,45	0,66	-0,000319	0,000438	-0,73	0,47
Together without children	-0,0758	0,149	-0,51	0,61	0,000132	0,000448	0,29	0,77
Single with children living at home or somewhere else	-0,15	0,171	-0,88	0,38	-0,000391	0,000523	-0,75	0,46
Single without children	**-0,299**	0,114	-2,62	0,01*	**-0,00103**	0,000339	-3,05	0*
Income (Bruto)								
40,000 or more	0,101	0,378	0,27	0,79	9,31E-05	0,00143	0,06	0,95
30,000 - 40,000 euro	-0,24	0,386	-0,62	0,53	-0,000164	0,00145	-0,11	0,91
20,000 - 30,000 euro	-0,103	0,383	-0,27	0,79	0,000266	0,00144	0,18	0,85
less than 20,000	-0,303	0,367	-0,82	0,41	-0,00123	0,00141	-0,87	0,38
Walking tool								
Yes	0,138	0,124	1,11	0,27	-0,000226	0,000384	-0,59	0,56
No	**-0,399**	0,0593	-6,72	0*	**-0,0011**	0,000181	-6,08	0*
Physically able to cycle								
Yes	0,0214	0,121	0,18	0,86	0,00063	0,000389	1,62	0,11
No	**-0,391**	0,107	-3,66	0*	**-0,00164**	0,000344	-4,78	0*
Cycle usage								
Yes	-0,0674	0,189	-0,36	0,72	-0,000556	0,000565	-0,98	0,33
No1	**-0,31**	0,178	-1,74	0,08	-0,000524	0,000531	-0,99	0,32
Car ownership								
Yes	0,16	0,134	1,19	0,23	6,62E-05	0,000396	0,17	0,87
No	**-0,494**	0,121	-4,09	0*	**-0,0012**	0,000354	-3,39	0*
Driving license								
Yes	0,12	0,143	0,84	0,4	0,000203	0,000431	0,47	0,64
No	**-0,467**	0,132	-3,55	0*	**-0,00133**	0,000395	-3,36	0*
Taken to or from destination by friends/family sometimes								
Yes	0,0115	0,105	0,11	0,91	-4,62E-05	0,000321	-0,14	0,89
No	**-0,369**	0,0698	-5,29	0*	**-0,00113**	0,000213	-5,31	0*
Valys usage								
Yes1	-0,01	0,184	-0,05	0,96	0,000406	0,000531	0,76	0,44
No	**-0,364**	0,0545	-6,68	0*	**-0,00118**	0,000168	-7,03	0*
Bus usage								
1 day per week or more	-0,0549	0,181	-0,3	0,76	-0,000193	0,000603	-0,32	0,75
1-3 days per month	-0,017	0,138	-0,12	0,9	0,000662	0,00047	1,41	0,16
6-11 days per year	-0,119	0,141	-0,84	0,4	0,000418	0,000498	0,84	0,4
5 days or less per year	4,43E-17	1,16E+05	0	1	**0,000798**	0,000384	2,08	0,04*
Never	**-0,338**	0,0731	-4,62	0*	**-0,00159**	0,000319	-4,98	0*
Public transport subscription/ticket								
Yes, including 65+ discount	-0,0972	0,117	-0,83	0,41	-0,000109	0,000356	-0,31	0,76
Yes, without discount or other discount	-0,163	0,148	-1,1	0,27	-0,000288	0,000474	-0,61	0,54
No	**-0,309**	0,0712	-4,34	0*	**-0,00107**	0,000218	-4,92	0*
Able to get to nearest bus stop without help								
Yes	-0,321	0,198	-1,62	0,11	-0,321	0,198	-1,62	0,11
No1	-0,0692	0,191	-0,36	0,72	**-0,00181**	0,00068	-2,66	0,01*
Distance to nearest bus stop								
600 meters or more	-0,0174	0,165	-0,11	0,92	-0,000523	0,000528	-0,99	0,32
400 - 600 meters	0,122	0,14	0,87	0,38	0,000502	0,000426	1,18	0,24
200 - 400 meters	0,0649	0,135	0,48	0,63	0,00033	0,000411	0,8	0,42
0 - 200 meters	**-0,413**	0,0888	-4,65	0*	**-0,00127**	0,000266	-4,79	0*
Minutes to nearest bus stop								
6 minutes or more	-0,12	0,16	-0,75	0,45	-0,000333	0,000478	-0,7	0,49
4-6 minutes	-0,0529	0,147	-0,36	0,72	-2,28E-05	0,000452	-0,05	0,96
2-4 minutes	-0,216	0,152	-1,42	0,15	-0,00034	0,000449	-0,76	0,45
0-2 minutes	**-0,278**	0,11	-2,53	0,01*	**-0,000984**	0,000325	-3,03	0*
Mobile phone posession								
Yes	0,0922	0,359	0,26	0,8	-0,000242	0,000919	-0,26	0,79
No1	-0,454	0,355	-1,28	0,2	-0,000909	0,000905	-1	0,31
Internet access mobile phone								
Yes	0,0982	0,0887	1,11	0,27	0,000106	0,000357	0,3	0,77
No	**-0,433**	0,0768	-5,64	0*	**-0,00123**	0,0003	-4,11	0*
Internet usage mobile phone								
One or several times per day	0,0516	0,155	0,33	0,74	0,000391	0,000475	0,82	0,41
A few times per week	-0,0482	0,204	-0,24	0,81	-5,40E-05	0,000633	-0,09	0,93
1 time per week or less	**-0,363**	0,133	-2,74	0,01*	**-0,00137**	0,000406	-3,36	0*
Reisplanner usage mobile phone								
Yes	0,107	0,125	0,85	0,39	0,000575	0,000387	1,48	0,14
No	**-0,391**	0,0898	-4,35	0*	**-0,00143**	0,000271	-5,27	0*

*Significant values are marked in green and with a * ($p < 0.05$)*

[1] = N < 30

G.3.3. Summary statistics MNL models with interaction effects

Table G.3: MNL interactions models Null LL, Final LL, R^2 and Adjusted R^2

MNL	df	Null LL	Final LL	R	Adjusted R^2
Base MNL with quadratic frequency	6	-2129,348	-1792,918	0,158	0,155
Gender	13	-2129,348	-1787,098	0,161	0,155
Age	27	-2129,348	-1773,142	0,167	0,155
Household situation	27	-2130,041	-1785,162	0,162	0,149
Income (Bruto)	27	-1705,142	-1421,415	0,166	0,151
Walking tool	13	-2129,348	-1785,163	0,162	0,156
Physically able to cycle	13	-2129,348	-1775,013	0,166	0,16
Cycle usage	13	-1688,507	-1382,537	0,181	0,174
Car ownership	13	-2129,348	-1789,648	0,16	0,153
Driving license	13	-2129,348	-1785,075	0,162	0,156
Taken to/from destination by friends/family sometimes	13	-2129,348	-1789,863	0,159	0,153
Valys usage	13	-2129,348	-1790,371	0,159	0,153
Bus usage	34	-2130,041	-1782,093	0,163	0,147
Public transport substricption/ticket	20	-2130,041	-1789,383	0,16	0,151
Able to get to nearest bus stop without help	13	-2129,348	-1781,363	0,163	0,157
Distance to nearest bus stop	27	-2079,442	-1739,549	0,163	0,15
Minutes to nearest bus stop	27	-2071,124	-1726,651	0,166	0,153
Mobile phone posession	13	-2129,348	-1790,184	0,159	0,153
Internet access mobile phone	13	-2062,806	-1737,069	0,158	0,152
Internet usage mobile phone	20	-1480,562	-1234,639	0,166	0,153
Reisplanner usage mobile phone	13	-1480,562	-1239,771	0,163	0,154

G.4. Latent Class Choice model

G.4.1. Biogeme syntax LC choice model with 4 classes

Figure G.1: LC 4 class choice model biogem syntax

```
from biogeme import *
from headers import *
from loglikelihood import *
from statistics import *

# Parameters to be estimated
# Parameters Class 1 RUM
BETA_TT_1       = Beta('BETA_TT_1',0,-100,100,0)
BETA_TC_1       = Beta('BETA_TC_1',0,-100,100,0)
BETA_FREQ_1     = Beta('BETA_FREQ_1',0,-100,100,0)
BETA_TF_1       = Beta('BETA_TF_1',0,-100,100,0)
BETA_SD_1       = Beta('BETA_SD_1',0,-100,100,0)

# Parameters Class 2 RUM
BETA_TT_2       = Beta('BETA_TT_2',0,-100,100,0)
BETA_TC_2       = Beta('BETA_TC_2',0,-100,100,0)
BETA_FREQ_2     = Beta('BETA_FREQ_2',0,-100,100,0)
BETA_TF_2       = Beta('BETA_TF_2',0,-100,100,0)
BETA_SD_2       = Beta('BETA_SD_2',0,-100,100,0)

# Parameters Class 3 RUM
BETA_TT_3       = Beta('BETA_TT_3',0,-100,100,0)
BETA_TC_3       = Beta('BETA_TC_3',0,-100,100,0)
BETA_FREQ_3     = Beta('BETA_FREQ_3',0,-100,100,0)
BETA_TF_3       = Beta('BETA_TF_3',0,-100,100,0)
BETA_SD_3       = Beta('BETA_SD_3',0,-100,100,0)

# Parameters Class 4 RUM
BETA_TT_4       = Beta('BETA_TT_4',0,-100,100,0)
BETA_TC_4       = Beta('BETA_TC_4',0,-100,100,0)
BETA_FREQ_4     = Beta('BETA_FREQ_4',0,-100,100,0)
BETA_TF_4       = Beta('BETA_TF_4',0,-100,100,0)
BETA_SD_4       = Beta('BETA_SD_4',0,-100,100,0)

# Class membership parameters
delta_s1 = Beta('delta_s1',0,-100,100,1)
delta_s2 = Beta('delta_s2',0,-100,100,0)
delta_s3 = Beta('delta_s3',0,-100,100,0)
delta_s4 = Beta('delta_s4',0,-100,100,0)
B_ABLECYCLE2 = Beta('B_ABLECYCLE2',0,-100,100,0)
B_ABLECYCLE3 = Beta('B_ABLECYCLE3',0,-100,100,0)
B_ABLECYCLE4 = Beta('B_ABLECYCLE4',0,-100,100,0)
```

```
# Class specific models
# Class 1 (RUM-MNL)
V1_1 = TTA * BETA_TT_1 + TCA * BETA_TC_1 + FREQA * BETA_FREQ_1 + TFA * BETA_TF_1 + SDA * BETA_SD_1
V2_1 = TTB * BETA_TT_1 + TCB * BETA_TC_1 + FREQB * BETA_FREQ_1 + TFB * BETA_TF_1 + SDB * BETA_SD_1

# Class 2 (RUM-MNL)
V1_2 = TTA * BETA_TT_2 + TCA * BETA_TC_2 + FREQA * BETA_FREQ_2 + TFA * BETA_TF_2 + SDA * BETA_SD_2
V2_2 = TTB * BETA_TT_2 + TCB * BETA_TC_2 + FREQB * BETA_FREQ_2 + TFB * BETA_TF_2 + SDB * BETA_SD_2

# Class 3 (RUM-MNL)
V1_3 = TTA * BETA_TT_3 + TCA * BETA_TC_3 + FREQA * BETA_FREQ_3 + TFA * BETA_TF_3 + SDA * BETA_SD_3
V2_3 = TTB * BETA_TT_3 + TCB * BETA_TC_3 + FREQB * BETA_FREQ_3 + TFB * BETA_TF_3 + SDB * BETA_SD_3

# Class 4 (RUM-MNL)
V1_4 = TTA * BETA_TT_4 + TCA * BETA_TC_4 + FREQA * BETA_FREQ_4 + TFA * BETA_TF_4 + SDA * BETA_SD_4
V2_4 = TTB * BETA_TT_4 + TCB * BETA_TC_4 + FREQB * BETA_FREQ_4 + TFB * BETA_TF_4 + SDB * BETA_SD_4

# Associate utility functions with the numbering of alternatives
V1 = {1: V1_1,
    2: V2_1}

V2 = {1: V1_2,
    2: V2_2}

V3 = {1: V1_3,
    2: V2_3}

V4 = {1: V1_4,
    2: V2_4}

# Associate the availability conditions with the alternatives
one = DefineVariable('one',1)

av = {1: one,
    2: one}

# Class membership model
utilClass1 = delta_s1
utilClass2 = delta_s2 + B_ABLECYCLE2 * (Sum(ABLECYCLE,'panelObsIter'))/Sum(1,'panelObsIter')
utilClass3 = delta_s3 + B_ABLECYCLE3 * (Sum(ABLECYCLE,'panelObsIter'))/Sum(1,'panelObsIter')
utilClass4 = delta_s4 + B_ABLECYCLE4 * (Sum(ABLECYCLE,'panelObsIter'))/Sum(1,'panelObsIter')

probClass1 = exp(utilClass1) / (exp(utilClass1) + exp(utilClass2) + exp(utilClass3) + exp(utilClass4))
probClass2 = exp(utilClass2) / (exp(utilClass1) + exp(utilClass2) + exp(utilClass3) + exp(utilClass4))
probClass3 = exp(utilClass3) / (exp(utilClass1) + exp(utilClass2) + exp(utilClass3) + exp(utilClass4))
probClass4 = exp(utilClass4) / (exp(utilClass1) + exp(utilClass2) + exp(utilClass3) + exp(utilClass4))



# The choice model is a logit, with availability conditions
prob1 = bioLogit(V1,av,CHOICE)
prob2 = bioLogit(V2,av,CHOICE)
prob3 = bioLogit(V3,av,CHOICE)
prob4 = bioLogit(V4,av,CHOICE)

#Conditional probability for the sequence of choices of an individual
ProbIndiv_1 = Prod(prob1,'panelObsIter')
ProbIndiv_2 = Prod(prob2,'panelObsIter')
ProbIndiv_3 = Prod(prob3,'panelObsIter')
ProbIndiv_4 = Prod(prob4,'panelObsIter')

# Iterator on individuals, that is on groups of rows.
metaIterator('personIter','__dataFile__','panelObsIter','ID')

# For each item of personIter, iterates on the rows of the group.
rowIterator('panelObsIter','personIter')

# Define the likelihood function for the estimation
BIOGEME_OBJECT.ESTIMATE = Sum(log(probClass1 * ProbIndiv_1 + probClass2 * ProbIndiv_2 + probClass3 * ProbIndiv_3 + probClass4 * ProbIndiv_4),'personIter')

# Statistics
BIOGEME_OBJECT.PARAMETERS['optimizationAlgorithm'] = "CFSQP"
BIOGEME_OBJECT.PARAMETERS['numberOfThreads'] = "1"
```

G.4.2. Summary statistics LC choice model with four classes including 'able to cycle'

Estimation report

Number of estimated parameters: 26
Sample size: 3072
Excluded observations: 0
Init log likelihood: -2129.348
Final log likelihood: -1578.492
Likelihood ratio test for the init. model: 1101.712
Rho-square for the init. model: 0.259
Rho-square-bar for the init. model: 0.246
Akaike Information Criterion: 3208.984
Bayesian Information Criterion: 3365.766
Final gradient norm: +5.350e-003
Diagnostic: CFSQP: Normal termination. Obj: 6.05545e-006 Const: 6.05545e-006
Iterations: 69
Data processing time: 00:00
Run time: 00:55
Nbr of threads: 1

Table G.4: Results Latent Class Choice model with 4 classes and personal characteristic 'Able to cycle'

Parameter	Name	Value	Std err	t-test	p-value
Frequency	BETA_FREQ_1	0,0355	0,0417	0,85	0,39
	BETA_FREQ_2	0,324	0,0359	9,03	0,00*
	BETA_FREQ_3	0,0507	0,0188	2,69	0,01*
	BETA_FREQ_4	0,211	0,0343	6,14	0,00*
Distance to stop	BETA_SD_1	-0,0025	0,0010	-2,44	0,01*
	BETA_SD_2	0,0003	0,0004	0,75	0,45
	BETA_SD_3	-0,0031	0,0003	-9,14	0,00*
	BETA_SD_4	-0,0006	0,0004	-1,49	0,14
Travel cost	BETA_TC_1	-1,90	0,289	-6,57	0,00*
	BETA_TC_2	-0,498	0,0863	-5,77	0,00*
	BETA_TC_3	-0,271	0,0685	-3,96	0,00*
	BETA_TC_4	-0,92	0,146	-6,31	0,00*
Transfers	BETA_TF_1	-0,345	0,167	-2,07	0,04*
	BETA_TF_2	0,251	0,116	2,16	0,03*
	BETA_TF_3	-0,968	0,108	-8,98	0,00*
	BETA_TF_4	-0,637	0,188	-3,39	0,00*
Travel time	BETA_TT_1	-0,027	0,0145	-1,82	0,07
	BETA_TT_2	0,004	0,009	0,45	0,65
	BETA_TT_3	-0,009	0,0063	-1,46	0,15
	BETA_TT_4	-0,127	0,0177	-7,16	0,00*
Class membership parameter	delta_s2	1,69	0,45	3,75	0,00*
	delta_s3	1,80	0,438	4,10	0,00*
	delta_s4	0,408	0,685	0,60	0,55
Able to cycle	B_ABLECYCLE2	-1,12	0,488	-2,3	0,02*
	B_ABLECYCLE3	-1,29	0,482	-2,68	0,01*
	B_ABLECYCLE4	0,392	0,69	0,57	0,57

*Significant values are marked in green and with a * ($p < 0.05$)*

G.5. Model estimations without non-bus users

G.5.1. Results MNL model without non-bus users

Parameter	Value	Robust Std err	Robust t-test	p-value
β_{FREQl}	0.354	0.112	3.17	0.00*
β_{FREQq}	-0.0258	0.0120	-2.15	0.03*
β_{SD}	-0.00104	0.000183	-5.68	0.00*
β_{TC}	-0.597	0.0346	-17.25	0.00*
β_{TF}	-0.346	0.0592	-5.85	0.00*
β_{TT}	-0.0322	0.00398	-8.08	0.00*

G.5.2. Summary statistics MNL model without non-bus users

Estimation report

Number of estimated parameters: 23
Sample size: 2400
Excluded observations: 0
Init log likelihood: -1663.553
Final log likelihood: -1236.772
Likelihood ratio test for the init. model: 853.563
Rho-square for the init. model: 0.257
Rho-square-bar for the init. model: 0.243
Akaike Information Criterion: 2519.544
Bayesian Information Criterion: 2652.558
Final gradient norm: +1.099e-002
Diagnostic: CFSQP: Normal termination. Obj: 6.05545e-006 Const: 6.05545e-006
Iterations: 88
Data processing time: 00:00
Run time: 00:12
Nbr of threads: 1

Estimated parameters

G.5.3. Results LC choice model without non-bus users

Parameter	Name	Value	Std err	t-test	p-value
Frequency	BETA_FREQ_1	0,352	0,0424	8,3	0,00*
	BETA_FREQ_2	0,0551	0,0242	2,28	0,02*
	BETA_FREQ_3	0,2	0,0322	6,2	0,00*
	BETA_FREQ_4	0,0323	0,0385	0,84	0,40
Distance to stop	BETA_SD_1	8,24E-05	0,000482	0,17	0,86
	BETA_SD_2	-0,00285	0,000394	-7,23	0,00*
	BETA_SD_3	-0,000654	0,000422	-1,55	0,12
	BETA_SD_4	-0,00224	0,000906	-2,48	0,01*
Travel cost	BETA_TC_1	-0,489	0,0995	-4,92	0,00*
	BETA_TC_2	-0,259	0,083	-3,13	0,00*
	BETA_TC_3	-0,946	0,136	-6,94	0,00*
	BETA_TC_4	-1,81	0,267	-6,79	0,00*
Transfers	BETA_TF_1	0,19	0,146	1,3	0,19
	BETA_TF_2	-1,08	0,132	-8,19	0,00*
	BETA_TF_3	-0,434	0,172	-2,53	0,01*
	BETA_TF_4	-0,297	0,177	-1,68	0,09
Travel time	BETA_TT_1	0,0118	0,011	1,07	0,28
	BETA_TT_2	-0,0144	0,0081	-1,77	0,08
	BETA_TT_3	-0,114	0,0149	-7,64	0,00*
	BETA_TT_4	-0,0138	0,0144	0,95	0,34
Class membership parameter	delta_s2	0,896	0,266	3,37	0,00*
	delta_s3	1,21	0,264	4,58	0,00*
	delta_s4	1,18	0,256	4,63	0,00*

*Significant values are marked in green and with a * ($p < 0.05$)*

H

Data analyses Groningen

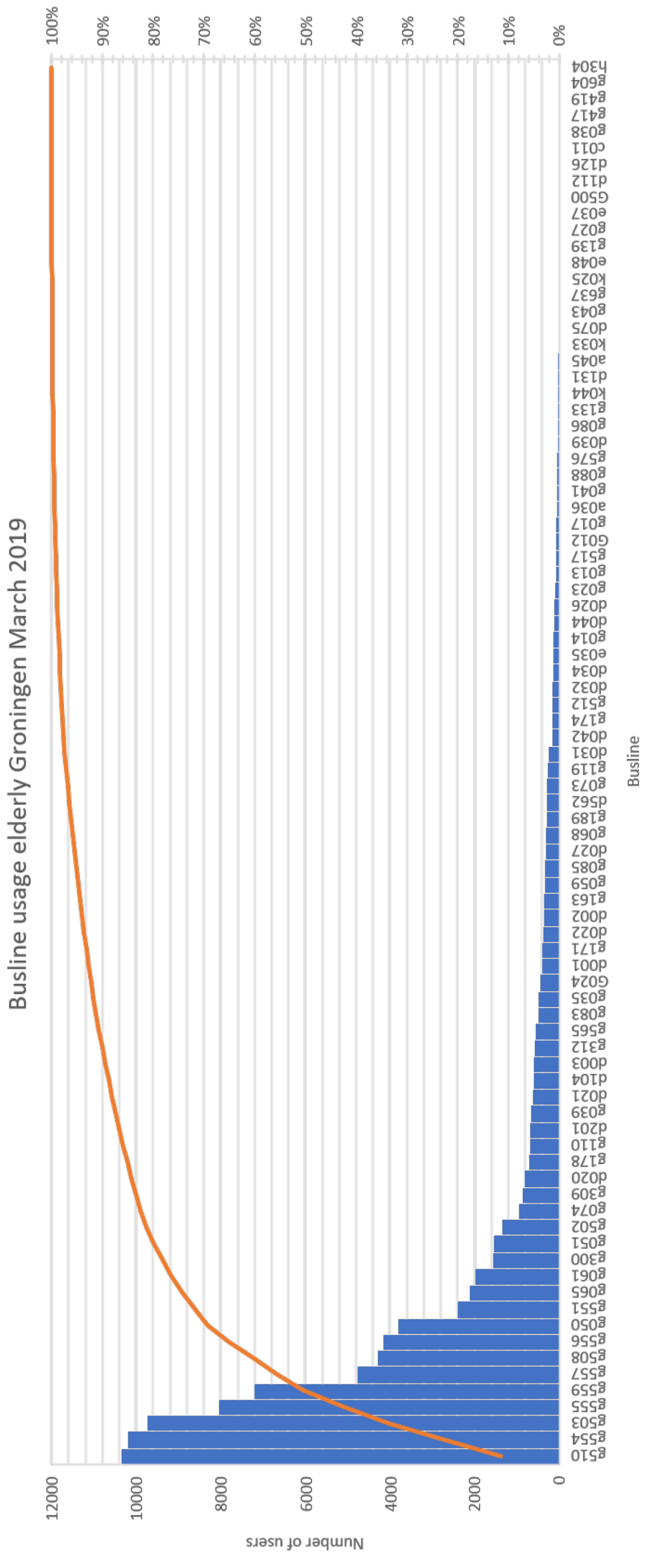


Figure H.1: Busline usage elderly Groningen march 2019

Table H.1: Usage of Q-link and city buses in Groningen, March 2019

Busline		boardings (% of total)
Q-link	1	2,66%
	2	1,50%
	3	10,76%
	4	11,27%
	5	8,89%
	6	4,60%
	15	0,63%
	100	0,01%
Q-link total		40,32%
City service	7	5,27%
	8	4,75%
	9	7,99%
	10	11,44%
	12	0,18%
	17	0,09%
	26	0,05%
	27	0,01%
City service total		29,80%

Table H.2: Bus stops with relatively high number of check-ins by elderly (number of check-ins by elderly relative to number of check-ins by bus users in total)

Bus stop	Total people boarding in 2018	Elderly boarding march 2019	Elderly boarding year 2019	Elderly boarding 2019 / Total people boarding 2018
Groningen, W. Dreesstraat	11114	362	4344	39,1%
Groningen, Palmelaan	25712	562	6744	26,2%
Groningen, Groenestein	12461	242	2904	23,3%
Groningen, Curacaostraat	14209	271	3252	22,9%
Groningen, C.Jetsesstraat	12589	235	2820	22,4%
Groningen, Siersteenlaan	19101	317	3804	19,9%
Groningen, J. van Goyenstraat	16553	268	3216	19,4%
Haren, Raadhuisplein	30852	476	5712	18,5%
Groningen, Overwinningsplein	55274	840	10080	18,2%
Emmen, Centrum	27921	419	5028	18,0%
Groningen, MartiniZKH Hoofdingang	100209	1290	15480	15,4%