UTRECHT UNIVERSITY

EXPLORING ELDERLY MOBILITY IN THE GREATER ROTTERDAM AREA:

ASSESSING THE INFLUENCE OF PERSONAL CHARACTERISTICS AND WEATHER CONDITIONS ON MODE CHOICE & THE NUMBER OF TRIPS.

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Images: BNR (2011), Echt voor Barendrecht (2014), Helmich Rigter (2014) & Drivers of change (2006).

Exploring elderly mobility in the greater Rotterdam area:

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Preface

In order to be able to conclude the Urban Geography master's programme at Utrecht University's faculty of Geosciences, I've been doing research on mobility patterns of the elderly during the past few months. Focus of the study were the elderly living within the greater Rotterdam area (also known as Rotterdam-Rijnmond) and factors that might influence their mobility characteristics, in this case their actual mode choice and number of trips. This has been done not just to diagnose the mobility of the elderly within the study area, it is more about gaining a deeper insight in how personal, household characteristics and weather conditions might influence elderly mobility behavior.

While there have clearly been moments of ups and downs while doing this research -not just for me but also -and perhaps especially- for people close to me, I can definitely say that I can look back at the research process and be very satisfied. I feel like the research process is a major contribution to my academic knowledge, gaining important insights concerning how to keep a good overview of the research process for example.

Therefore, I would like to thank a number of people. Of course, the first person I would like to thank is my thesis supervisor M. Helbich. Without his guidance, doing this research would have been a lot more difficult, as at some moments it was necessary to convince me to be less broad. The second person I would like to thank is L. Böcker for giving access to the dataset(s) as well as a good explanation of its structure. Of course I would also like to thank my family, friends, colleagues and fellow students for their support during the research process. Finally, I would also like to thank all the elderly respondents living within the greater Rotterdam area who decided to participate in the survey and the administration of the travel diaries.

P.A.M. van Amen
July 2014

Summary

The aging society caused by the demographic transition has a number of important consequences for mobility. Although there has been a lot of research to the mobility of the elderly, very little is known about the effect of weather conditions on mobility of the elderly; therefore (next to personal and household characteristics) this research adapted a more specific focus on weather conditions (temperature, precipitation, wind and snow cover). The aim of this research is to provide insights into the mobility of the elderly mobility by elaborating upon the following research question:

'Which personal and weather related factors significantly influence the number of trips and mode choice of the elderly within the greater Rotterdam area, and to what extent?'

Literature suggests that age, gender, education, employment status, household income, ethnicity and car availability are able to influence elderly mobility characteristics. Some of the literature also explored the influence on trip characteristics (such as trip motive and trip distance) on mode choice and the number of trips. Others focused on the influence of the built environment such as residential environment, diversity (land use and building use), density and access to transport. Also temperature, precipitation and wind speeds might all affect mobility characteristics.

A combination of different datasets was used (personal and household characteristics, travel diaries, built environment statistics and weather conditions) from 147 elderly respondents by the means of a number of Chi-square tests, T-tests and two regression models (multinomial logistic regression for mode choice and zero-inflated negative binomial regression for the number of trips). Unfortunately, the sample did not appear to be representative for the greater Rotterdam area, therefore the results from the statistical analysis could only relate to the sample of elderly respondents.

Concerning mode choice, car ownership and being male appeared to have a negative effect on the use of other transport modes compared to the car. Educational attainment seemed to have a negative effect, but only on public transport use, while income seemed to have mixed effects. Native Dutch elderly were more likely to choose for the bicycle over the car than their non-western counterparts. Not having a public transport card had significant negative effects on using transport modes other than the car, while not owning a bicycle only had a significant negative effect on bicycle use in favor of the car. No significant effects were found for age and employment status. For the number of trips, significant effects were found for the variables age (negative), bicycle availability (positive) and owning a public transport card (positive). Results also indicated that males appeared to make significantly more trips, tended to be more reliant on the car than females (who walk more often) and that people older than 75 make significantly less trips than people aged 65-76 (and use public transport more often). Concerning weather conditions, results indicate significant negative effects of wind speed on the use of all transport modes other than the car, significant positive effects of the daily air temperature on cycling compared to the car, and significant negative effects for precipitation sum on the number of trips.

Despite these results, there are a number of remarks. Next to the sample not being representative, it was unknown whether the respondents had a driver's license, making it impossible to include this variable. Secondly, it was not possible to do justice to this diversity of the elderly (compare groups with the same lifestyles or health for example). Thirdly, the explained variance for the number of trips remained relatively low, indicating the importance of other variables. Next to addressing these shortcomings, future research could focus on using more accurate data collection methods, and compare different trip motives. Concerning the effect of weather conditions, it might be interesting idea to add respondents weather expectations and weather conditions at the hourly level.

Table of contents

1. Introduction

1.1 Problem indication, scope and relevance

Problem indication

“The population of elderly adults is a growing one; life expectancy continues to increase. [..] In 1986, there were 29.2 million residents of the United States who were 65 or more years old and 2.8 million residents who were 85 or more years old. If projected conservatively, these numbers will grow to 52 million and 6.7 million by the year 2020.” (Schultz, 1992, pp. 1). Although this quote focusses on the situation in the United States, the trend of increasing life expectancy is a global phenomenon (World Health Organization, 2014). Also in the Netherlands it is expected that by the year of 2020, roughly 20% of the entire population will be of the age of 65 and above (Jorritsma & Olde Kalter, 2008).

In this context it is important to ask ourselves the question what this means for the behavior concerning mobility of the elderly (Alsnih & Hensher, 2003; Currie & Delbosc, 2009; Mercado et al, 2010; Metz, 2012) and how this will impact the quality of life for this age group (Banister & Bowling, 2004; Delbosc & Currie, 2011; Jorritsma & Olde Kalter, 2008; Metz, 2000; Schultz, 1992). Research done in the Netherlands seems to suggest that activity patterns of the Elderly (in the Netherlands at least) increasingly occur in areas other than the domestic location (which in itself is also different than for example years ago) and at different times of the day (increasingly after 10:00 AM), resulting in an additional growth of the total mobility of almost three per cent (Jorritsma & Olde Kalter, 2008).

In the past few years, there has been a discussion on the use of automobiles by the elderly (Robertson & Vanlaar, 2008) as driving a car at older age might cause certain problems to arise (increased crash rates for example). The loss of the ability to drive and the increasing focus on public transport and transit-oriented developments (TOD’s) in order to reduce CO_2 emissions which can help combat global warming can also influence the mobility of the elderly (Boschmann & Brady, 2013), as the use of public transport might prove to be problematic (Deseret News, 2006).

Therefore, the accommodation of the total growth of mobility as well as the before mentioned dimension of travel behavior and the impact of mobility on quality of life of the elderly will be very important in the coming years. “Will they be years of freedom and personal fulfillment or years of confinement and dependence? Maintenance of mobility is central to this issue.” (Schultz, 1992, pp. 1).

Scope

While the issues discussed above are increasingly a global issue, this research project will focus on the mobility of the elderly (people aged 65 and older) in the greater Rotterdam area (also known as Rotterdam Rijnmond), which also comprises other municipalities such as Schiedam and Vlaardingen. An important reason why the greater Rotterdam area was chosen is because the study area counted 1,221,746 inhabitants at the start of 2014 (Centraal bureau voor de statistiek, 2014) and therefore is the largest city region when looking at the total number of inhabitants. In addition, the province of south-Holland (in which the greater Rotterdam area is located) has to cope with an increasing amount of elderly, and a shrinking amount of younger people (Provincie Zuid-Holland, 2007). Next to some other characteristics of the greater Rotterdam area which make the region a suitable study area (see research methodology), this research is related to other research done in the area regarding mobility, modes of travel and the way this relates to weather and factors such as the built environment. These factors, in combination with the trends discussed above show why the choice for this research area is relevant.

Relevance

The trend of increasing life expectancy and its consequences for both transport choice/behavior discussed above illustrate why it is becoming increasingly relevant to society to do research on mobility of the elderly. The results of this kind of research contribute to exploration of the local demands for (certain types) of mobility, so that the future needs of the population concerning mobility can be met in order to maintain and further accommodate our mobility to prevent isolation, dependence and increase –or at least sustain- our quality of life. Of course, the increased understanding of the topic in its local context resulting from this research can also be of great use for policy makers and spatial planners as they can account for possible changes of future needs of (certain types) of mobility and factors which influence these needs and integrate this in their policies and/or planning.

Another aspect is the scientific relevance of this research. There has been a lot of research to the mobility of the elderly and factors that are able to influence this mobility during the past few years (including policies, personal characteristics and the built environment for example) (Alsnih & Hensher, 2003; Currie & Delbosc, 2009; Mercado et al, 2010; Metz, 2012) and the impacts this may have on the quality of life (Banister & Bowling, 2004; Delbosc & Currie, 2011; Jorritsma & Olde Kalter, 2008; Metz, 2000; Schultz, 1992). While there have been some studies to the influence of weather conditions on mobility patterns in general (Böcker et al, 2013; Sabir et al 2009/2010) the influence of weather conditions on mobility patterns of the elderly remains more or less unexplored. Therefore, this research will adapt a specific focus on weather conditions (temperature, wind, precipitation and snow cover) on the mobility of the elderly. This will be done by exploring their mode choice and the number of trips, just like is done in existent research on the topic of elderly mobility. In addition to these aspects of the scientific relevance, it is important to realize that, while the issues of mobility happen in a global context, the challenges and effects on mobility are of local nature and are different between local scales (Keeling, 2009), therefore it is very important to study this phenomenon on a local level (the city region of Rotterdam in this case).

Therefore, the aim of this research project is to provide insights into the mobility of the elderly on the local scale of Rotterdam and its surrounding area and factors that may influence this mobility, the focus will be on personal characteristics and factors and the influence of weather which has been relatively undocumented before, especially on local scale.

1.2 Problem statement & sub-questions

The problem indication, relevance and scope have led to the formulation of the following research question (and sub-questions).

'Which personal and weather related factors significantly influence the number of trips and mode choice of the elderly within the greater Rotterdam area, and to what extent?'

With the following sub-questions:

1. Which personal and household characteristics are influencing the mode choice and the number of trips of the elderly in the study area?
2. Are there any differences in mode choice and the number of trips of the elderly in the study area when looking at different age groups (65-75, >75) and gender?
3. To what extent do weather related factors influence the mode choice and the number of trips of the elderly in the study area?

By further investigating the mode choice and the number of trips of the elderly within the Rotterdam area, it is possible to gain an increasing understanding of the factors that might help shape this mobility. These factors can be personal characteristics (sub-question one and two), but also factors related to the weather, as sub-question number three suggests.

1.3 Reading guide

In addition to this introductory chapter, this research report consists of four parts: the literature review, the research methodology, the statistical analysis and the conclusion.

The literature review (chapter 2), will addresses the following :

- Paragraph 2.1 focusses on the aging society and increasing mobility, by elaborating upon demographic developments, passenger transport trends and mobility characteristics.
- Paragraph 2.2 will focus on the consequences of an ageing society for mobility in general, with a more specific focus on the elderly.
- Paragraph 2.3 explores the personal (and household) characteristics and factors that have been shown (by existent research) to influence elderly mobility and it’s characteristics.
- Paragraph 2.4 elaborates upon how weather conditions might influence (elderly) mobility according to existent literature on the topic.
- Paragraph 2.5 explores the influence of the built environment on elderly mobility.
- Paragraph 2.6 provides an overview of the reviewed literature and different topics which have been cover in the entire literature review.

The next part is the research methodology (chapter 3), which will elaborate upon the following:

- Paragraph 3.1 is about the conceptual model which has been at the base of the empirical research, by visually displaying the relationships between the different variables (discussed in chapter 2).
- Paragraph 3.2 focusses on the study area of greater Rotterdam, by providing a short sketch of the environment.
- Paragraph 3.3 elaborates upon the different types of data (as well as its collection) which have been used for this research.
- Paragraph 3.4 explains which methods have been chosen for this research, as well as why they were chosen.

The statistical analysis (chapter 4) consists of:

- Paragraph 4.1 elaborates upon the sample composition and its representativeness.
- Paragraph 4.2 focusses on the (analysis of the) mode choice of the elderly and which factors influence this mode choice.
- Paragraph 4.3 focusses on the (analysis of the) number of trips made by the elderly and which factors influence the number of trips.

The last part of this research is the conclusion (chapter 5), in which the research question(s) are answered. This chapter also discusses some of the possible implications, features a reflection of the research process and provides some suggestions for future research.

2. Literature review

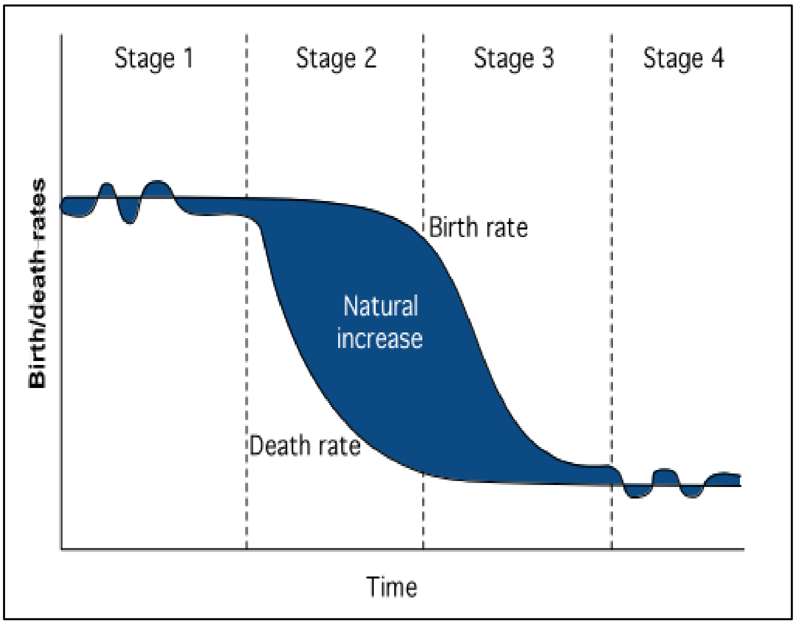
The outline sketched in the previous part of this study show the aging of society and the potential impact this has on the mobility of the elderly (transport choice and behavior). In order to be able to discuss the existing literature and to eventually give a satisfactory answer to the research question it is first necessary to investigate two major trends within the contemporary society: an aging population and increasing mobility. As this chapter will illustrate these trends are strongly interrelated and also highlight the relevance of this research. Although it is at the basis of the demographic aspect of human geography the model of demographic transition can explain the aging of the population and therefore is a good starting point.

2.1 An aging society & increased mobility

An aging society

The model of demographic transition is derived from Warren Thompson's (1929) interpretation of birth and death rates and the changes between these rates as the society moved from a pre-modern to post-industrial one. The model of demographic transition consists of four stages: pre-modern (1) , urbanizing/industrializing (2), mature industrial (3) and the post-industrial phase (4) (image 2.1) (Daniels et al, 2008; Montgomery, 2014).

Image 2.1: The demographic transition model.



Source: Population reference bureau, 2006.

Stage 1 (pre-modern):

The first stage within the model is associated with high death rates (as a result of bad hygiene, infectious diseases, rudimentary healthcare, war and food shortages). The birth rates however, were also much higher at that time due to a number of reasons. This stage is also called the high stationary phase (image 2.1). This stage of the model comprises all countries of the world until the 17th century (Daniels et al, 2008; Montgomery, 2014).

Stage 2 (urbanizing/industrializing):

In the second stage the death rate declines because increased personal hygiene which significantly increased public health. Agricultural improvements and increasing wealth caused the birth rate to stay constant or see a small increase. The declining death rate and the constant or slightly increasing birth rates caused a fast paced population growth (image 2.1) which started in the north-west of Europe and spread to other countries over time. (Daniels et al, 2008; Montgomery, 2014)

The conditions of a decreasing death rate and a constant (or slightly increased) birth rate also has important consequences for the age structure of the population: "In Stage One the majority of death is concentrated in the first 5-10 years of life. Therefore, more than anything else, the decline in death rates in stage two entails the increasing survival of children. Hence, the age structure of the population becomes increasingly youthful." (Montgomery, 2014). This effect is multiplied when these children become parents themselves and maintain the same fertility rate as their parents, leading to a population with a large amount of young people and only a small amount of older (Daniels et al, 2008; Montgomery, 2014).

Stage 3 (mature-industrial):

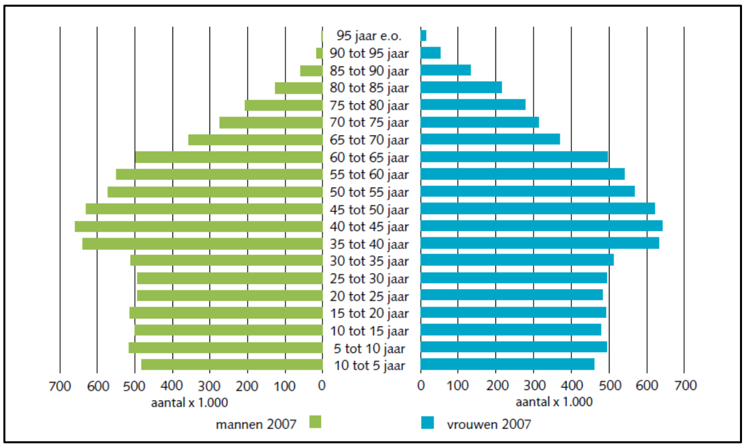
In the third stage the birth rate also starts to decline (image 2.1), which is mostly related to the increase of economic wealth and the process of urbanization. As a result, the level of natural increase started to decline. In the long term, this of course also has consequences for the age structure of the population: the base (young part) of the population pyramid is now nog longer expanding. (Daniels et al, 2008; Montgomery, 2014)

Somewhere during this stage, the fertility rate falls beneath the replacement level (2.1), but the total population may still increase to grow because there is still a relatively large amount of people who are in the age groups that are likely to have children. Eventually however, the number of births will be equal to the number of deaths which means the start of the fourth stage of demographic transition. (Daniels et al, 2008; Montgomery, 2014)

Stage 4 (post-industrial phase):

The post-industrial phase of the demographic transition model is characterized by a relative stability of both death rate and birth rate (image 2.1). This stage is also characterized by a population age structure with an increasing share of people aged 65 and above and a decreasing amount of younger people (image 2.2).

Image 2.2: The population pyramid of the Netherlands (2007)



Source: Jorritsma & Olde Kalter, 2008

In some cases this might also cause the fertility rate to drop even further below the replacement level, causing a population decline. At the same time the death rate might also increase due to the aging of the population and by the cause of lifestyle diseases such as Alzheimer's disease and obesity. This fast paced population decline is often also referred to as a possible stage 5 of the model (Daniels et al, 2008; Montgomery, 2014; Williams, 2009).

It is of course also important to realize that population growth is also influenced by migration (Botev, 2012; Williams, 2009) Migration however, is usually only a minor factor, especially when only looking to the regional level instead of the national level (Bongaarts, 2009) which is also why it isn't being elaborated here any further.

Apart from not taking into account migration, it is also very important to remember that the demographic transition theory is only a model. Therefore, it cannot be used to give an accurate prediction of the future. The research by Myrskylä et al (2009) for example shows "Although development continues to promote fertility decline at low and medium HDI levels, our analyses show that at advanced HDI levels, further development can reverse the declining trend in fertility." (Myrskylä et al, 2009, pp. 741). Another source of critique on the model is that the model is centered on western-Europe and north-America and therefore not always applicable to countries that are less-developed (Daniels et al, 2008; Hoff, 2007; Lee, 2003; Williams, 2009). Also local and regional political situations and decisions, like policies and war might also influence the mortality rate and death rate (Caldwell et al, 2006; Daniels et al, 2008; Williams, 2009).

The above shows that the view of the model is a contested one. But while there is a lot of discussion It can however still be used to get a general indication of how population demographics might change in the course of a countries development. It also remains a fact that the average age of the population continues to rise and that the share of the elderly within the population is the largest to date. Also, in some parts of the world the older people (older than 60) already outnumber children since somewhere in the 1990's. A prognosis also suggests that the percentage of people older than 60 will be more than double than that of the percentage of children by the year of 2050 (Hoff, 2007).

The aging of our population can have a lot of different consequences on different aspects of our society. This report will however only focus on the consequences of an aging society regarding mobility, but before discussing the potential consequences of the aging for mobility in it is very important to look at another the second trend: increasing mobility.

Increasing mobility: general passenger transport trends & characteristics

The total amount of passengers kilometers (pkm) for countries within the European union has been steadily increasing in the period from 1995-2011. During this period the total amount of passenger kilometers for all modes of transport increased with an average of 1,4% per year. The years 2000-2011 however showed an average increase of 0,8%, indicating a slight decrease in the average growth of the total amount of passenger kilometers in the more recent years (European commission, 2013a).

The latest figures illustrate that the car remains by far the most important mode of transport (European commission, 2013a). In 2011 the passenger car was responsible for 73,4% of the total amount of passenger transport within the European union (EU-27). Interestingly enough this percentage has remained more or less constant throughout the years. Another interesting development is the increase in air transport, from 6,5% in 1995 to 8,8% in 2011. Other transport modes remain only responsible for a relative small share of the total passenger transport (image 2.3).

Image 2.3: EU modal split for passenger transport.

MODAL SPLIT

%	PASSENGER CARS	P2W	BUS & COACH	RAILWAY	TRAM & METRO	AIR	SEA
1995	73.3	2.3	9.3	6.5	1.3	6.5	0.8
1996	73.3	2.3	9.2	6.4	1.3	6.7	0.8
1997	73.3	2.3	9.1	6.3	1.3	7.0	0.8
1998	73.4	2.3	9.0	6.1	1.3	7.2	0.8
1999	73.5	2.3	8.8	6.1	1.3	7.3	0.7
2000	73.5	1.8	8.7	6.2	1.3	7.7	0.7
2001	73.9	1.9	8.6	6.2	1.3	7.5	0.7
2002	74.5	1.9	8.4	6.0	1.3	7.3	0.7
2003	74.5	1.9	8.4	5.8	1.3	7.5	0.7
2004	74.2	1.9	8.3	5.8	1.3	7.8	0.6
2005	73.4	2.0	8.3	6.0	1.3	8.4	0.6
2006	73.3	1.9	8.1	6.1	1.3	8.6	0.6
2007	73.1	1.8	8.2	6.1	1.3	8.8	0.6
2008	73.1	1.9	8.2	6.3	1.4	8.6	0.6
2009	74.2	1.9	7.9	6.1	1.4	8.0	0.6
2010	74.1	1.8	7.8	6.2	1.4	8.0	0.6
2011	73.4	1.9	7.8	6.2	1.4	8.8	0.6

Notes: Air and Sea: only domestic and intra-EU-27 transport; provisional estimates.
P2W: Powered two-wheelers.

Source: European commission, 2013a.

These developments are also visible in the Netherlands: during the last 25 years, the total amount of passenger kilometers (for all modes of transport) increased by roughly 40% , especially in the 80's and 90's. Just like the average European situation, the growth of the total amount of passenger kilometers also declined in the Netherlands. Between 2000 and 2012 this amount only increased by about 5%. This reduction of growth is especially evident after the year of 2005, and is especially caused by a decline in car use (Kennisinstituut voor mobiliteitsbeleid, 2013). In the Netherlands, car use even accounts for a larger part of the total amount of passenger kilometers (82,7%), followed by train (9,3%), bus & coaches (7,0%) and finally tram & metro (0,9%) (European commission, 2013a).

Although the recent years may show a stagnant growth of the total mobility it is import to realize that the total amount of passengers kilometers is projected to keep on growing (but at slower rates), even after the year of 2030 (European commission, 2013b). In order to be able to keep up with this growth and the resulting future transport needs €7.21 billion was invested by the European union between 2007 and 2013, with more investments in the near future (European commission, 2013a).

Another important aspect of the current and future situation regarding mobility is related to the tension between growth of this mobility (and how to accommodate this growth) and sustainability & climate change. "Transport accounts for 26% of global CO2 emissions and is one of the few industrial sectors where emissions are still growing. Car use, road freight and aviation are the principal contributors to greenhouse gas emissions from the transport sector." (Chapman, 2006, pp. 1). Because of this, transport has become a very important point on the political agenda, especially after implementation of policies which aim to reduce worldwide greenhouse gas emissions (such as the Kyoto protocol for example)(Chapman, 2006).

In order to be able to accommodate future growth while still being able to reach the goals of the Kyoto protocol it will be necessary to plan for more sustainable forms of mobility (walking, cycling and public transport) and less focus on car-based travel (Hickman et al, 2013). One of the strategies for discouraging car use while promoting the use of mass transportation is the creation of Transit-oriented developments (TOD's), which offer concentration sites for urban growth and provide access to surrounding facilities by offering a wide range of transport mode choices. Research shows that residents of a TOD-area tend to make less use of their car as mode of transport (Boschmann & Brady, 2013). It should be mentioned however that it remains unknown whether this is because of the availability of other, different modes of transport or because of the other qualities of TOD'S: focus on walking as transport mode, central, high density, good quality housing and the presence of retailing and commercial facilities (Boschmann & Brady, 2013; Chatman, 2013).

The trend of increasing mobility (and the need for this mobility to become more sustainable) sketched in this paragraph will have important consequences for our society. This is certainly the case because this is combined with the trend of an ageing population discussed in the first paragraph. What are the implications of the combination of both trends?

2.2 The consequences of aging for mobility

As was already sketched in the first paragraph there is a growing amount of elderly within the society, also in the Netherlands. It is even estimated that that the total share of elderly (aged 65 and over) will be approximately 25% by the year of 2030 (Centraal bureau voor de statistiek, 2014). This development of course also means that in the future, an increasing share of the total amount of participants in traffic will be among the higher age groups. There is even a scenario that seems to suggest that the elderly (aged 65 and above) in the Netherlands will be responsible for almost 50% of the total growth of mobility (Jorritsma & Olde Kalter, 2008). This of course, has a number of implications for mobility because:

- Today's elderly (but also the future elderly) are more accustomed to their higher mobility rates and the freedom to travel (whenever they want, to wherever they want). Because they are used to this freedom, they are also not likely to give this up willingly.
- The higher age groups will also remain in better shape health wise because of increased living standards. This might mean that they attain higher mobility patterns for a longer time (continue working after reaching retirement age for example Brusch & Büsch, 2013).
- Because living in urban areas is often associated with negative consequences (higher living costs due to higher rents for example), the elderly often choose to move away from these areas, this results in a greater need for mobility in areas outside of the city center and more rural areas.
- At the same time however, it is increasingly important for older people to continue living independently and at the same place as they did before. This of course also influences the amount of trips as it is still required to do their shopping's and other visits themselves. (European commission, 2009; OECD, 2002)

The enumeration illustrates the fact that the 'new generation' of elderly will strongly differ from previous generations (of elderly). As they are projected to have more active lifestyles in which mobility and access to others (and activities) are very important. Research even suggests that mobility is crucial factor for the quality of life of the elderly (Banister & Bowling, 2004; Metz, 2000; Spinney et al, 2009).

The accustomization of elderly to higher mobility and the desire to travel whenever they want is strongly related to these increasingly more active lifestyles. Therefore it should not be a surprise, that the elderly have increasingly become automobile (Rosenbloom, 2001).

(Auto)mobility

This is illustrated by the increase in the percentage of elderly who are in the possession of a driver's license (Alsnih & Hensher, 2003; Jorritsma & Olde Kalter, 2008; Robertson & Vanlaar, 2008; Rosenbloom 2001). In the Netherlands for example, the percentage of people aged 65 and above with a driver's license strongly increased in the period 1997-2007: While in 1997, 75% of the males had a driver's license, this share increased to 83% in 2007. For females, these figures even increased from 29% to 46% during the same time period. On average 62% of the people aged 65 and above was in the possession of a driver's license in the year of 2007 (Jorritsma & Olde Kalter, 2008).

At the same time, the percentage of car ownership increased during this time period, in 2008 a large share (72%) of the males and 25% of the females had their own private car (Jorritsma & Olde Kalter, 2008). According to these figures, the car is the most important transport mode for the elderly, and they are also able to use the car as their primary mode of transport at higher ages than before which makes them less reliant on forms of public transport or other people. At higher ages however, car use tends to decrease strongly (Jorritsma & Olde Kalter, 2008).

The increasing automobility of the elderly participating in traffic is also said to have some negative consequences. Rosenbloom (2001) for example, mentions that because the elderly are so reliant on the car as their main mode of transportation, mobility of this group might increasingly contribute to pollution and environmental problems. At the same time, research seems to suggest that the elderly are also more likely to be involved in car crashes (caused by declining driving skills for example) and have higher mortality rates when they are involved in a car crash (OECD, 2001; Robertson & Vanlaar, 2008; Rosenbloom, 2001).

Other transport modes

It is however also necessary to look at transport modes other than the car. Just like the overall situation, the car remains the most important transport modes for the Elderly in the Netherlands: In 2007, about 55% of all trips of the elderly takes place by car. It is necessary to make a remark here though, as this includes about 10% in which case one is being driven around by someone else in a car). Other important modes of travel are (motorized)bicycles (approximately 25%), travelling by foot (approximately 15%), public transportation is the least favored transport mode among the elderly as this accounts for not even 5% (Jorritsma & Olde Kalter, 2008). This might be explained by the fact that these figures show the situation in the Netherlands as a whole, while the share of public transport use is strongly related with urbanization (Schmöcker et al, 2008; Schwanen et al, 2001). The research done by Schwanen et al (2001) even indicates that elderly who are living in urban areas even tend to use public transport eight times more often than their rural counterparts. This means that the figures related to transport mode discussed above need to be approached with caution, as the use of public transport in urban areas tend to be higher than is indicated by these figures. Another interesting finding is that the availability of better public transport services does not necessarily mean that the elderly make less use of the car as a main mode of transport, it mostly tends to replace the role of the bicycle as transport mode.

Also habit seems to be an important factor: "those who commuted by public transport when younger (and who generally had higher incomes) continue to use it when older" (Schmöcker et al, 2008, pp. 259). (Schwanen et al, 2001).

A factor that might contribute to the car being the main transport mode of the elderly is the event of trip chaining, which has become an increasing phenomenon since the 90's. The elderly seem to be less able to chain trips with the different modes of transport than others, which leaves the car as their main mode of transport to chain trips together efficiently (Su & Bell, 2009). Also, the use of public transport might be problematic because of mental and physical barriers of elderly and disadvantaged people (Schmöcker et al, 2009).

Different trip behavior

It should be clear that the trip behavior of the elderly is different when compared to younger people. The first important difference is that the number of trips decreases with age and that also the mean distance travelled per trip is shorter than when they were younger (Alsnih & Hensher, 2003; Metz, 2000; Rosenbloom, 2001). An important factor that is contributing to this development is retirement (as It is no longer necessary to make long trips for work). Also, loss of income might also play an important role (Metz, 2000). According to research done in the Netherlands, distance covered, travel time and the total amount of trips all decreased as people grew older. The elderly also prefer to do their trips outside of the rush-hours (Jorritsma & Olde Kalter, 2008).

An important notion to this is that the elderly nowadays tend to make more trips with a greater average travel distance than the older people of a few years ago (Jorritsma & Olde Kalter, 2008; Rosenbloom, 2001). This is might of course be related to the fact that the elderly in general are increasingly used to being mobile, are able to attain higher mobility patterns for a longer time and that their views about (and societal views towards the elderly) the living location and situation seems to be changing (OECD, 2002; Powell, 2012; Walker & Naeghele, 2000).

Future mobility and elderly

As was stated before the total mobility is projected to keep on growing the coming years (European commission, 2013b). Scenarios for the Netherlands even seem to suggest that the increasing share of elderly will be responsible for about 20% of this growth. Mostly, this is because of changes in their attitudes and other (increasingly diverse) characteristics (having a car, continue working). It is expected that as a result of these changes the future elderly will undertake more trips (in which they will probably also travel a greater distance) than the elderly today and in the past. (Jorritsma & Olde Kalter, 2008; OECD, 2002; Powell, 2012; Walker & Naeghele, 2000).

2.3 Personal characteristics & factors influencing elderly mobility

The previous sections of this report treated the elderly as a fairly homogenous group. The truth is that the elderly are far from homogenous. Because society has become more diverse in the past (and still continues to do so) it is safe to assume that the older age groups will also become increasingly more diverse and possess different characteristics (which possibly influences mobility). These characteristics and possibilities are not only personal, but can also be dependent and explained by other effects. This is illustrated by the distinction made in the research by Hjorthol & Sagberg (OECD, 2002) in which they describe three types of effects:

1. "Age effects": This is directly associated with getting older and its consequences which can be easily compared between people of different ages.
2. "Cohort effects": These are effects that influence a group of people that experienced the same events/experiences over time, which might not be experienced by those of different age (groups).
3. "Period effects": These are effects that occur in a moment of time which have an impact on the entire population, Hjortol & Sagberg (OECD, 2002) mention policies and natural disasters. (OECD, 2002)

While the comparison between these effects is not the direct focus of this research, they illustrate the fact that the elderly are a diverse group and that the characteristics they possess are not only personal but also dependent and 'shaped' by incredibly complicated effects. Instead, this research will focus on these characteristics and how they might influence the mobility (mode choice and the number of trips) of 'the elderly'.

In their article, Schwanen & Páez (2010) introduce the topic of elderly mobility and its many aspects. They elaborate upon the relevance of the topic and acknowledge that there has been an increasing focus on elderly mobility during the last few years. While they don't review the entire articles, they mention that personal characteristics such as age, gender, ethnicity, income and education might all influence elderly mobility characteristics, they also mention how some of the articles find that the built environment might influence the number of trips and mode choice of the elderly.

Personal characteristics / factors

In their extensive literature review, Alsnih & Hensher (2003) stress that it is important to realize that the elderly are not a homogenous group. Based on the findings of their reviews they make a distinction between the 'young' elderly (65 – 75 years old) and the 'old elderly (older than 75). Using census data and comparing both age groups, they show that mobility becomes a bigger issue when people reach the age of 80, resulting in different mobility characteristics and transport needs. They also mention differences between both age groups when looking at transport mode, although the car seems often to be the preferred mode of transport among the elderly. Finally, they show that while the largest part of the studies to mobility patterns of the aging population are done in the western world (The United States, The United Kingdom, but also in the Netherlands) they still can provide useful information for countries in other parts of the world (Alsnih & Hensher, 2003).

Currie & Delbosc (2009) researched the use of public transport of the elderly in Melbourne (Australia) using a travel survey documented in the period of 1994-1999. When comparing people younger than 60 years old with people of the age of 60 and above they found that the overall amount of trips for the older age group was (30%) lower than the younger age group. Currie & Delbosc (2009) also recognize that age might play an important role when looking at mode choice, therefore they also compare the transport modes for both age groups. In line with Alsnih & Hensher (2003) they find that the car is the preferred mode of transport among the elderly in their study area. In addition, their results showed that the elderly in Melbourne also used public transport less than other transport modes. Currie & Delbosc (2009) also analyzed cohort effects for the Baby Boomer generation, but because this is not the focus of this research report it will not be discussed here. (Currie & Delbosc, 2009)

The study be Newbold et al (2005) focused on the travel behavior of Canada's elderly. They used Canada's General Social Survey (GSS) for their analysis in which they compared the travel characteristics of different age cohorts in three moments in time (1986, 1992 & 1998). Just like Currie & Delbosc (2009) they find that the older age groups make a smaller amount of trips (they also find that these trips tend to be shorter) and that the likelihood of using the car as a transport mode (as a driver at least) also decreases at higher ages, indicating an influence of age on mode choice. Their findings did however not indicate an increasing use of form of transport modes other than the car. Newbold et al (2005) also looked at gender differences and mobility, as they found that females overall performed trips with an average shorter duration than trips done by men. According to their study, being employed was found to have no impact on the number of trips, but that being an unemployed elderly caused people to travel shorter distances. According to the authors, this is because elderly who are no longer employed "replace work trips with shorter non-work trips" (Newbold et al, 2005, pp. 350)(Newbold et al, 2005).

Mercado & Páez (2009) also did research in Canada, although they focused on factors that might influence the distance traveled by the elderly. Using a multilevel analysis, they analyze official census data from the Hamilton Census Metropolitan area (CMA) in combination with travel surveys and land use data. Their study confirms that older people tend to cover less distance during their trips, but that this is not the case for distance travelled by bus. Their research also verifies the finding by Newbold et al (2005) that women in general tend to perform shorter trips than men. Other findings of the study are that being employed is in some situations also found to have a negative effect on the distance travelled. Also the finding by other studies that income (Stradling et al, 2005) and owning a license and /or vehicle can have a positive effect on the distance travelled are confirmed by this study. The authors of this article also investigated the relationship of the household size and travelled distance (as it has been shown to have a negative effect in other studies, for example Stradling et al, 2005), but this was not the case for this study (Mercado & Páez, 2009).

Just like the research by Mercado & Páez (2009) the research by Páez et al (2007) investigates trip making by the elderly in Hamilton, Canada. For their analysis they used data gathered by a travel diary survey (Toronto's Transport Tomorrow Survey) and a series of regression analysis. Like other research, their results confirm that older age groups significantly make fewer trips in general, although females are more likely to travel more overall. The authors also included the factors of having a driver's license and car access to the models and found that these variables had a positive significant influence on overall amount of trips. Also having a job proved to have a positive influence on the number of trips. Just like the study by Mercado & Páez (2009), also the household structure was included into the model and were shown to have significant negative influence on the amount of trips. This research however, compares work trips and non-work trips and it has been shown that the influence of certain variables might be different for work trips than for non-work trips (Páez et al, 2007).

Kim (2011) also investigated mobility characteristics of the elderly, but in the United States. The author used data collected by a national telephone survey and randomly selected a sample of 402 participants, to check for potential differences between certain variables and missed activities due to lack of transportation. Perhaps the most interesting finding is that older minority females tend to make less trips than the average elderly, therefore ethnic background might also be a relevant factor to take into account. Like other studies elaborated, Kim (2011) also found that elderly with a lower income might experience difficulties regarding mobility.

Li et al (2012) investigate travel patterns for the elderly in the United Kingdom using national survey data. They also looked at attitudes to transport using data from the Scottish Household Survey. Their results confirm the finding of earlier mentioned studies that although the car is an important mode of transport for the elderly, car use tends to decrease at higher ages. In line with Mercado & Páez (2009) they found that higher age groups perform more trips, although these tend to be over shorter distances. They also find that gender seems to influence mobility patterns of the elderly, especially that older females take the bus more often and that females tend to be less mobile than other age groups (older males included) (Li et al, 2012).

Schmöcker et al (2008) investigated mode choice of older and disabled people for shopping trips in London. For their analysis they used the London Area Travel Survey (LATS). Just like other studies they find that the car use is the most important transport mode and that males are more likely to take the car than females (and they are also more likely to be the driver), they also mention that women are more likely to take the bus than males, which is in line with the study by Li et al (2012). The study also seems to indicate that income has a negative effect on public transport use, which is in conflict with the results of Schwanen et al (2001) but is also evident in other studies (Kim & Ulfarsson, 2004).

Hjorthol et al (2010) researched mobility characteristics of different generations of older people in Denmark, Norway and Sweden. They used data from the National travel surveys of these countries to perform a cohort analysis. When looking at the frequency of trips, they find that women tend to do less trips than men (this is especially true for the amount of trips taken by car) and that owning a license tends to decrease the use of other modes of transport. They also stress that it is important to keep in mind that this factor is related to gender because less females tend to be in the possession of a driver's license and they also use the car less as a transport mode, which might also influence the rate at which they choose for other travel modes. Just like having a driver's license, car ownership is related to gender as males tend to keep their cars even when they are older, especially when compared to females (Hjorthol et al, 2010).

Also in the Netherlands there has been research to factors that might influence the mobility of the elderly.

An example is the research done by Schwanen et al (2001), who analyze the leisure trips and the determinants of mode choice. They used data from the Dutch National Travel Survey, from which they selected 28,419 seniors. They confirm the finding that also for leisure trips the elderly frequently use the private car and that the number of these trips also seems to decline at higher ages. They also find that the older elderly tend to make more use of public transportation compared to elderly of younger ages and that they are also less likely to walk or use the bicycle. In addition, their findings suggest that older women are more dependent on public transport modes. Moreover, elderly that are employed tend to use both car and public transport more often, this also seems to be the case with higher income. When looking at education Schwanen et al (2001) find that higher educated elderly tend to choose more for public transport in comparison to the lower educated and that education in linked to a higher number of trips as it has been shown to be strongly related to activities away from home. An important aspect of this research is the focus on the potential influence of car and /or license ownership. Tied to this are the results that car ownership is of course strongly related to choosing the car as a transport mode and that car ownership also decreases the likelihood that the elderly make use of other modes of transport (especially public transport). Also having a drivers' license tends to decrease use of other modes of transport, although this has a much smaller effect than owning a car (Schwanen et al, 2001).

A more recent example is the study by Van den Berg et al (2011), who investigate the characteristics of social trips. For their study they gathered data from 732 respondents living in Eindhoven, by letting them fill in a social interaction diary and travel data. Using regression analysis they found that the number of social trips does not seem to be significantly influenced by age, which is in conflict with the findings by Li et al (2012). In addition, they find that the younger elderly seem to travel greater distances for social activities than the older elderly. Regarding to employment and education, their study seems to suggest that (full-time) employed people perform less trips for social goals and that higher educated seem to undertake more of these trips than the lower educated. Just like Schwanen et al (2001) car ownership seems to be strongly related to choosing the car as a transport mode. Also, the lower educated are more likely to travel by car (for social visits at least)(Van den Berg et al, 2011).

It should be clear that the personal characteristics mentioned in these articles are in some cases strongly interrelated. An example of this is income, as income is also often found to decline with age. Car ownership and access also tends to be dependent on age, but on gender as well. It is important to be aware of this interconnectedness and it will be very interesting to discover how these personal characteristics might influence the mobility of the elderly in the study area. There are of course also other factor that might influence these mobility patterns, the built environment and influence of the weather, will also be discussed.

2.4 Weather conditions and mobility

Next to the personal characteristics, research has shown that circumstances related to the weather are also able to influence mobility. However, most studies tend to focus on the impact of the weather extremes on transportation systems as a whole. As a result of this focus on weather extremes and the macro level, the influence of the everyday weather on individual travel behaviors has been explored to a lesser extent (Böcker et al, 2013). However, studies that have focused on the influence of the everyday weather on the micro scale have shown that the weather is also able to influence the characteristics of individual travel behaviors (Böcker et al, 2013; Sabir, 2011). This literature review will discuss weather components that have been receiving the most attention in scientific research: temperature, wind & precipitation (Sabir, 2011).

It is important to keep in mind that research related to the weather and mobility is often done with a focus on the general population (and not the elderly specifically). Because this part of the topic is relatively undocumented, this literature review also includes research that does not specifically have this focus (but will try to so as much as possible). But because these weather related factors are in many cases shown to have an influence on mobility patterns in general, it can be assumed that they also influence mobility patterns of the elderly. It remains to be seen however, to what extent this influence is the same for the elderly as it is for the general population, if it is at all.

Muhammad Sabir did a lot of research on the influence of weather conditions on individual travel characteristics in the Netherlands (Sabir, 2011; Sabir et al, 2009; Sabir et al 2010). In the latest of these studies, Sabir (2011) uses transportation data from the Dutch central bureau of statistics (CBS) in combination with weather data by the royal Netherlands Meteorological institute (KNMI), to analyze the number of trips, distance travelled and mode choice for trips with different trip purposes using multiple types of regression analysis. According to his results, extremely cold weather leads to a decreased of bicycle, while at the same time increasing car use as a transport mode. Contrasting to this, higher temperatures tend to increase cycling (and also walking, but on a much smaller scale) while decreasing the use of the car, busses, tram and metro. When looking at forms of precipitation, Sabir (2011) found that precipitation tends to decline use of the bicycle in favor of car, bus tram metro. Wind strength seemed to have an effect on mode choice, but it didn't appear to change mode choice significantly. It did however, seem to have an effect on the individual travel demand / number of trips, "especially if a weather warning/alert is given as well." (Sabir, 2011, pp. 47).

A more recent study is the work by Böcker et al (2013), in which they review 54 studies and elaborate the effects of temperature, wind and precipitation. According to them, studies in different countries found that precipitation might especially have a negative effect on the amount of traffic that takes place by car. Some of these studies also show that riding the bus and train might also be negatively affected by precipitation, which is in contrast with the findings by Sabir (2011) that precipitation causes people to prefer other modes than active transport. Some research even seems to suggest that precipitation has no effect on the use of public transport at all. When looking at temperature, European studies have shown that temperature positively influences the likelihood of active modes of transport, while having a negative effect on travelling by car and public transportation. Although less research tends of focus on the impact of wind (in comparison with precipitation and temperature), some studies reviewed by Böcker et al (2013) find that higher wind speeds tend to increase travelling by foot and that these higher wind speeds especially have a negative effect on the use of the bicycle as a mode of transport.

2.5 Built environment factors & mobility of the elderly

Research has shown that the built environment is able to influence the mobility of the elderly (Borst et al, 2009; Kim, 2011; Schmöcker et al 2008; Schwanen et al, 2001). It is also stressed that the neighborhood environment is of great importance when exploring mobility of the elderly. Especially because the older age groups tend to have a stronger focus on the residential environment than people of other age groups. An important aspect of this neighborhood environment is the built environment, which is defined as ''the human-made or human-altered space in which individuals live out their daily lives.” (Rosso et al, 2011, pp. 2).

This built environment is the focus of the study by Rosso et al (2011), as they recognize that research regarding neighborhoods effects has focused too much on younger- an middle-aged adults and on environmental factors other than the built environment. In their study, they mention three aspects of the built environment: transportation systems, land use patterns and urban design (Rosso et al, 2011). Transportation systems comprise the actual infrastructure needed for transportation (roads and trails for example). Land use relates to the spatial mix of certain types of zoning (residential, commercial & industrial) but also to the density of this zoning. Examples of urban design related factors are the presence of sidewalks and number of lanes (Rosso et al, 2011).

Another useful distinction between the different dimensions of the built environment is made by Ewing & Cervero (2010). According to Ewing & Cervero (2010), important factors of the built environment can be categorized into five dimensions, the five Ds’. The first one is density, which is of course related to the number of residents and/or workers that are located within a certain area. The second category is that of (land use) diversity, which corresponds with the different types of land use (mix) within a certain area. It is argued that a higher diversity reduces the likelihood that it is necessary to travel outside of that area. The third dimension is (pedestrian oriented) design, and facilities that (possibly) influence how suitable a certain area is for walking, such as pedestrian crossings, quality of the network and other pedestrian facilities. The fourth dimension comprises the destination accessibility, which is about how easily regional trips opportunities are accessible (measured in distance or in travel time). The last dimension is the distance to transit, which basically is about the distance to the nearest station or stops for public transportation (Ewing & Cervero, 2010).

Factors related to the built environment can often be categorized in certain dimensions as mentioned by Rosso et al (2011) and Ewing & Cervero (2010). The focus of the research to the influence of the built environment on mobility however, seems not to be on the elderly specifically (and if it is it often focusses on walking behavior). Because of this, the elaboration of research will also take into account this more general focus, but will focus on the elderly when possible.

The research done by McKibbin (2011) focusses on mode choice for journeys to work in relation to the built environment in the greater Sydney region. Using the five dimensions of the built environment as mentioned by Ewing & Cervero (2010) in a series of regression models, McKibbin finds that density had a moderate influence on the car as a mode of transport and that land use diversity only had a small effect on transport mode choice. The influence of the (pedestrian oriented) design on mode choice seemed to be insignificant. Destination accessibility however, seemed to be the factor with the biggest influence on transport mode choice: a higher accessibility by public transport proved to decrease the car as a mode of transport. Also the distance to stops of public transport proved to have a significant a small significant influence on mode choice.

Reilly & Landis (1996) also investigated the influence of the built environment and land use on the mode choice of residents (not elderly residents in particular) of the San Francisco bay area in 1996. For their analysis they used the data of two-day travel diaries by 14.431 respondents in combination with GIS-analysis tools and multinomial logistic regression models. Built environment factors within the analysis are: population density, access to commercial land uses and activities, land use heterogeneity, housing stock diversity, average block size, intersection density, average parcel size and visual heterogeneity. While their analysis shows that some factors of the built environment might influence mode choice they mention that this not necessarily means that this is because of a causal relationship. This is because it might be the case that people that are likely to use transit for example, also decide to live in areas in which this is possible / more enjoyable to do so. This also means that just adjusting the built environment in order to stimulate the use of transit might not per se be enough, it is also necessary to influence attitudes towards transport modes.

Mercado & Páez (2009) investigated the determinants of distance travelled of the elderly in Hamilton (Canada). In their regression models, they also added two variables to the built environment: density and land use mix. Their results indicate that if the built environment consist of a mix between residential and commercial zones this is associated with an average shorter travel distance among the elderly (Mercado & Páez, 2009).

When looking at the walking behavior of the elderly research has shown that the presence of car free zones has been positively related to the probability of walking as a mode of transport (Gomez et al, 2010). Research also indicated that the presence of pavements, dwellings, gardens and shops positively influence walking as a mode choice among the elderly (Borst et al, 2009). Also, having walking paths in direct proximity had a positive impact on the amount of daily walking trips (Hall & McAuley, 2010), but not with the amount of walking trips made within the neighborhood (Michael et al, 2006). The presence of nearby stops of public transportation seemed to have no influence on the walking behavior of the elderly (Gomez et al, 2010; Nagel et al, 2008).Results concerning street connectivity have been mixed, some authors found no influence (Nagel et al, 2008; Satariano et al, 2010), other a positive one (Li et al, 2005), and others found a negative association (Gomez et al, 2010). These mixed results are presumably the case because of the use different definitions concerning what was seen as a neighborhood but also because there was no standard operationalization of the concept of 'walking' (Rosso et al, 2009).

While the built environments tend to be of importance, this research will mainly focus on factors related to the weather, personal and household characteristics and their influence on mobility patterns.

2.6 Remarks and Overview

Mixed findings

As the previous paragraphs have shown, research to mobility of the elderly might yield different and sometimes also contrasting results.

When looking at personal characteristics, this might be the case because different research makes use different methods, and in some cases also measure certain variables differently. An example of this is the variable age (groups) and in which ages belong to the ‘young’ elderly and the ‘old’ elderly (see for example the studies of Alsnih & Hensher (2003) and by Currie & Delbosc (2009), that both use different age group thresholds. This can of course have a huge impact on the results of such studies. This highlights the necessity to give a clear definition of used variables. Moreover, not all studies included the same control variables, which might also influence the results (McKibbin, 2011)

Also when looking at the built environment and the mobility of the elderly it is apparent that research is yielding different results. Many authors also recognize this and mention several explanations for this issue. As seen in the last paragraph Rosso et al (2009) mentions that this might be because there are no standard concepts and operationalization’s that are used when doing research. Some authors use neighborhood borders as they are given by the municipality while others use socioeconomic characteristics to define the neighborhood (Rosso et al, 2009). Also, the different studies do not always add the same control variables, and because of that it is not always possible to compare and explain these different outcomes (McKibbin, 2011).

The different findings between the studies elaborated in the earlier paragraph about the weather, but especially the study by Böcker et al (2013) illustrate that research to weather effects in relation to mobility might yield different and often contradicting results. These differences between studies might be explained by a number of factors. Location might be an important aspect, as culture might have an important impact characteristics and attitudes towards mobility. An example of this is the difference between the bicycle culture in the Netherlands (Pelzer, 2010) and the car culture in North-America (Legates & Stout, 2011). The climate (and weather characteristics) is of course also dependent on location as in some climates weather is relatively stable while at other locations weather conditions are incredibly diverse, therefore some forms of mobility (behavior) might be less suited in certain climates, also influencing results (Böcker et al, 2013). Next to these locational/cultural and climate related factors also the used methods, techniques and operationalization’s can cause dissimilarities to arise. Böcker et al (2013) mentions that some studies use stated mobility behavior, while others use actual behavior. Weather data from official institutes are often linked to travel behavior, which can influence results if this is not done carefully. Another important difference is that some studies also take into account weather expectations/forecasts while others do not. Moreover, while most studies focus on urban environments, others focus on rural environments which might also lead to different results (Böcker et al, 2013) This illustrates that it is often difficult to compare the results of different studies. It also shows the need to do local research as it is not enough to just transfer findings from other research to the research area in question, although it gives a general idea of the factors that are of importance.

Trip purpose

The literature has also shown that trip purpose can also play an important role when looking at mobility, as trip purpose as an exploratory variable might influence characteristics of mobility, but also that other explanatory variables can have different effects on trips with certain purposes.

An example that illustrates that trip purpose can also influence mode choice and the number of trips are also related is the work of Van den Berg et al (2011), who mainly focusses on social trips, but also finds that at higher ages (and retirement) the total number of trips drops, while shopping and leisure trips keep the same rates. An example concerning mode choice is illustrated in the research by Schmöcker et al (2008), who finds that especially shoppers tend to be positive about the use of public transport.

Influence of weather conditions might of course also have different effects be for trips with different purposes. An example of this can be found in one of the older European studies to the influence on weather related conditions and how this might possibly influence travel decisions is the study by Khattak & De Palma (1997). Khattak & De Palma (1997) performed their study by doing a travel behavior survey amongst 1218 commuters living in Brussels and used this data to perform a regression analysis. They found that weather conditions had a much larger influence on the time of departure in comparison with route and mode choice. This can be explained by also looking at trip purpose: "Trips made for visiting family and friends are also sensitive to weather conditions compared with other trips. These trips are more flexible and can be easily rescheduled or cancelled, especially compared with commuting and business trips." (Sabir, 2011, pp. 52). Elaboration of scientific research illustrates that weather related effect seem to be especially important for mode choice and appear to have a smaller effect on the total number of trips. It also shows however, that it is also necessary to take trip purposes into account, when looking at mode choice and number of trips, and the effect of personal characteristics and weather conditions.

Overview literature review

This chapter elaborated upon a large number of topics, starting with two trends which are also intertwined: an aging society and increasing mobility. Of course, these developments have important consequences for our society and for the transport sector. While these topics provided useful background information, the focus of this research is on the personal (& household) characteristics and weather conditions and their effects on the mobility of the elderly (while controlling for built-environment factors).

While the majority of studies investigating the mobility characteristics of an aging population are from the USA with a growing number from the United Kingdom, The Netherlands, and a few examples from Canada and Australia. "A review of travel patterns of the elderly in a range of western nations (with similar age profiles and life styles) will provide useful insights for other societies" (Alsnih & Hensher, 2003, pp. 905). This indicates that it is not enough to just assume that the same variables (that were found to have a significant effect on the mobility characteristics of the elderly in other studies) are also likely to have a significant effect in this particular study area. Only when research is done at the local scale, it can be said with certainty which factors have a significant influence on the mobility of the elderly in that specific area.

In order to give an overview of the existing literature, the most important variables for this research (personal characteristics and weather conditions) are displayed in Table 2.1 together with the studies in which their influence on mobility is mentioned. It is important to state that this influence is not on elderly mobility per se (but mobility in general) and that there is no distinction between mode choice and the number of trips.

Table 2.1: Overview personal (& household) and weather variables on mobility (of the elderly).

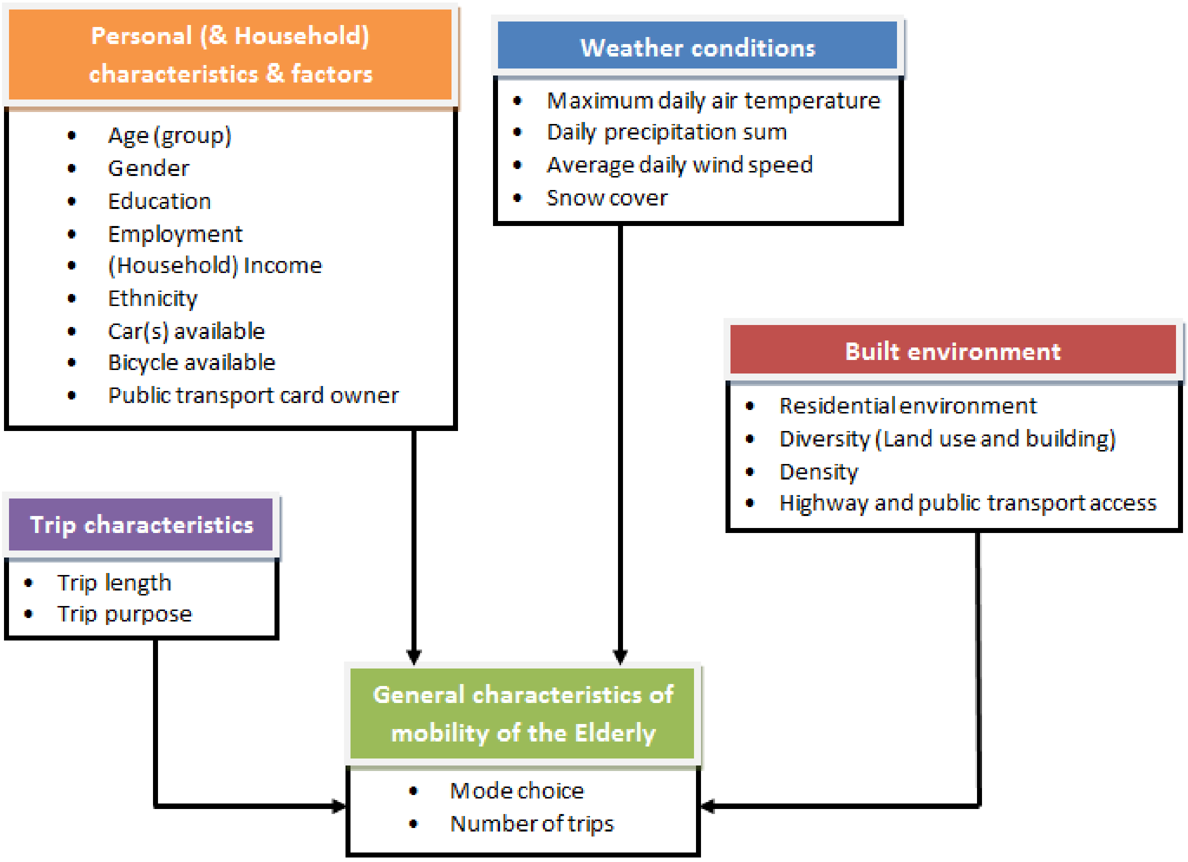
	Focus													
	Personal characteristics												Weather	
	Alsnih & Hensher (2003)	Currie & Delbosc (2009)	Hjorthol et al (2010)	Kim (2011)	Li et al (2012)	Mercado & Páez (2009)	Newbold et al (2005)	Páez et al (2007)	Schmöcker et al (2008)	Schwanen et al (2001)	Schwanen & Páez (2010)	Van den Berg et al (2011)	Böcker et al (2013)	Sabir (2011)
Personal characteristics														
Age	X	X	X	X	X	X	X	X		X	X	X		
Gender			X	X	X	X	X	X	X	X	X			
Education	X									X	X	X		
Employment	X					X	X	X		X	X	X		
Household income	X			X		X			X	X	X			
Ethnicity				X							X			
Driver's license	X	X	X			X		X		X				
Car access			X			X		X		X	X	X		
Weather conditions														
Temperature													X	X
Precipitation													X	X
Wind speed													X	X
X= Influence on (elderly) mobility.														

3. Research methodology

3.1 The conceptual model

The literature review yielded a number of factors that have been shown to influence mobility characteristics of the elderly in other study areas. The factors can be broadly placed into four categories: personal characteristics, trip characteristics, weather conditions and built environment factors. Based on these factors, the following conceptual model was composed (figure 3.1).

Figure 3.1: Conceptual model Mobility of the Elderly.



The conceptual model shows how the personal and household characteristics and factors, trip characteristics, weather conditions and the built environment can influence the mode choice and the number of trips performed by the elderly. It should be mentioned however, that this conceptual model is a very straightforward and simplified version of the real situation. As in reality some of the exploratory variables does affect only one or two of the mobility characteristics, and not all of them like is suggested here. Another important aspect of the conceptual model is the inclusion of trip purpose, as these trip purposes as independent variables can also influence mobility characteristics, and it has also been shown that for some trip purposes certain factors might have a different influence. In addition, factors related to the built environment have also been added to the conceptual model. Although these factors are not the direct focus of this research, they have been shown to have a significant influence on mobility characteristics in some cases. Therefore they are added into the analysis as control variables. The influence of the independent variables (and which dependent variables they affect) has become evident in the in the literature review.

3.2 Study area

By now it should be more than clear that this research report is about the mobility of the elderly, and more specific on the influence of personal characteristics and weatherly conditions on their mobility characteristics. Because this research focusses on the elderly who are living within the greater Rotterdam area, the units of analysis of this research are the elderly inhabitants of this region (they also comprise the target population), the greater Rotterdam area. But what makes this an interesting study area? This question can be answered by looking at a number of dimensions of the region: population, weather/climate and the built environment.

The greater Rotterdam area (also known as Rotterdam Rijnmond) is located in the west of the Netherlands, in the province of South-Holland. The greater Rotterdam area is a part of what is known as the Randstad, a densely populated metropolitan area that comprises the four biggest cities in the Netherlands (Amsterdam, Rotterdam, The Hague and Utrecht), which makes it an area that is very important for the Dutch economy. The greater Rotterdam area is a so called COROP-region, a classification that is based on the principle of an (urban) core –the municipality of Rotterdam in this case- with its surrounding area that it provides services to (RegioAtlas, 2014). The greater Rotterdam area consists of 15 municipalities, with a total of more than 1,2 million inhabitants in 2014 (Table 3.1), which makes it the largest COROP-region in the Netherlands (RegioAtlas, 2014). The largest share of the total number of inhabitants of the greater Rotterdam area are living in the city of Rotterdam, which has almost 620,000 inhabitants, more than half of the entire region (Table 3.1).

Table 3.1: Absolute and relative number of inhabitants of the greater Rotterdam area (2014)

Municipality	Number of inhabitants	Share of inhabitants (%)
Albrandswaard	25071	2,05%
Barendrecht	47371	3,88%
Bernisse	12375	1,01%
Brielle	16304	1,33%
Capelle aan den IJssel	66204	5,42%
Hellevoetsluis	38955	3,19%
Krimpen aan den IJssel	28825	2,36%
Lansingerland	57111	4,67%
Maassluis	32091	2,63%
Ridderkerk	45237	3,70%
Rotterdam	618261	50,60%
Schiedam	76406	6,25%
Spijkenisse	72539	5,94%
Vlaardingen	71025	5,81%
Westvoorne	13971	1,14%
Total greater Rotterdam area	1221746	100,00%

Source: CBS Statline, 2014.

The region is even expected to keep on growing, with about six to ten per cent in the period 2002-2020 (Demos, 2004). At the same time, the province of south-Holland has to cope with an increasing amount of elderly and a shrinking amount of younger people: it is expected that by the year of 2025 at least 40% of its inhabitants are older than the age of 55 (Provincie Zuid-Holland, 2007). Although the most of these elderly tend to be living in the more urban areas of the region, it is expected that this share will decrease in the near future, following from the trend that the elderly increasingly prefer the more suburban areas near urban cores. This of course also influence their mobility needs.

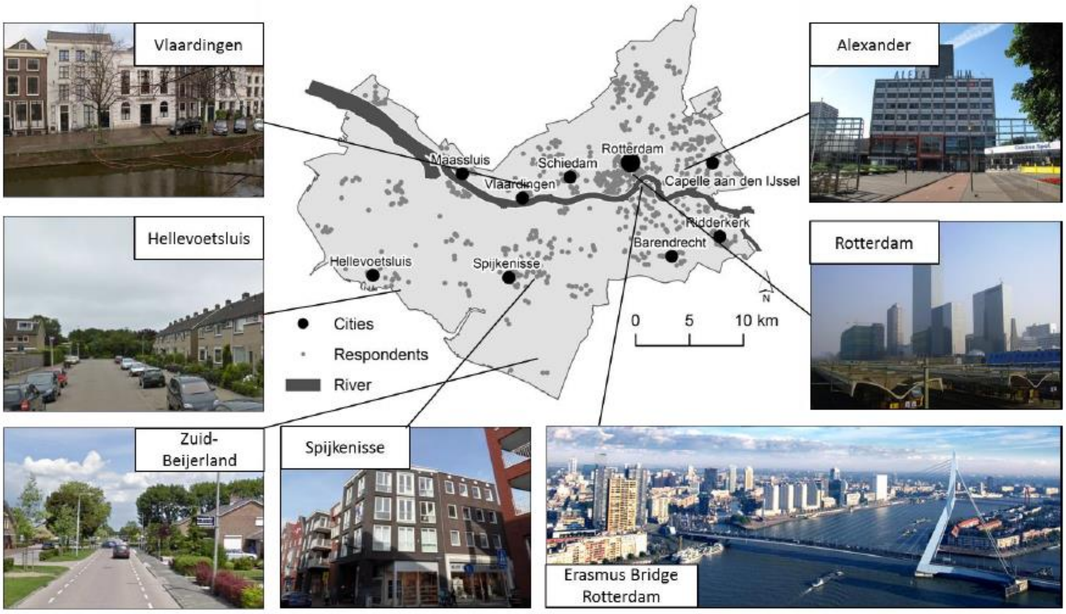
Due to the geographical location of the Netherlands and the fact that the greater Rotterdam area is located at the coast of the North-sea, the study area is characterized by a maritime climate. Because of this climate, weather conditions be relatively unstable on the short term, while there is a clear distinction between the different seasons (especially between the winter and summer). Winters are usually reasonably mild, with the coldest month having minimum temperature of -3˚C, while the average minimum winter temperature is 1˚C and the maximum winter temperature is 6 ˚C. The summers are relatively warm: with a minimum average temperature of 12˚C and maximum temperature of 21˚C. Moreover, the seasonal precipitation patterns are relatively stable (Helbich et al, 2014; KNMI, 2014). The characteristics of this type of climate and its weather conditions also illustrate how this research area can contribute to the study to the influence of weather effects to the mobility of the elderly.

Another important factor is the built environment. The built environment in the greater Rotterdam area is diverse, ranging from the more suburban landscape of Zuid-Beijerland and Hellevoetsluis to the dense inner-city of Rotterdam and its modern high-rise buildings which were constructed after the destruction of the city center during the Second World War. The modern city center of Rotterdam caused by this renewal is exactly what distinguished Rotterdam from the other cities in the Netherlands. In order to cope with this diversity, four different types of residential environments are distinguished within this research (Image 3.1 & 3.2):

- Inner-city
- Outer-center
- Suburban
- Rural

This diverse built / residential environment in the greater Rotterdam area also contributes to the study of elderly mobility, especially because the travel behavior (patterns) might also be influenced by the built environment.

Image 3.1: Impression of the study area and the location of the respondents.



Source: Helbich et al, 2014.

3.3 Data (collection)

This study used quantative methods of data collection and analysis. The advantage of using quantative methods is that it is possible to provide systematic insights into the ways that mobility characteristics of the elderly are influenced by personal characteristics and weather conditions. In addition it is possible to make generalizations about the target population of the study area (Boeije et al, 2009). When taking samples, another important concept is the 'operational population'. The operational population indicates that when taking samples it is necessary to make choices and/or concessions concerning the selection of the sample (Boeije et al, 2009). For this research the operational population comprises the elderly (ages 65 and above) inhabitants of the greater Rotterdam area.

When doing quantative research, it is often necessary to collect data from a large number of respondents by means of a survey. In this case however, data collection was not needed, as there was already a large dataset available. This dataset was collected for another research done by Utrecht University, which also focuses on the influence of weatherly conditions on mobility patterns. Unlike this research, the elderly are not the direct focus of the research the data was initially collected for. But because the dataset also includes enough data about the elderly and their mobility characteristics, it has been feasible to make use of the same dataset.

Questionnaire

The original survey has been conducted with the help of Intomart GFK, using an existing internet panel. The original sample randomly selected panel members aged 18 years and above , living in the four different types of residential environments (inner-city, outer-center, suburban and rural) of the greater Rotterdam area. The respondents were able to submit their data by the means of multiple Computer assisted web interviews (CAWI's) in the period from August 2012 to February 2013.

During the administration of the original survey, there has been a lot of attention on the background characteristics of the respondents, as these might influence preferences and travel behavior. In order to achieve a good distribution between the respondents with different characteristics such as ethnicity and living environment there was some oversampling for groups that were expected to have lower response rate (GFK, 2012).

The survey consisted of 95 questions (open ended, multiple choice and a number of statements), which were also used to filter determine if the respondents were suited for the research (and in a way that certain quota thresholds weren't crossed). In order to make sure that the results of this research project are as reliable and valid as much as possible, the used methods and constructs (as well as their measurement) have been the same as in similar existing research. The factors of reliability and validity of the research can also be facilitated by measuring complex concepts by using a number of sub-questions on a 5-point scale; the Likert-scale. This is important because the operationalization of concepts can also affect the reliability and validity of statistical research (Boeije et al, 2009; De Vocht, 2011).

The original survey included questions of a wide range of personal and household characteristics, ranging from Body Mass Index (BMI) to the availability of air-conditioning. Because not all of these variables are relevant for this research (and have not all been used for this research), only the relevant variables (that have already been mentioned in the literature review and the conceptual model) and their scale of measurement will be shown here and elaborated where necessary (Table 3.2).

Table 3.2: Description, scale and possible values of the relevant survey variables.

Variable	Description	Scale	Values
Age	Age of the respondent, measured in years.	Ratio	Current age
Gender	Gender of the respondent.	Nominal (Dichotomous)	0= Female
			1= Male
Education	Highest education degree.	Ordinal	0= Lower
			1= Middle
			2= Higher
			9= Unknown
Employment	Employment status.	Nominal (Dichotomous)	0= Working
			1= Retired
Household income	Monthly net household income.	Ordinal	1= <€2000
			2= €2000-€3000
			3= €3000-€4000
			4= >€4000
			9= Unknown
Ethnic group	Ethnic group of the respondent.	Nominal (Dichotomous)	0= Native Dutch
			1= Non-Western
Number of cars	Number of cars in the household.	Ordinal	1= 1 Car
			2= 2 Cars or more
			99= No cars
Bicycle availability	Access to a bicycle.	Nominal (Dichotomous)	0= No
			1= Yes
Public transport card	Possession of a public transport card.	Nominal (Dichotomous)	0= No
			1= Yes

Concerning the variable age, it should be mentioned that the variable will also be categorized in order to compare possible differences between age-groups. This is done by using the same categories as Alsnih & Hensher (2003) who distinguish the groups of people aged 65-75 years old and respondents aged 75 and above. In addition, people younger than the age of 65 will be categorized into an age group in order to be able to identify different mobility characteristics between these different age groups.

The original survey (Appendix 1) has been sent to 1953 potential respondents, and has eventually been filled in by 1305 of them, which corresponds with a response rate of 67%. The respondents that completed the first survey were invited (while taking into account over- and undersampling) to participate in the second phase of the research; the administration of travel diaries, which is the source of the data in the second dataset used by this research.

Travel diaries

The administration of travel diaries was used in order to monitor respondents mobility behavior, which included data about for example their mode choice and trip purpose. The respondents were not able to choose the moments in which their travel behavior was monitored themselves. They were however able to mention certain days on which they were not available, in order to make sure that both the general questions and the different stages of their travel diaries would be filled in. Respondents had to keep track of their travel behavior for a total of six days; two in summer (August and September), two in autumn (October and November) and two during the winter (December, January and February).

In order to 'prepare' the respondents for administrating their travel behavior, they also received the travel diary in advance (digital), but in the period of the travel pattern data collection they also received a physical copy as a form of support for their administration. As already mentioned the data collection took place online.

In order to prevent non-response as much as possible the goal and the relevance of the research was explained to the respondents as the willingness to respond tends to increase with this knowledge (GFK, 2012). In addition, respondents also received a monetary reward for filling in the survey and the different days of the travel diary.

The travel diaries (Appendix 2) that were used to monitor the mobility behavior of the respondents also included a wide range of variables, ranging from the departure time to the number of minutes of cycling per day. The relevant variables for this research have been elaborated below (Table 3.3).

Table 3.3: Description, scale and possible values of the relevant travel diary variables.

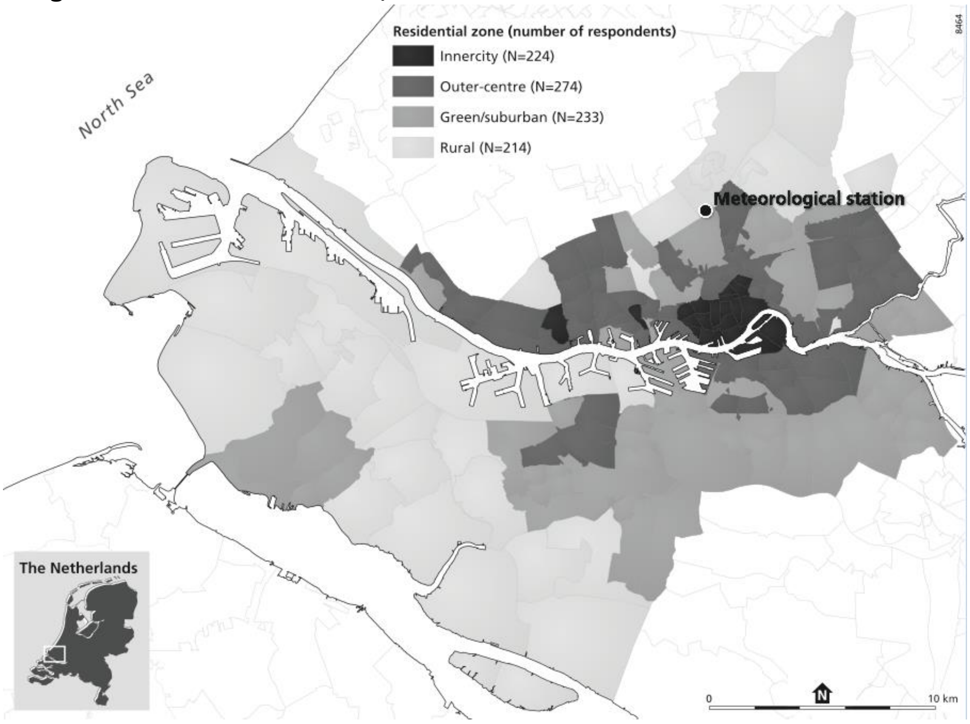
Variable	Description	Scale	Values
Trip length	Total length of the trip in meters.	Ratio	Trip length
Trip purpose	Purpose of the trip.	Nominal	1= Work / Study
			2= Errands[a]
			3= Social visits
			4= Leisure[b]
Transport mode	Main mode of transport used for the trip.	Nominal	1= Cycling
			2= Walking
			3= Public transport
			99= Car
Trips per person per day	Total number of trips per person per day.	Ratio	Number of trips
[a]=Includes grocery shopping and picking up persons.			
[b]=Includes fun shopping.			

It should be mentioned that the trip purpose variable has been reclassified into two new categories: commute and leisure, as it is expected that mobility behavior during free time allows for more or less the same mobility behavior. Mainly because it's voluntarily to a larger extent and allows for a more flexible time schedule than work related trips (with a fixed starting time).

Weather conditions

In order to be able to take into account weather conditions, the weather data was collected by the Dutch Meteorological Institute (KNMI). The data used were collected by the meteorological station in the greater Rotterdam area located north of Rotterdam (Image 3.2) in the period from August 2012 – February 2013, and comprised information about wind speed, air temperature, precipitation and snow cover.

Image 3.2: The Rotterdam area, its residential zones and the location of the meteorological station.



Source: Böcker & Thorsson, in press.

In order to be able to analyze to what extent the weather conditions influence the mobility of the elderly that are living in the study area, daily meteorological variables were used. These daily variables were based on hourly observations done by the meteorological station between 6:00 and 12:00 (A.M.), which is the timeslot in which most mobility takes place (Böcker & Thorsson, in press). The decision to use daily meteorological variables (instead of hourly) has been made because of a number of reasons. The first reason –and perhaps the most important one- is that similar studies also use daily meteorological variables, which means that the results of this study can be more easily compared to others. The second reason for making use of daily variables is because it was only possible to analyze the number of cycling trips on the daily level. By using this uniform approach, it was possible to compare the different models within this research. In addition, the choice for a certain mode of transport is in many cases also made on the daily level. Because the decision to choose for a certain mode of transport on departure also influences the mode choice when returning from the trip (Böcker & Thorsson, in press). While meteorological variables might not always reflect the weather conditions on a certain hour (of the day), both hourly and daily meteorological variables have proved to perform roughly similar in a comparable study (Böcker & Thorsson, in press). The statistical analysis proved that this also was the case in this specific research.

The meteorological variables that have been used are shown and elaborated below (Table 3.4).

Table 3.4: Description, scale and possible values of the relevant meteorological variables.

Variable	Description	Scale	Values
Daily maximum air temperature	Air temperature (˚C) daily maximum.	Interval	Temperature in ˚C
Daily average wind speed	Wind speed in m/s daily average.	Ratio	Speed in m/s
Daily precipitation sum	Precipitation sum in mm daily average.	Ratio	Precipitation in mm
Snow cover	Snow cover on the ground.	Nominal (Dichotomous)	0= No
			1= Yes

The influence of the daily air temperature on mobility behavior has been examined by using the daily maximum temperature instead of the daily average temperature. This is mainly the because the maximum air temperature gives a better indication of what type of day it is, as the average temperature might show a distorted image.

In order to be able to make visual representations of the influence of the weather related variables on for example the mode choice, the values of the daily temperature, wind speed and precipitation have been recoded into classes (Table 3.5), which also have been used in the study by Böcker & Thorsson (in press).

Table 3.5: Description, scale and possible values of the relevant meteorological classes.

Variable	Description	Scale	Values
Daily maximum air temperature class	Temperature classification	Ordinal	0= Less than 0 ˚C
			1= ≥0 <5 ˚C
			2= ≥ 5 <10 ˚C
			3= ≥10 <15 ˚C
			4= ≥15 <20 ˚C
			5= ≥20 <25 ˚C
			6= ≥25 <30 ˚C
			7= ≥30 ˚C
Daily precipitation class	Precipitation classification	Ordinal	0= None
			1= 0.01 <1 mm
			2= ≥1 <5 mm
			3= ≥5 <10 mm
			4= ≥10 mm
Daily wind speed class	Wind speed classification	Ordinal	0= 0 <2 m/s
			1= ≥2 <4 m/s
			2= ≥4 <6 m/s
			3= ≥6 m/s

Built environment data

Data about the built environment have also been provided by Utrecht University, which have been linked to the residential location of the respondents. The first of these variables is about the four types of residential environments which have been distinguished by similar studies in the greater Rotterdam study area (Böcker & Thorsson, in press; Helbich et al, 2014): inner-city, outer-center, suburban and rural areas. It is this classification that has been used for comparing the different residential environments of the respondents. The other variables are the land-use diversity, building diversity, address density, green land-use percentage, and the access to the nearest highway exit, intercity station, train station and metro station (Table 3.6).

Table 3.6: Description, scale and possible values of the relevant built environment variables.

Variable	Description	Scale	Values
Land-use diversity	Land-use diversity index (Shannon) in a 300m buffer.	Ratio	Index
Building diversity	Building diversity index (Shannon) in a 300m buffer.	Ratio	Index
Address density	Address density in a 300m buffer.	Ratio	Number
Green percentage	Green land-use percentage in a 300m buffer.	Ratio	%
Highway access	Access to the nearest highway exit in minutes by car.	Ratio	Minutes
IC station access	Access to the nearest intercity station in meters.	Ratio	Meters
Train station access	Access to the nearest train station in meters.	Ratio	Meters
Metro station access	Access to the nearest metro station in meters.	Ratio	Meters

For all of the built environment variables shown above it is necessary to make the remark that they are measured in meters around the residential location of the respondent and that it is also important to keep in mind that the access to the nearest highway exit is measured in minutes by car and not in meters like the other access variables (Intercity-, train- and metro station).

Concerning the diversity variables it is necessary to elaborate further on the Shannon index. The Shannon index is calculated by using data concerning the number of different land-use types and the proportional distribution of these land-use types across the entire surface of the area (in this case 300 meters around the residential location of the respondent). While "the Shannon index is the common approach to measure diversity" (Kuosmanen, 2010), the exact calculation won't be addressed here, the interpretation of the Shannon index is as follows: the higher the value the Shannon index, the higher the diversity in the area. In this case the Shannon index is calculated for both land-use and building diversity in order to examine their possible influence on mobility behavior.

Overview

By combining the data(sets) which were described in the previous pages with each other, the goal of this research is to investigate the influence of personal characteristics and weather conditions on mobility characteristics (while controlling for built environment factors) of the elderly people (aged 65 and above) living in the greater Rotterdam area.

3.4 Methods

Next to the descriptive statistics and visual representations of the data, for example the weather effects on modal split, this research also uses some advanced statistical methods. In order to determine to what extent personal characteristics and weather effects influence mode choice on the trip level, respondents personal characteristics, travel behavior and weather effects have been added into a multinomial logistics regression model (multinomial LOGIT). With mode choice as the dependent variable and the personal and weather data as the independent variables. The process is the same as normal logistic regression, the difference being that multinomial regression allows for a dependent categorical variable with more than two classes (in this case walking, cycling, public transport and car). This way personal characteristics, trip characteristics and weather conditions with a significant effect on mode choice have been identified, with the car as the reference category, in order to allow for comparison with other research. This has been done while controlling for the influence of the built environment factors.

In the case of the number of trips, the same data has been used, with the number of trips as the dependent variable. The only difference is that this data are of interval/ratio scale, but because the number of trips is a count variable it was not possible to perform a normal multiple regression analysis. For the number of trips per person per day, a zero-inflated negative binomial regression model has been used, mainly because the standard regression that deals with counts - the Poisson method- regression is less suited for dealing with the absence of negative values and a large number of zero's (because of the likelihood that some of the elderly respondents might not make any trips at all during a certain day), while the zero-inflated negative binomial regression models is able to handle the presence of excessive zero's and over dispersed dependent count variables (Institute for digital research and education, 2014).

The question whether there are any significant differences concerning mode choice for trips performed by different age groups (younger than 65, 65-75 and older than 75), a chi-square test has been used, because this is the only way to test for significant differences between categorical variables. In order to see if there are any significant differences between the age and gender groups for the different types of number of trips per day a student T-test has been used to compare both means.

4. Statistical analysis & discussion

4.1 Sample composition and representativeness

As already mentioned in the previous chapter, the population from which the sample was drawn consisted of the panel members of GFK Intomart living in the greater Rotterdam area, aged 18 and above. Eventually 962 out of the 1953 panel members filled in both the survey and participated in the administration of the travel diaries, a response rate of 49,3% (almost 0,08% of the entire population). Of all the data that were submitted by the respondents there have been no missing values concerning the variables that were used during the representativity analysis (gender, age (classes) and ethnicity). This has been done for the total sample but also for the elderly, as the goal of this research is to do statements about the elderly and to be able to make generalizations about the entire elderly population of the study area.

Sample composition

The total sample consisted of 476 males (49,5%) and 486 females (50,5%), of which most (43%) are between the age of 45 and 65. The elderly group sample (respondents aged 65 and above), consists of a total of 147 respondents, of which 93 males (63,3%) and 54 females (36,7%). Concerning ethnicity the largest part of the total sample consists of native Dutch (89,7%). When looking at the elderly group sample the share of respondents that are native Dutch is even higher (95,2%). Most of the respondents had an average education (36,1%), while for the elderly sample group the largest share only had a lower education degree (43,5%) (Table 4.1).

Table 4.1: Population, sample and sample elderly compositions for the representativity variables.

Variable		Sample Elderly (≥65)[d]	Total sample[d]	Population[a]
Gender	Male	63,30%	49,2%	49,2%
	Female	36,70%	50,8%	50,8%
Age	18-25	-	8,7%	12,6%[b]
	25-45	-	33,4%	28,2%
	45-65	-	49,9%	27,1%
	65-80	-	13,9%	10,9%
	>80	-	1,2%	4,1%
Ethnicity	Native Dutch	95,2%	89,6%	69,2%
	Non-native Dutch	4,8%	10,4%	30,8%
Education	Higher	23,1%	35,3%	8%[c]
	Average	32,0%	35,9%	20%[c]
	Lower	43,5%	28,1%	72%[c]
	Unknown	1,4%	0,6%	0%[c]
[a]= Population statistics Rijnmond COROP region for 2010 (2014).				
[b]= Population class is 15-25 instead of 18-25.				
[c]= % of the entire Dutch population.				
[d]= Sample data.				

Representativeness

By comparing the data from the population and the sample(s) it can be said that there is only a small difference between the variable 'gender' between the population and the total sample, while the sample that only comprises the elderly strongly differs from the population (Table 4.1). In order to test whether the population and the sample(s) are significantly different, a Chi-square goodness-of-fit test was performed. In this analysis, the expected values of the sample were equated to the same proportion as that of the population. According to the results of the Chi-square goodness-of-fit test (Chi-Square=0,037, p=0,874), there was no significant difference between the population and the total sample at the 95% confidence level. For the people of the ages of 65 and over, there appeared to be a significant difference at the 95% confidence level (Chi-Square=12,005, p=0,001).

At first sight the differences between the population and the total sample concerning the different age classes appears to be relatively small (Table 4.1). In this case it was not possible to compare the proportions of the elderly sample to the population as the population proportions also account for the other age classes. In order to test whether the population and the sample(s) are significantly different, a Chi-square goodness-of-fit test was performed. According to the results of the analysis (Chi-Square= 95,476, p=0,000), there appeared to be a significant difference between the sample and the population at the 95% confidence level. Because the importance of age within this research, it would have been necessary to weigh the cases in order for them to give a representative image. Unfortunately it was not possible to weigh the cases in order to make up for the different proportions between the sample and the population, as the weight factor of would have exceeded 1.5 (Schreurs Onderzoek, 2014). Therefore it is not possible to make generalizations about the study area and its population, which means that the findings of this research only relate to the sample (and not to the study area as a whole).

The last variable for which the representativeness was tested is ethnicity. According to Table 4.1, there seems to be a relatively big difference between the total sample and the population concerning the variable 'ethnicity'. The results of the Chi-square goodness-of-fit tests (Chi-Square=189,383 & 46,760, p=0,000) confirmed the presence of significant differences between both samples and the population of the research area at the 95% confidence level.

4.2 Mode choice of the elderly

4.2.1 Descriptive statistics

Elderly respondent's access to transport modes

From the literature review it has become quite clear that there are a number of differences between the 'previous generations', the 'new generation' of elderly and younger people concerning mobility. Perhaps the most important difference between the 'old' and the 'new' elderly, is that they have become increasingly automobile. Sample data concerning car ownership, reflects the image of the increasing automobility of the elderly like it has been illustrated in the existent literature. In total, 114 (77,6%) of the elderly respondents had one car or more available within their households, while only 33 (22,4%) of the elderly respondents had no car available within their household at all. When looking at people below the age of 65, 81,7% of the respondents have at least one car available within their household, which is almost the same percentage as the respondents aged 65 and above (77,6%). An important difference between both groups is that the respondents aged 65 and above were less likely to have two cars or more within their households (13,6%) than people below the age of 65 (33,4%). After comparing these figures and having performed a Chi-square test, it can be said that the distribution of the number of cars available within the household is significantly different for both groups (Chi-Square=23,153, p=0,000). In other words: there appears to be a (weak) significant relationship between the number of cars in the household and the different age groups (at the 99% confidence level), which might in turn also influence the likelihood for choosing the car as a transport mode.

Another factor that might influence the availability and actual use of certain transport modes is having access to a bicycle. When comparing both age groups for bicycle availability the older respondents are less likely to have a bicycle available (78,9%) than the respondents below the age of 65 (88,2%). To check whether there is a significant difference between both groups and the distribution of bicycle availability a Fisher's Exact Test (Chi-square test for 2x2 tables) was performed. The results of the test (Chi-Square= 9,419, p=0,003) indicate that the distribution of bicycle availability is significantly different for both groups which means that there is a (weak) significant relationship between age (groups) and having a bicycle available (at the 95% confidence level), which might of course also affect mode choice.

The last factor that will be looked at here (concerning a possible influence on the availability of transport modes) is whether the respondent owns a public transport card or not. When comparing both a groups for owning a public transport card, interestingly enough the older respondents are more likely to own a public transport card (51,7%) than the respondents belonging to the younger age groups (30,6%). In order to assess whether there is a significant difference in the distribution of owning a public transport card for both age groups, a Fisher's Exact Test was performed. The results of the test (Chi-Square= 24,899, p=0,000) show that the distribution of owning a public transport card is significantly different for both groups: there appears to be a (weak) significant relationship between age (groups) and owning a public transport card (at the 95% confidence level).

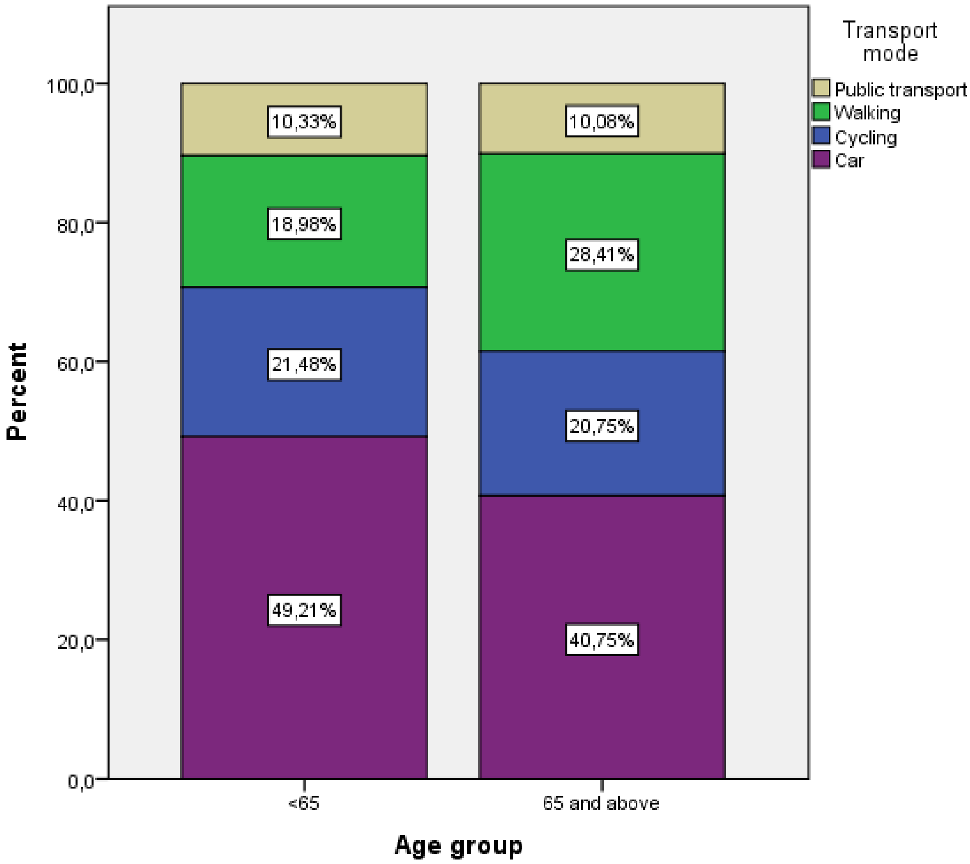
It is important to keep in mind that the presence of significant relationships between the variables discussed above and age do not indicate the direction of the relationships, as this should be tested in other ways, which will not be done within this research (as the availability and access to certain mode of transport is not the direct focus). The presence of the different distributions concerning transport mode access/availability between the elderly and non-elderly however, illustrates that older people have different characteristics concerning access and availability to certain transport modes and therefore provides a useful context for the subsequent analysis: the actual mode choice.

Actual mode choice

In total a number of 13752 trips were recorded during the administration of the travel diaries by the respondents. In 280 of these trips the transport mode was not specified, resulting in a total of 13472 trips. Out of these trips 1855 (13,77%) were made by de elderly; it are these trips that have been used as the base of the analysis corning the different transport modes.

Of the 1555 trips that were made by the elderly, the largest share (40,75%) was made by car (Figure 4.1), which confirms the overall situation that the car remains the most important transport mode for the elderly in the Netherlands. The second important transport mode among the elderly respondents appears to be travelling on foot, which accounted for 28,41% of the trips. The other transport modes, cycling and public transport, accounted for respectively 20,75% and 10,08% of all trips done by the elderly respondents (Figure 4.1). To a large extent this also corresponds with findings done described in the literature review (by Jorritsma & Olde Kalter (2008), in which the car accounts for 55% of the trips made by the elderly (although this also included 10% in which case the elderly person was not driving the car him/herself) and the bicycle for approximately 25%. An important difference between this data however, is that the share of the trips that are made by foot or public transport appear to be higher in the sample data (28,41% by foot and 10,08% by public transport) than the figures found by Jorritsma & Olde Kalter (2008), which found that walking accounted for approximately 15% of all trips and public transport for (only) 5%. This difference might be explained by the fact that, although the sample comprises data from respondents that are living in different types of areas within the greater Rotterdam area (see methodology), this does not necessarily mean that this corresponds to the average situation of the Netherlands as a whole (like the data from Jorritsma & Olde Kalter (2008), which also included data from other, more rural parts of the country. Keeping in mind the findings of the research done by Schwanen et al (2001) for example (that the elderly living in urban areas tend to use public transport more often than their rural counterparts, might explain this difference. In addition, it can be assumed that the more dense (near)urban space might prove to be more feasible for elderly to make trips by foot, hence the higher share of walking as a mode of transport.

Figure 4.1: Actual mode choice (all trips) for non-elderly (left) and elderly (right).



When comparing the elderly respondents to the respondents below the age of 65, it can be said that for the non-elderly, the car is even a more important transport mode as it is used in 49,21% of the trips. While bicycle and public transport use are mostly the same, a striking difference between both groups is the share of walking as a transport mode: the younger respondents only walk in 18,98% of the trips, while this is true for 28,41% of the trips done by the elderly (Figure 4.1) In order to assess whether there is a significant difference in the distribution of transport mode for both age groups, a Chi-square test was performed. The results of the test (Chi-Square= 94,427, p= 0,000) show that the distribution of transport modes is significantly different for both age groups, therefore it can be concluded that there appears to be a (weak) significant relationship between age (groups) and mode choice (at the 99% confidence level. But what about mode choice differences for gender- and age-groups?

Mode choice differences for gender- and age-groups

The first part second research question focusses on another aspect of elderly mobility, and is about identifying the possible influence of gender- and age-groups on mode choice.

When comparing the mode choice for all trips made by the elderly by both gender-groups, it is evident that there are some important differences in transport modes for males and females. While males used a car for 46,0% of their trips, women only used a car for 28,3% of the cases. At the same time, female respondents relatively make more of their trips by foot (38,4%) than males (24,2%) The other transport modes shares tend to be more or less the same for males and females (Table 4.2).

Table 4.2: Transport modes for the different gender-groups.

Variable / Values		**Gender**				**Total**	
		Male		Female			
		Count	% within Gender	Count	% within Gender	Count	% within Gender
Transport mode	Cycling	270	20,7%	115	20,8%	385	20,8%
	Walking	315	24,2%	212	38,4%	527	28,4%
	Public transport	118	9,1%	69	12,5%	187	10,1%
	Car	600	46,0%	156	28,3%	756	40,8%
Total		1303	100,0%	552	100,0%	1855	100,0%

Whether there is a significant difference between both groups when looking at transport modes, a Chi-Square test has been performed. The results of the test (Chi-Square= 62,303, p=0,000) indicate that there is indeed a significant difference concerning the distribution of transport mode when comparing both groups (at the 99% confidence level). Therefore it can be concluded that there is indeed a relationship between gender and transport mode of the respondents.

There are multiple studies which have stressed the importance of age-groups when assessing elderly transport mode choice. This analysis will make use of the same age-groups as the research by Alsnih & Hensher (2003), who distinguish the young elderly (aged 65-76) from the old elderly (aged 75 and above). The most striking difference between both groups is that the older age-group tends to use public transport more often (with a total share of 19,6%) than the younger age-group (with a total share of 7,6%), mostly at the expense of the car. The other transport modes shares (cycling and walking) seem to be roughly similar (Table 4.3).

Table 4.3: Transport modes for the different age-groups.

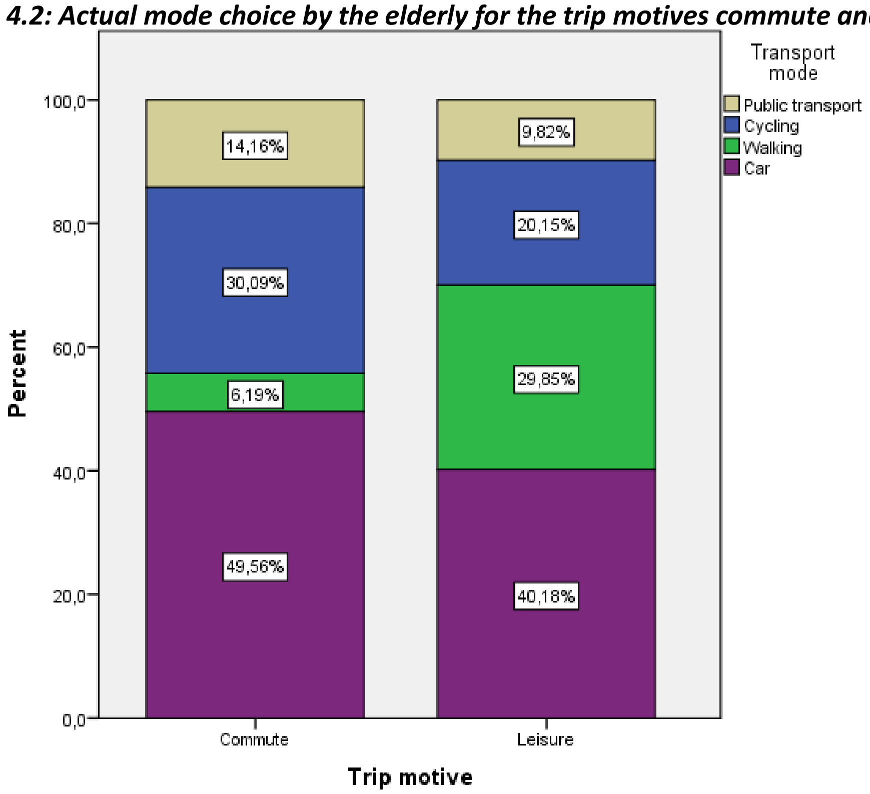
		Age-group				Total	
		65-75		75 and above			
		Count	% within age group	Count	% within age group	Count	% within age group
Transport mode	Cycling	308	21,0%	77	19,9%	385	20,8%
	Walking	424	28,9%	103	26,6%	527	28,4%
	Public transport	111	7,6%	76	19,6%	187	10,1%
	Car	625	42,6%	131	33,9%	756	40,8%
Total		1468	100,0%	387	100,0%	1855	100,0%

To assess if there is a significant difference between both groups when looking at transport modes, a Chi-Square test has been performed. The results of the test (Chi-Square= 50,759, p= 0,000) indicate that there is indeed a significant difference concerning the distribution of transport mode when comparing both age-groups (at the 99% confidence level). Therefore we can conclude that there is indeed a relationship between age-groups and transport mode choice of the respondents.

Trip characteristics and mode choice

Out of the 1855 trips made by the elderly respondents only 6,1% was made for commute purposes. Although this is only a relatively small share, the differences regarding mode choice for both trip purposes are quite clear. For leisure purposes car use and bicycle use are approximately 10% lower than trips for commutes, while the walking tends to be a more popular choice for leisure purposes (29,85%) than for commuting (6,19%) (Figure 4.2). After comparing the different transport modes for both trip motives and performing a Chi-square test (Chi-Square= 30,227, p=0,000), it can be concluded that there is a significant difference between the distribution of mode choice concerning both groups, indicating a (weak) significant relationship between trip motive and mode choice (at the 99% confidence level).

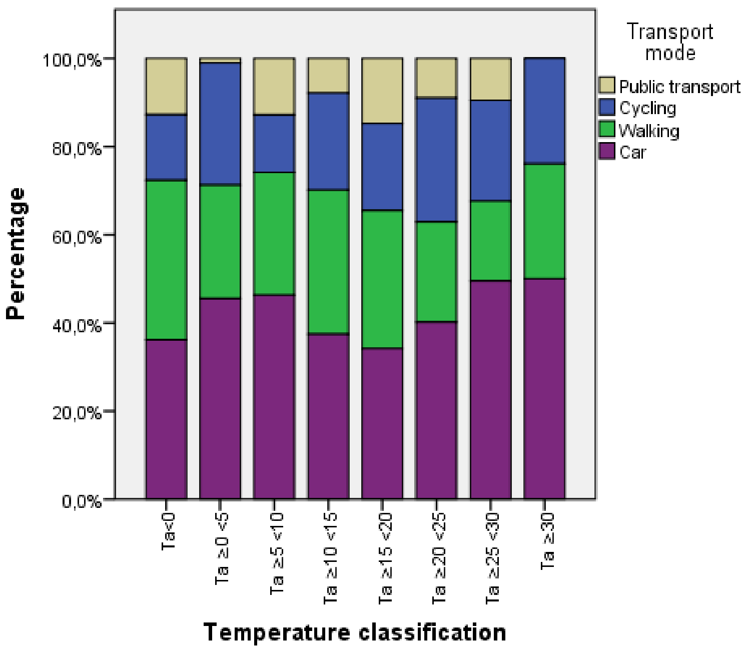
Figure 4.2: Actual mode choice by the elderly for the trip motives commute and leisure.



Weather conditions and mode shares

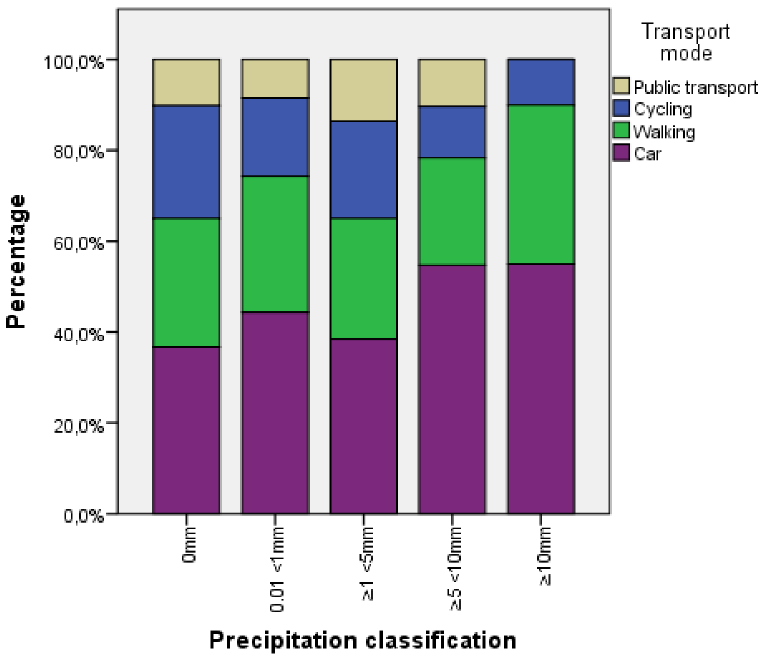
Within this research there four weather conditions which will be assessed concerning their possible influence on mobility of the elderly: the maximum daily air temperature, the daily precipitation sum, the daily average wind speed and whether there is snow cover on the ground or not.

Figure 4.3: Temperature effect on modal split.



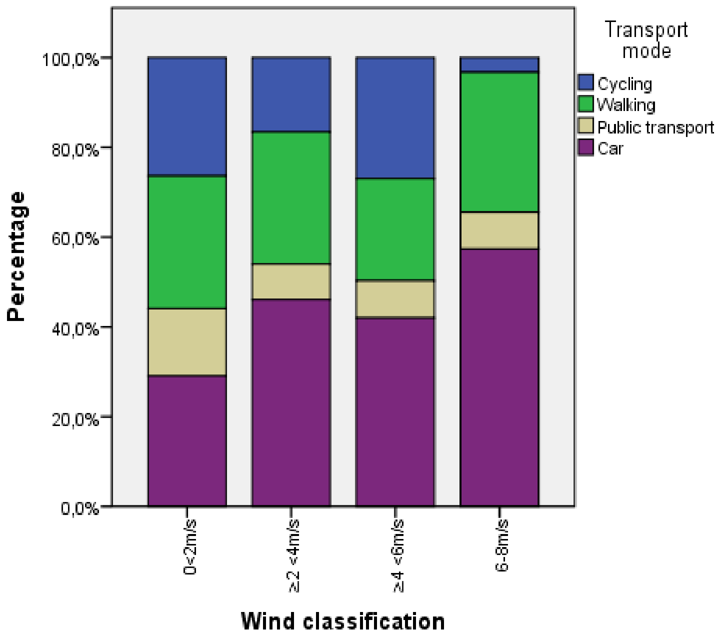
Regarding the temperatures it can be said that modes of transportation chosen by the elderly are to some extent influenced by the maximum daily air temperature, but the overall effects seem to be a bit random (Figure 4.3). When looking at car use it is worth mentioning that car use seems to be lower at days which are characterized by more average maximum air temperatures (10-25°C). This could possibly be the case because these temperatures are more suited for other forms of transportation, especially active transportation (walking and cycling). Concerning walking shares there seems to be no clear effect of the maximum air temperature although walking rates appear to be higher at temperatures below 0°C and on days with the more average maximum air temperatures. Cycling shares seems to be also positively affected by the maximum air temperatures, with the largest share of cycling trips taking place on days with temperatures between 20-25°C. (Figure 4.3)

Figure 4.4: Precipitation effect on modal split.



According to figure 4.4, the daily precipitation sum, seems to have a sigificant effect on mode choice. Especially car use seems to be postively affected by the precipitation sum, as at dry days the car use by the elderly is lower than at days with precipitation (yet it still accounts for almost 40%). At days with heavy precipitation, car use tends to be higher (approximately 10%). While there appears to be no extreme effects of the precipitation sum on walking shares, cycling seems to be negatively affected by rainfall as on days with no rainfall, cycling accounts for more than 20% of all trips, with its share steadily decreasing as the precipitation sum increases. At days which are characterized by a precipitation sum of more than 5mm, cycling shares have decreased to about 10% only (less than half of the rate at dry days). (Figure 4.4)

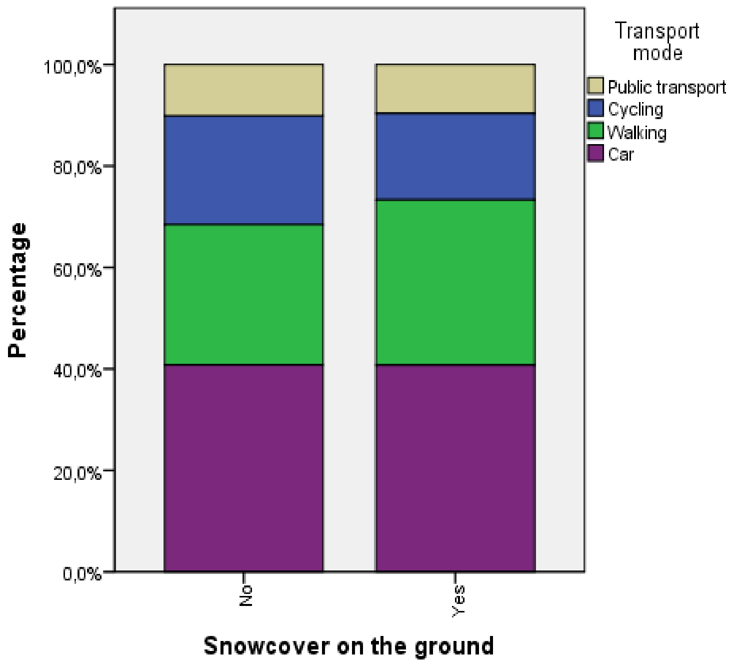
Figure 4.5: Wind speed effect on modal split.



Concerning the effect on wind speed on modal split, figure 4.5 reveals that there seems to be a very strong effect on mode choice by the elderly respondents. A striking effect is the influence on cycling share, as wind speed increases the share of cyclists tends to strongly decrease: from more than 20% for days with a wind speed ranging from 0-2 m/s to not even 5% at days with wind speeds between 6-8 m/s. At the same time, car use tends to increase at higher wind speeds, from almost 30% at days with wind speeds ranging from 0-2 m/s to almost 60% in days with wind speeds between 6-8 m/s. These findings correspond with the existing literature on the topic, although it remains to be seen whether the wind speed effects on modal split appear to be significant in this case as well.

The last weather effect that has been explored is whether snow cover has an effect on mode choice of the elderly (Figure 4.6). Figure 4 reveals that there appear to be no strong effect of snow cover on passive transport mode shares. There does appear to be a small effect of snow cover on active transport modes, as the share of cyclists tends to be a bit (not even 5%) lower on snowy days, mostly at the expense of walking as a transport mode, as the use of public transport and the car remains more or less the same. It appears to be very unlikely however that this effect/difference is significant.

Figure 4.6: Snow cover effect on modal split.



4.2.2 Multivariate model for mode choice

The last few pages illustrated that there appears to be a relationship between mode choice, personal (and household) characteristics, trip characteristics and weather conditions. In order to be able to tell something about the direction of the relationships and to what extent mode choice is influenced, a multinomial logistic regression analysis has been performed, with mode choice as the dependent variable. The independent variables within the model were the personal (and household) characteristics, trip characteristics, weather conditions and variables related to the built environment (Table 4.3). According to this, the assumptions of multinomial logistic regression concerning the variables have been met (a nominal dependent variable and metric or dichotomous independent variables). Another assumption that was met is that there is no multicolinearity between the (continuous) independent variables, with the highest correlation coefficient for intercity station access and metro station access (R=0,81) (de Vocht, 2008). Multinomial regression has no assumptions of normality, linearity and homogeneity of variance, and therefore it can be concluded that all of the assumptions regarding multinomial logistic regression are met.

According to the regression model output the model as a whole is significant (-2LL= 2904,235, Chi-Square= 1230,927, p=0,000), indicating that there is a significant relationship between the independent variables and mode choice, the dependent variable (at the 99% confidence level). The quality of the model is indicated by Nagelkerke's pseudo R-square from which it can be concluded that the model fits the data reasonably well (Nagelkerke's R^2= 0,576). Concerning the accuracy of the model it can be concluded that the 63,8% was predicted correctly, which is a modest increase over the initial model (the model excluding the independent variables).

According to model output it can be concluded that there are a number of personal and household characteristics that significantly contribute to differences concerning the mode choice of the elderly respondents. These characteristics are: age, gender, education, income, ethnicity, car ownership (within the household), bicycle availability and having a public transport card. Considering trip characteristics, both distance travelled and trip motive seemed to have a significant influence on mode choice. When looking at weather conditions, only the average daily wind speed seemed to have a significant effect on the mode choice of the elderly, while the daily air temperature only significantly influenced cycling as a transport mode. The variables related to the built environment will be elaborated on later.

Table 4.3 presents a summary of the different effects on mode choice, the variables will be discussed per variable category (personal characteristics, trip characteristics and weather conditions) in order of their relative importance (which can be derived from the Wald-statistic).

Personal and household characteristics

Out of all the personal variables, the relative most important variable influencing mode choice is having a car available within the household. When all transport modes are compared to the reference category (car as a mode of transport), owning one or more cars in all cases negatively affects the use of other transport modes in favor of the car (at the 99% confidence level) (Table 4.3). Having one car decreased the likelihood of respondents to choose for cycling and walking over the car by about 70 to 80%, for public transport this was even almost 90%. Having more than two cars even decreased the likelihood of choosing transport modes other than the car even further, by about 96% for cycling, 80% for walking and approximately by 97% for public transport. From these results it can be concluded that there is a significant negative relationship between having one or more cars available and the use of transport modes other than the car. This is consistent with findings by other studies, for example the study by Schwanen et al (2001), who found that car ownership has a strong relationship with choosing the car as a transport mode, and that it decreases the use of other modes of transport, public transport in particular.

Table 4.3: Results multinomial logistic regression model for mode choice.

Variable	Values	Transport mode					
		Cycling		Walking		Public transport	
		B	Sig.	B	Sig.	B	Sig.
Intercept	-	,047	,977	4,132	,008*	,745	,761
Personal characteristics							
Age	Age	,022	,257	-,027	,148	,033	,206
Gender (ref= Female)	Male	-1,166	,000**	-1,367	,000**	-1,415	,000**
Education (ref= Lower)	Higher	,491	,080	,410	,111	-,992	,027*
	Middle	-,151	,542	,096	,669	,053	,860
Employment (ref= Yes)	No	,784	,171	,299	,546	-,657	,441
Household income (ref= <€2000)	€2000-€3000	-,126	,589	,289	,192	,800	,013*
	€3000-€4000	,127	,667	,496	,088	1,430	,001*
	>€4000	1,941	,000**	1,151	,006*	,969	,248
Ethnicity (ref= Non-Western)	Native Dutch	1,798	,026*	,504	,343	-1,084	,179
Number of cars (ref= No cars)	1 Car	-1,772	,000**	-1,154	,000**	-2,192	,000**
	2 Cars or more	-3,148	,000**	-1,610	,000**	-3,480	,000**
Bicycle available (ref= Yes)	No	-4,484	,000**	,203	,486	,097	,788
Public transport card owner (ref= Yes)	No	-1,165	,000**	-1,157	,000**	-1,901	,000**
Trip characteristics							
Trip distance	Meters	-1,406E-04	,000**	-3,283E-04	,000**	1,453E-05	,005*
Trip motive (ref= Leisure)	Commute	,365	,318	-2,358	,000**	-,742	,128
Weather conditions							
Maximum daily air temperature	°C	,026	,044*	,016	,213	-,014	,452
Daily precipitation sum	mm	-,032	,404	-,023	,513	-,015	,793
Average daily wind speed	m/s	-,218	,001*	-,147	,014*	-,281	,002*
Snow cover (ref= Yes)	No	-,086	,779	-,373	,180	-,100	,808
Built environment (control) variables							
Residential environment (ref= Rural)	Inner city	-2,078	,006*	-,393	,554	-1,682	,061
	Outer-center	-1,126	,005*	-,536	,141	-,469	,418
	Green/suburban	-,005	,985	,869	,001*	,332	,520
Land-use diversity	Index	-2,283	,008*	-,020	,982	-2,126	,137
Building diversity	Index	-1,116	,121	,936	,138	-,808	,372
Address density	Index	2,477E-04	,126	1,402E-04	,327	,001	,000**
Green percentage	%	,018	,008*	-,004	,599	,001	,962
Highway access	Minutes	-,053	,104	,003	,927	,170	,022*
IC Station access	Meters	2,172E-05	,640	4,863E-06	,917	7,485E-05	,441
Train station access	Meters	7,306E-07	,985	-8,061E-05	,056	-1,433E-04	,169
Metro station access	Meters	5,949E-05	,197	7,691E-05	,102	-1,490E-04	,169
a. The reference category is: car.	***p<0,05, **p<0,01**						

Another important variable influencing mode choice is gender. When comparing other transport modes to the reference category (car), being male in all cases has a significant negative effect on the use of all modes of transport other than the car (at the 99% confidence level)(Table 4.3). Compared to females, males tend to be approximately 70% less likely to choose other modes of transport over the car. These findings support the research by Su & Bell (2012), who found that there were strong travel differences by gender and the research by Schmöcker et al (2008), which concluded that males are more likely to take the car than females. This is of course also related with the finding by Schwanen et al (2001) who found that women tend to be more dependent on public transport, although they have become more automobile in the more recent decades (Schwanen & Páez, 2010). The research by Schwanen et al (2001) & Schwanen & Páez (2010) also suggested that older women were more likely to use the busses than males, but because the different forms of public transport are not distinguished within this research this cannot be confirmed, although it seems to be in line with the finding that females are more likely to choose public transport over the car than males.

Having a public transport card also seemed to influence mode choice. Compared to the reference category not having a public transport card has significant negative effects on the likelihood of choosing all other transport modes over the car (at the 99% confidence level)(Table 4.3) Elderly respondents not owning a public transport card were almost 68% less likely to cycle & walk and even 85% less likely to choose for public transport over the car. At the moment of writing, the author is unaware whether there is any other research that found significant relationships between owning a public transport and mode choice, therefore there is no discussion/comparison with other research.

Concerning the variable income, respondents having a total household income of more than €4000,- a month were almost seven times more likely to choose the bicycle as a mode of transport over the car and approximately three times more likely to choose to travel on foot (compared to the car)(both at the 95% confidence level), the other income classes seemed to have no significant effect on walking and cycling use over the car (Table 4.3). When looking at public transport, respondents having a total household income between €2000,- and €4000,- seemed to be more (two to four times) likely to use public transport over the car when compared to people of the lowest (reference) income category (at the 95% confidence level). The other income classes seemed to have no significant effects on mode choice (Table 4.3). These results seem to support the findings by Schmöcker et al (2008) and Kim & Ulfarsson (2004) that lower income is associated with higher use of public transportation. What is curious is that this does not corresponds entirely with the findings by Schwanen et al (2001) that higher income is associated with higher use of public transportation, which is confirmed in the research by Schwanen & Páez (2010). So, although there seems to be a positive effect of the higher income groups in other research, there appears to be no significant effect in the study area of greater Rotterdam.

A variable that has received much less attention in the reviewed literature was the availability of a bicycle, although it is of course quite clear that this will have an effect on mode choice. Of course, having no bicycle available had a significant negative effect on choosing cycling as a mode of transport compared to the car (at the 99% confidence level)(Table 4.3). Having bicycle seemed to have no significant effects on the likelihood of choosing other transport modes compared to the car.

Also education seemed to have a significant effect on the mode choice of the elderly respondents. According to the analysis, being higher educated had a significant negative effect on the use of public transport compared to the car (at the 95% confidence level). The higher educated respondents were approximately 63% less likely to choose public transport over the car than their lower educated counterparts. Interesting here is that this is in contrast with the findings by Schwanen et al (2001) and Van den Berg et al (2011) who finds that the higher educated tend to be more likely to choose for public transport compared to the car.

According to the analysis ethnicity did not seem to significantly affect elderly respondents choice for travelling by foot or using public transportation. It did however appear to have a significant effect on the use of the bicycle as a transport mode (at the 95% confidence level)(Table 4.3). According to the results, native Dutch elderly respondents were almost six times more likely to choose for the bicycle over the car compared to their non-western counterparts. Compared to the other personal characteristics, this variables has received relatively little focus, but these results do indicate that ethnicity is a significant contributor to mode choice. Kim (2011) found that older minority females tend to make less trips compare to no-visible minority females, but this will be discussed in the paragraph concerning the number of trips.

The personal and household characteristics that seemed to have no significant effects on the other transport modes compared to the reference category are age and employment status (Table 4.3). According to the results it can be said that age seemed to have a negative (but insignificant) effect on choosing for walking as a transport mode, while having a positive effect on choosing for cycling and public transportation compared to the car. This might be explained by the findings from Mercado & Páez (2009) an Li et al (2012) that at higher ages car use tends to decrease, hence the increase of cycling and public transportation. When looking at employment status there appeared to be no significant effects, but being unemployed seemed to have positive effects on cycling and walking compared to the car, while having a negative effect on the use of public transportation. This corresponds with the findings by Schwanen et al (2001), that the retired are likely to cycle more often and are also less likely to use public transportation.

Trip characteristics

According to table 4.3, trip distance appeared to have a significant effects on mode choice, concerning all transport modes at the 95% confidence level when comparing to the reference category (car). There appeared to be negative effects for cycling and walking, with walking having the largest negative coefficient (as it is the most unlikely that people will walk larger distances). At the same time, distance seemed to have a positive effect on the likelihood of choosing for public transportation compared to the car. When looking at trip motives there appeared to be no significant effects on the likelihood of respondents choosing for cycling or public transport compared to the car. The results do indicate however, that when trips are being made for commute purposed (compared to trips for leisure purposes) this has a significant negative effect on the likelihood (almost 90% less likely) of respondents choosing for walking as a transport mode compared to the car.

Weather condition effects

Just like the personal, household and the trip characteristics, the weather conditions were added into the same multinomial regression model to assess the role of the possible significant contributors concerning mode choice. Winds speed appears to have significant negative effects on the likelihood that elderly respondents choose for all transport modes compared to the car (at the 95% confidence level). What this means is that that for days that are characterized with higher average wind speeds the chance that elderly respondents were going to make a trip by car significantly increased (compared to the other transport modes)(Table 4.5). Increases in wind speed even made the respondent about 20% less likely to choose the bicycle over the car as a transport mode, which corresponds with relative decrease of bicycle use shown in figure 4.5. When comparing these results to the findings by other studies that were elaborated upon in the literature review, it can be concluded that this corresponds with the findings by Böcker et al (2013), who found that higher wind speeds especially have a negative effect on the use of the bicycle as a mode of transport. Although this research did not specifically focus on the elderly, the findings of this study confirm that elderly transport mode choice is also affected by wind speeds. The reviewed study by Sabir (2011) found that wind speeds had no significant effects on mode choice (but more on the number of trips), which differs from the findings by this study but also from the study by Böcker et al (2013).

The maximum daily air temperature appeared to have a significant positive effect on cycling shares (at the 95% confidence level). The temperature also appeared to have a positive effect on walking and a negative effect on the use of public transport compared to the car, although these effects did not prove to be significant. These findings correspond with the findings by Sabir (2011) who also found that higher temperatures positively affect cycling shares, and at the same time also negatively affected public transport shares. Sabir (2011) also found that higher temperatures increased walking shares (but on a much smaller scale than cycling). Just like Sabir (2011), Böcker et al (2013) found that temperature positively influences the likelihood of active modes of transport. The results of this study indicate the same positive effects (although only significantly for cycling).

The daily precipitation sum has also been shown to affect transport mode choice. According to the results of the regression analysis precipitation had a negative effect on walking, cycling and the use of public transport (compared to the car), although these effects appeared to be insignificant (Table 4.3). These results are in line with some of the studies reviewed by Böcker et al (2013), that also found that precipitations appeared to have no significant effect on mode choice. But at the same time they differ from the findings by Sabir (2011) that precipitation makes people prefer other modes than active transport. Results concerning precipitation appear to be mixed however, as others research reviewed by Böcker et al (2013) find negative effect of precipitation on public transport use.

The variable that has received much less attention in research related to the influence of weather conditions on mobility is the presence of snow cover on the ground. According to the regression coefficients, the presence of snow cover on the ground appeared to have a negative effect on the use of all transport modes compared to the car. Just like the daily precipitation sum however, the presence of snow cover on the ground appeared to have no significant effects on mode choice of the elderly respondents (Figure 4.6).

Built environment factors

In addition to the former mentioned types of variables, some factors related to the built environment were also included into the model in order to be able to control for their -possible- influence on mode choice. When looking at these variables, building diversity, IC station access, train station access and metro station access seemed to have no significant effects on mode choice of the elderly. There did however appear to be significant effects on mode choice for the type of residential environment, land-use diversity, address density, percentage of green and highway access.

When looking at the type of residential environment, when respondents were living in the inner-city or outer-center this seemed to have a significant negative effect on bicycle use as a mode of transport compared to the car. This might be because urban areas are often seen as a less attractive environment for cyclists compared to rural environments. Respondents living in a green/suburban type of residential environment were significantly more likely to walk compared to the car, perhaps because these environments are seen as more attractive to walk in, but this would of course also depend on the trip motive. In both cases there appeared to be no significant effects for other transport modes. Another interesting finding is that the percentage of green has a significant positive effect on cycling compared to the car. All of these formerly mentioned findings are at the 95% confidence level. The last variable that will be looked at is the address density, which according to the findings has a significant positive effect on the use of public transport compared to the car (at the 99% confidence level). This might be because more dense areas (urban environments) often have more public transport options, which might make it a better alternative compared the car than in less dense areas (with -in many cases- less coverage and/or forms of public transportation). In order to prove this statement, more research would be needed, but as this is not the direct focus of this research it is important to realize that it is just an assumption.

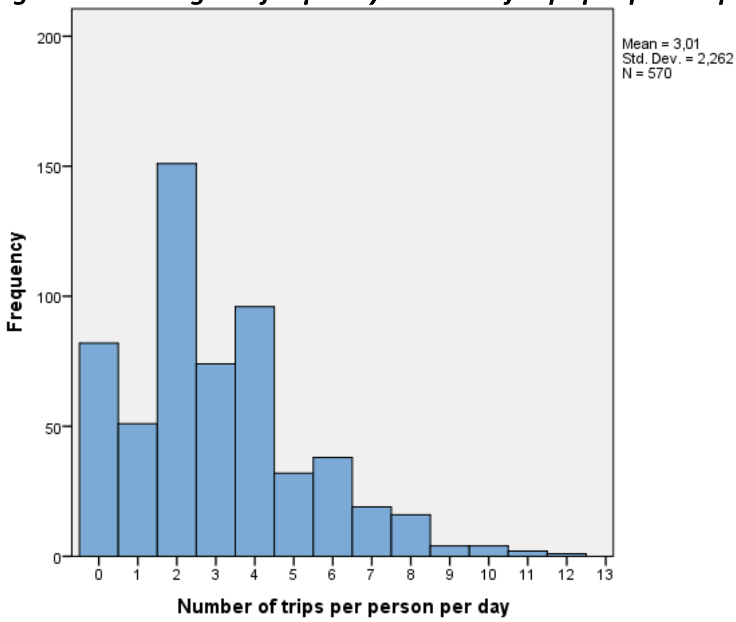
4.3 Number of trips of the elderly

4.3.1 Descriptive statistics

Elderly respondent's number of trips

Other than mode choice (which was analyzed at the trip level), the number of trips has been analyzed at the per person per day level. In total there were 570 day records made by elderly respondents, with an average that is slightly higher than three trips per person per day. According to the histogram with the frequencies of the number of trips per person per day (figure 4.7), there is also a fair amount of elderly respondents (approximately 80) that did not make any trips at all. This paragraph focusses on differences in trip rates between different groups of elderly and factors that might influence these trip rates.

Figure 4.7: Histogram frequency number of trips per person per day.



Differences in trip rates for gender- and age-groups

According to the sample data males tend to make the most trips, approximately 3,12 per day. The mean number of trips tends to be lower for females, who tend to make 2,66 trips per day (Table 4.4). In order to assess whether females in general make a smaller average amount of trips per day a T-test for the equality of means was used. According to the results (t=2,494, p=0,013) it can be concluded that females on average make significantly less trips per day than males (at the 95% confidence level). These findings confirm the findings by Su & Bell (2012) that there are significant travel difference for gender concerning the number of trips.

Table 4.4: Statistics concerning the average number of trips per person per day for both groups.

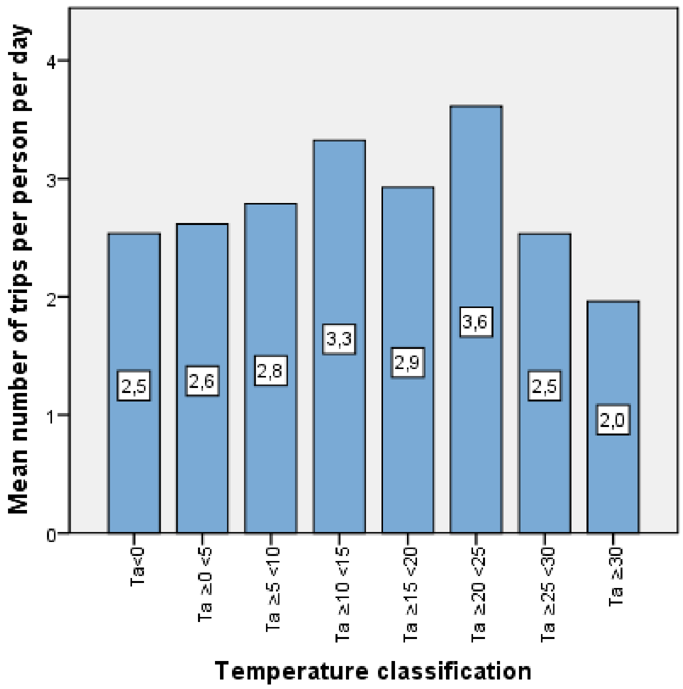
Variable			Count	Mean	Standard Deviation
Average number of trips per person per day.	**Gender**	Male	421	3,12	2,214
		Female	215	2,66	2,249
	Age group	65-75	481	3,10	2,291
		75 and above	155	2,55	2,004

When comparing the average number of trips per person per day for both age groups, the sample data indicates that elderly belonging to the younger age category make more trips on average (with a mean of 3,10 trips per person per day) than elderly belonging to the older age category (with a mean of 2,55 trips per person per day)(Table 4.4). Just like gender groups, a T-test for the equality of means was used to assess whether there is a significant difference between the average number of trips made per person per day for both age groups. From the results of the T-test (t=2,819, p=0,005) it can be concluded that there is indeed a significant difference between the mean trip rate per person per day (at the 95% confidence level): elderly belonging to the older age category, significantly make less trips than elderly belonging to the younger age-group. This confirms the findings of the reviewed literature that older age-groups significantly make fewer trips in general (Currie & Delbosc, 2009; Newbold et al, 2005; Páez et al, 2007).

Weather conditions and the number of trips

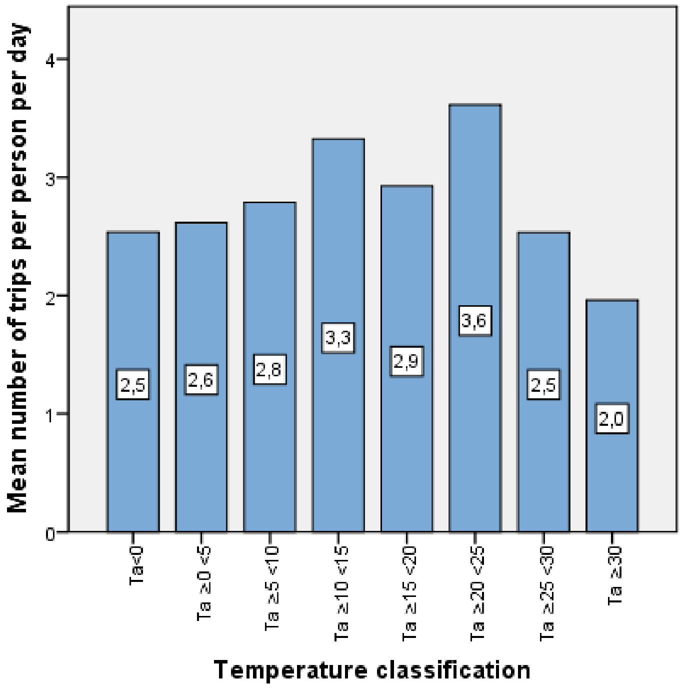
The four weather conditions will also be assessed concerning their possible influence on the number of trips. The influence of weather conditions on the number of trips will be elaborated by looking at the maximum daily air temperature, the daily precipitation sum, the daily average wind speed and whether there is snow cover on the ground or not.

Figure 4.8: Temperature effect on the number of trips per person per day.



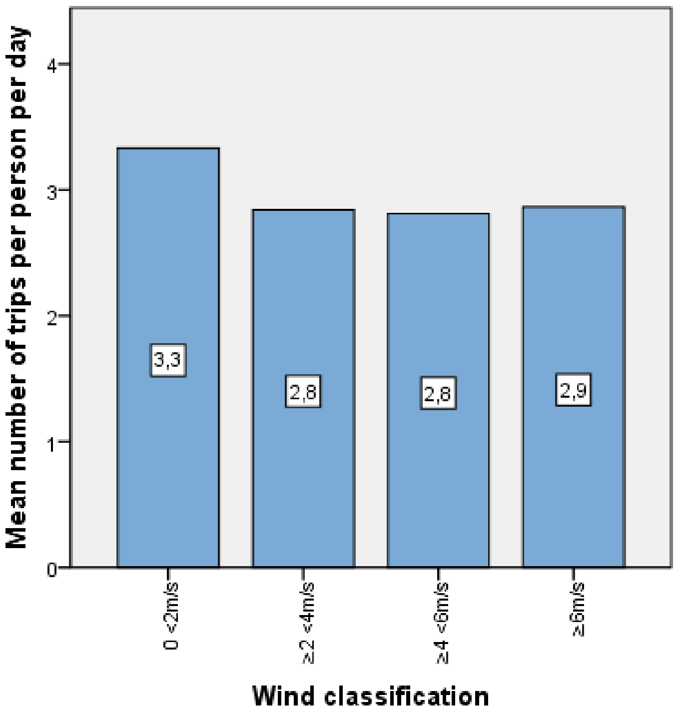
Concerning the effect of the daily maximum air temperatures, it can be said that the average number of trips per person per day seems to be influenced to some extent (Figure 4.8). With average temperatures, the average number of trips per person per day tends to be higher than on colder days, while at days with maximum air temperatures higher than 25°C the mean number of trips per person per day tends to be lower. This might be the case because higher temperatures might be strongly related to outdoor activities and leisure patterns, resulting in less trips that comprise longer distances. This seemed to be especially true for bicycle trips (Böcker & Thorsson, in press) and might also be the case for other transport modes as the figure concerning the mean number of trips per person per day includes all transport modes in this case.

Figure 4.9: Precipitation effect on the number of trips per person per day.



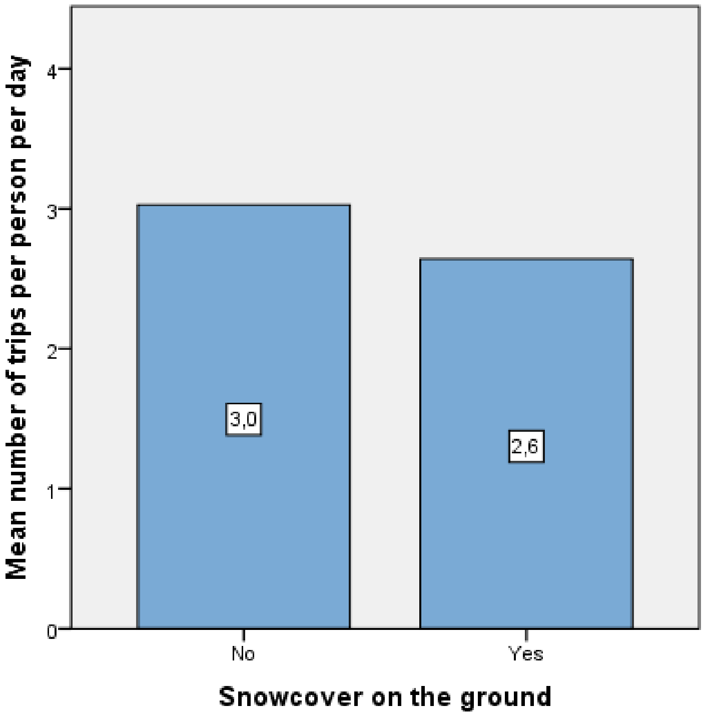
When looking at the daily precipitation sum, the mean number of trips per person per day seems to be only influenced to a small extent (Figure 4.9). It should be possible however, to make a careful statement that on days with a larger precipitation sum, the average number of trips per person per day performed by the elderly seems to be marginally lower than on days without / with less amounts of rain. Whether this negative effect is significant however, will need to be assessed by interpreting the results of the regression model for the number of trips per person per day.

Figure 4.10: Wind speed effect on the number of trips per person per day.



Looking at the effect of the different wind speeds on the mean number of trips per person per day there appears to be no significant differences between the number of trips at speeds higher than 2 m/s (as the average number of trips per person per day is either 2,8 or 2,9). Days characterized by wind speeds ranging from 0-2 m/s however, appeared to have slightly higher mean numbers of trips per person per day (with a mean number of 3,3 trips per person per day)(Figure 4.10). These small differences might be the case because of the fact that the elderly respondents might still make their trips, but with another transport mode, because wind speed does seem have significant effects on the use of certain transport modes, which the regression analysis concerning mode choice has indicated.

Figure 4.11: Snow cover effect on the number of trips per person per day.



The last weather related condition that will be explored is whether there is snow cover on the ground or not. By looking at figure 4.11 it can be said that there appears to be a small difference concerning the average number of trips per person per day for days with snow cover on the ground, and for days without. For days that are characterized by having no snow cover on the ground, the average number of trips per person per day appears to be slightly higher (with an average of 3,0 trips per person per day) than for days with snow cover on the ground (with an average of 2,6 trips per person per day. But whether wind speed has a significant effect on the number of trips performed by the elderly respondents will need to be assessed by interpreting the results of the regression model.

4.3.2 Multivariate model for the number of trips

Just like mode choice, a regression analysis was used in order to assess whether there are significant relationships between the independent variables and the dependent variable. Because the number of trips is a count variable a negative binomial regression model was used, this was preferred over the use of a Poisson model because negative binomial regression is more suited for analyses with overdispersed count outcomes. Because there is also a fairly large amount of zero's present in the count data, a zero-inflated negative binomial model was used (this proved to be a significant improvement over the regular negative binomial model according to Vuong's test: z=1,93 & p=0,0267), with the number of trips per person per day as the dependent variable. The independent variables within the model were the personal (and household) characteristics, trip characteristics, weather conditions and variables related to the built environment (Table 4.5). When looking at the assumptions of the zero-inflated negative binomial model, it can be concluded that all of the assumptions have been met: a dependent variable with counts (with zero's), metric or dichotomous independent variables and independent observations.

According to the model information, the model as a whole is significant, indicating that there indeed is a significant relationship between the number of trips per person per day and the independent variables (at the 99% confidence level). The quality of the model is indicated by Cragg & Uhler's R-square (which is the same as Nagelkerke's R-square, with a range between 0 and 1), but for zero-inflated negative binomial models), which indicates that the model is not the best fitting model (Cragg & Uhler's R^2= 0,133). The study by Páez et al (2007), also reports that a fairly large amount of the variance in the number of trips remains unexplained. It is important to realize however, that while regression models with a low percentage of explained variance might be less suited for making predictions the results still illustrate that: "other factors should be considered to make the models useful in making predictions in the study area. In any case, the results of the models provide evidence on the effects (direction and magnitude)" (Mercado & Páez, 2009, pp. 69). Another indicator of the model quality is the log-likelihood which was equal to -1163,764. Even though the log-likelihood is slightly higher for the basic negative binomial model (-1172,5528), the Vuong test is used as the main decision criterion that a zero-inflated negative binomial model fits better (Institute for digital research and education, 2014).

From the output of the zero-inflated negative binomial model it can be concluded that the personal (and household) characteristics that can be identified to have a significant effect on the number of trips performed by the elderly are: age, bicycle availability and owning a public transport card. Concerning the trip characteristics, only the trip distance seemed to have a significant effect on the number of trips. When looking at weather effects, only the daily precipitation sum seemed to significantly affect the number of trips made by the elderly.

Personal and household characteristics

The first variable that seemed to significantly affect the number of trips made by the elderly is the age of the respondents. According to the model output age appears to have a significant negative effect on the number of trips (at the 95% confidence level): for a one-unit increase in age, the log(count) is expected to change by -0,012. This means that elderly respondents with higher ages make significantly less trips than their younger counterparts (Table 4.5). This corresponds with findings by other studies that older elderly tend to make significantly fewer trips in general (Currie & Delbosc, 2009; Newbold et al, 2005; Páez et al, 2007). This might of course be the case because the elderly with higher ages are for example no longer able to (properly) drive their cars and bicycles, or they might have difficulties walking. Because age is also related to a lot of other factors (health for example), which also possibly affect the number of trips, more research would be needed in order to check this assumption.

Table 4.5: Results zero-inflated negative binomial regression model for the number of trips.

Variable	Values	Number of trips	
		B	Sig.
Intercept	-	2,112	,000**
Personal characteristics			
Age	Age	-,012	,039*
Gender (ref= Female)	Male	-,105	,281
Education (ref= Lower)	Higher	,102	,271
	Middle	,052	,523
Employment (ref= Yes)	No	,246	,154
Household income (ref= <€2000)	€2000-€3000	,005	,942
	€3000-€4000	,033	,766
	>€4000	-0,241	,112
Ethnicity (ref= Non-Western)	Native Dutch	-0,016	,934
Number of cars (ref= No cars)	1 Car	0,049	,647
	2 Cars or more	0,144	,356
Bicycle available (ref= Yes)	No	-0,056	,000**
Public transport card owner (ref= Yes)	No	-0,251	,001*
Trip characteristics			
Trip distance	Meters	-3,550E-06	,037*
Trip motive (ref= Leisure)	Commute	,064	,579
Weather conditions			
Maximum daily air temperature	°C	-,001	,778
Daily precipitation sum	mm	-,029	,025*
Average daily wind speed	m/s	-,001	,980
Snow cover (ref= No)	Yes	,182	,093
Built environment (control) variables			
Residential environment (ref= Rural)	Inner city	,175	,448
	Outer-center	,048	,720
	Green/suburban	,008	,929
Land-use diversity	Index	-,082	,789
Building diversity	Index	-,266	,253
Address density	Index	-2,800E-05	,566
Green percentage	%	-,004	,088
Highway access	Minutes	-,001	,903
IC Station access	Meters	-6,590E-06	,715
Train station access	Meters	9,180E-06	,543
Metro station access	Meters	1,640E-04	,363
***p<0,05, **p<0,01**			

Another variable that appeared to have an influence on the number of trips made by the elderly appears to be bicycle availability. According to results of the regression analysis having no bicycle available had a significant negative (B= -0,056) effect on the respondents number of trips at the 99% confidence level (Table 4.5). Meaning that older respondents that did not own a bicycle were less likely to make a larger amount of trips than the elderly respondents who did own a bicycle, indicating that bicycle availability might be an important factor when exploring the number of trips.

Being a public transport card owner also seemed to have a significant impact on the number of trips performed by the elderly (at the 95% confidence level). The results indicate that owning no public transport card had a significant negative (B=-0,251) effect on the respondents number of trips (Table 4.5). From these figures it can be concluded that elderly respondents who did not own a public transport card were less likely to make a larger amount of trips than the elderly respondents who did own a public transport card.

Yet another variable that has been taken into account, but seemed to have no significant effect on the number of trips is the gender of the respondent. The output of the regression analysis seems to indicate however, that when the respondent is a male this seems to have a negative effect on the number of trips (B=-0,105) compared to females, although insignificant (Table 4.5). At the same time this differs from the earlier finding by this study (pp. 44) that (when not controlling for the other variables), females on average make significantly less trips per day than males. According to the literature however, their appeared to be significant travel differences by gender (Su & Bell, 2012). When not controlling for other variables, the findings of this study seems to correspond with the findings by Su & Bell (2012), but according to the regression analysis (which also controls for other variables) the findings of this study seems to differ from the findings by Su & Bell (2012).

According to Schwanen et al (2001), “Educational attainment is most strongly related to engagement in out-of-home activities” (Schwanen et al, 2001, pp. 353), which should therefore result in a larger amount of trips. Also van den Berg et al (2011) found that the higher educated seemed to make more trips, but especially for social visits. The results of the regression analysis indicate that there does indeed seems to be a positive effect of educational attainment on the number of trips, although the relationship appears to be insignificant in this case(Table 4.5).

Also employment status seemed to have no significant effect on the number of trips performed by the elderly respondents. When exploring the regression coefficients however, it does seems to be the case that being unemployed has a positive (but insignificant) effect on the number of trips compared to being employed (Table 4.5). This might be the case because unemployed elderly might have more free time available in which they can make more trips, while employed elderly are obliged to commute but have less free time available in which they can make other trips. These findings seem to differ from the findings by Newbold et al (2005) that employed people tend to make a larger number of trips, and from the findings by Schwanen et al (2001) that employed people use both car and public transport more often, while retired elderly tend to walk and cycle more often. It is however not possible to compare these results, as the found relationship appears to be insignificant in this case and the fact that the dependent variable includes trip rates from all transport modes.

According to the model output, household income also seemed to have no significant effects on the number of trips made by the elderly respondents. When looking at the regression coefficients however, respondents earning between €2000 and €4000 a month seemed to be slightly more likely to make a larger amount of trips compared to the reference category (earning less than €2000,-). For respondents earning more than €4000,- however, there appeared to be a negative effect (B=-0,241)(Table 4.5). It is possible to question this, but it does corresponds with the statement made by Mercado & Páez (2009) that that findings on trip frequency and income has been mixed.

Another variable that has been elaborated upon was ethnicity. Kim (2011) for example found that older minority females tended to make less trips than other elderly. The results of this study indicate that there appears to be no significant effect of ethnicity on the number of trips, although the regression coefficient does seem to indicate that elderly with a native-Dutch origin appear to be slightly less likely to make a larger amount of trips than their non-western counterparts (Table 4.5) This is not in line with what would be expected when looking at the findings by Kim (2011) but it is important to keep in mind that the model output appears to be insignificant in this case.

While the number of cars did prove to have a significant effect on mode choice of the elderly respondents, the variable did not seem to have a significant effect on their number of trips (Table 4.5) When exploring the regression coefficients of the variables however, it seems to be the case that car ownership has a positive effect on the number of trips made by the elderly. In some way this corresponds with the findings by Páez et al (2007), that access to a car / car ownership seemed to results in a significantly larger amount of trips performed by the elderly. It should be stressed however, that according to the findings by this study, the number of cars within the household appears to have no significant effect.

Trip characteristics

According to the model output, only trip distance appeared to have a significant positive effect on the number of trips performed by the elderly respondents (at the 95% confidence level). The regression coefficient indicates that for a one-unit increase in age, the log(count) for the number of trips is expected to decrease slightly. This finding seems to be a logical one, as it is highly unlikely that respondents are able to make a large number of trips per day in which they cover very large distances. For trip motives there appeared to be no significant effects, although the regression coefficient tends to indicate that trips for commute purposes have a positive effect on the number of trips, which seems to be in line with the findings by Newbold et al (2005) that employed people tend to make a larger amount of trips.

Weather condition effects

The only weather condition variable that appeared to have a significant effect on the number of trips per person per day seemed to be the daily precipitation sum. According to the results of the regression analysis, the daily precipitation sum has a slight significant negative effect (B= -0,029) on the number of trips (at the 95% confidence level)(Table 4.5). This means that the higher the precipitation sum, the less likely it is for elderly respondents to make a larger amount of trips. This corresponds with existing literature on the influence of weather conditions on the number of trips. Some of the studies reviewed by Böcker et al (2013) for example, found that precipitation might especially have on the amount of traffic that takes place by car, and that public transport rates might also be negatively affected. This of course could mean that in total less trips per person per day are made when these trips are not performed by another transport mode (although it seems to be unlikely that people prefer active modes of transport during rainy days).

Also the maximum daily air temperatures appeared to have no significant effect on the number of trips per person per day, although there appeared to be a slight negative effect of the temperature on the number of trips (B= -0,001)(Table 4.5) This to some extent corresponds with already existent literature on the topic, which seems to find that temperature affects mode choice especially (Böcker et al, 2013; Sabir, 2011). This of course does not necessarily mean that it therefore also affects the number of trips per person per day.

The average daily wind speed also appeared to have no significant influence on the number of trips per person per day. The regression coefficient also proved to be negative (B= -0,001), indicating a slightly negative effect of the average daily wind speed on the number of trips performed by the elderly respondents (Table 4.5). This finding is rather odd, because other studies found significant relationships and effects between wind speed and the number of trips. Sabir (2011) for example found that wind speed had a significant effect on individual travel demand / the number of trips.

In addition, snow cover also seemed to have no significant effects on the number of trips per person per day. When interpreting the regression coefficients however (Table 4.5), the absence of snow cover on the ground appeared to have a positive effect (B= 0,182) on the number of trips compared to the reference category (snow cover on the ground). Results by existing studies indicate that the presence of snow cover on the grounds appears to effect mode choice especially (Böcker et al, 2013; Sabir, 2011).

Built environment factors

Unlike for mode choice, none of the built environment factors seemed to have a significant effect on the number of trips performed by the elderly (Table 4.5).

When looking at the residential environment it seems to be the case that when the elderly respondents are living in more dense urban environments this seems to have a positive (but insignificant) effect on their number of trips compared to less dense residential environments. This did however seem to be rejected by looking at the coefficients of the address density which seemed to imply that when areas were more dense this had a negative effect on the number of trips. It can therefore be concluded that the variables concerning density did seem to report mixed and insignificant findings (Table 4.5)

Concerning the diversity of the built environment there appeared to be no significant effects on the number of trips performed by the elderly. There do appeared to be some evidence however, that more diverse environments seemed to have negative (but insignificant) effects on the number of trips made, meaning that the elderly seemed to make less trips when living in more diverse area (Table 4.5) This does however not necessarily mean that this is because the respondents were able to chain their trips as each visit was administrated separately.

Looking at the different types of access to certain transport modes there also appeared to be no significant effects on the number of trips made by the elderly. Distance to the highway and Intercity station seemed to both have negative (but insignificant) effects on the number of trips, while distance to regular train and metro stations seemed to have positive effect (Table 4.5). Because of these mixed results it is hard make any remarks concerning their effects on the number of trips, as they seemed to be more important for mode choice.

5. Discussion and conclusions

The increasing life expectancy has been recognized to have a number of important consequences for mobility, especially because older people are able to maintain their mobility rates for a longer time while having a greater need of mobility because of different living preferences and the desire to continue living independently (European commission, 2009; OECD, 2002). In the Netherlands research seems to suggest that this may result in additional growth of the total mobility of almost three per cent (Joritsma & Olde Kalter, 2008), meaning that there will be an increasing share of elderly in traffic which might cause certain problems to arise (increased crash rates for example). While this illustrates that elderly mobility is both important and relevant, the topic remains relatively unexplored (although the topic seems to have been receiving more focus during the last few years).

According to existing literature on the topic, there is a large number of factors that might influence the mobility of the elderly (indicated by mode choice and the number of trips). The majority of the authors focus on the effect(s) of personal and household characteristics such as age, gender and education (for example Alsnih & Hensher, 2003; Newbold et al, 2005; Van den Berg et al; 2011). In addition to personal and household characteristics, the built environment also received attention by elaborating upon the effects of density, diversity and accessibility on the mobility of the elderly (for example Borst et al, 2009; Rosso et al, 2010). While studies have shown that weather conditions (temperature, precipitation, wind speed and snow cover) are also able to affect mode choice and the number of trips in general (Böcker et al, 2013; Sabir, 2011), the effects of these weather conditions on mobility of the elderly in particular have remained particularly unexplored. That's why next to the influence of personal and household characteristics (while also controlling for the influence of the built environment and trip characteristics) the goal of this research was to gain a better understanding of the effects of weather conditions on elderly's mode choice and the number of trips. This was done by focusing on the elderly living in the greater Rotterdam area, because of a number of reasons: a large population with an increasing amount of elderly and a shrinking amount of younger people (Provincie Zuid-Holland, 2007), its climate (relatively unstable on the short term, with a clear distinction between the different seasons) and a diverse built environment.

5.1 Mode choice and number of trips of the elderly

From the literature it has become evident that the elderly have become increasingly automobile (Rosenbloom, 2001). This is confirmed by the results from the descriptive analysis, as a large number of elderly respondents (77,6%) had one car or more available within the household, which is more or less the same than the non-elderly / people below the age of 65 (81,7%). At the same time, Elderly respondents were less likely to have two cars or more available within the household (13,6%) and they were also less likely to have access to a bicycle (78,9%) compared to their younger counterparts (33,4% and 88,2% respectively). Interestingly enough, older respondents were more likely to own a public transport card (51,7%) than people below the age of 65 (30,6%). All of these findings appeared to be significant at the 95% confidence level, illustrating that there is a difference in the distribution of access to transport modes when comparing the elderly to the non-elderly. When comparing the actual mode choice of the respondents, elderly respondents take the car in less cases (40,75%) and walking seems to be a more important transport mode for them compared to people below the age of 65 (49,21% and 18,98% respectively), indicating a significant difference in the distribution of actual transport mode use at the 99% confidence level.

Regarding mode choice, the personal and household characteristics which were found to have a significant effects were: gender, education, income, ethnicity, car ownership (within the household), bicycle availability and owning a public transport card. In line with previous research (Schwanen et al, 2001), car ownership seems to have a negative effect on the use of transport modes other than the car. Also the finding that males are less likely to use all modes of transport other than the car are supported by other studies (Schmöcker et al, 2008; Schwanen et al, 2001; Schwanen & Páez, 2010; Su & Bell; 2012) that also find travel differences by gender, and that males are more likely to drive the car than females (who are more dependent on other transport modes than the car). According to the results, educational attainment had a negative effect on the use of public transportation, which is in contrast with the findings by Schwanen et al (2001) and Van den Berg et al (2011) who find that the higher educated tend to be more likely to choose for public transport compared to the car. When looking at income, respondents in the highest income category (more than €4000,-) appeared to be significantly more likely to use active forms of transportation compared to the car. Also, respondents having a total household income between €2000,- and €4000,- a month were more likely to use public transport over the car. Results concerning income in previous research has been mixed, and it can be said that these findings are in line with Schmöcker et al (2008) and Kim & Ulfarsson (2004), while it differs from the studies by for example Schwanen & Páez (2010), who found that higher income is associated with higher use of public transportation. There were also a number of variables that received much less focus in previous research, that proved to affect mode choice in the study area. The results for example indicated that native Dutch elderly were more likely to choose for the bicycle over the car than their non-western counterparts (possibly because of the Dutch 'bicycle culture'), and that not having a public transport card has significant negative effects on choosing all other transport modes other than the car. In addition, having no bicycle available had a negative effect on choosing for the bicycle as a transport mode. Factors that were found to have significant effects on mode choice in other studies but had no significant effects in the greater Rotterdam area are age and employment status (Mercado & Páez, 2009; Li et al, 2012; Schwanen et al, 2001), although the direction of the effects seem to be in line with these studies.

Looking at the number of trips made by the elderly, the personal and household characteristics that appeared to have a significant effect were: age, bicycle availability and owning a public transport card. In line with previous research (Currie & Delbosc, 2009; Newbold et al, 2005; Páez et al, 2007) age was found to have a negative effect on the number of trips, as higher ages possibly poses some problems to maintain higher trip rates. Also having no bicycle available and not owning a public transport card seemed to have a negative effect on the number of trips made by the elderly, as these transport modes offer more viable alternatives to the car on longer distances (when one is no longer able to drive) and the unavailability of these transport modes might therefore also negatively affect the number of trips. While there appeared to be no other significant predictors for the number of trips made by the elderly, the direction of the effects seemed to match previous research: for the variables gender (Su & Bell, 2012), education (Schwanen et al, 2001) and car access (Páez et al, 2007). Just like for mode choice income has been reported to yield mixed findings (Mercado & Páez, 2009), which also seemed to be true in this case. The (insignificant) findings by this study concerning employment status and ethnicity seemed to differ from previous studies (Kim, 2011; Newbold et al, 2005; Schwanen et al, 2001).

When exploring differences between gender-groups, males make significantly more trips per person per day (3,12) than females (2,66) and they also tend to be more reliant on the car than females, which tend to walk more often. These findings could be related to gender roles, indicating that females might be more focused on doing tasks within the household, which would result in them making less trips than males, who often needed the car for their commutes (resulting in different transport habits). When comparing age groups (65-75, >75), the older age group makes significantly less trips per person per day (2,55) than the younger age group (3,10) and the older age groups tend to use the car less compared to the younger age groups, while the share of public transport tends to be higher. This could be explained by difficulties arising from the aging process, making it less feasible for elderly to attain their trip rates. At the same time their ability to drive the car themselves might decrease, resulting in a need for a suitable alternative. This might help to explain the higher share of public transport use at higher ages.

Concerning the influence of weather related factors on the mode choice and the number of trips of the elderly respondents, the results indicate that wind speed has significant negative effects on the use of all transport modes compared to the car. For a part, this is in line with the findings by Böcker et al (2013), who found that higher wind speeds negatively affect bicycle use. Although the study by Böcker et al (2013) does not specifically focus on the elderly, the findings by this study confirm that elderly transport mode choice is also affected by wind speed. The maximum daily air temperature also appeared to have a significant positive effect on cycling shares. In addition, the maximum daily air temperature also had a positive effect on walking shares and a negative effect on the share of public transport (but insignificant), which corresponds with the studies by both Böcker et al (2013) and Sabir (2011). No significant effects were found for the daily precipitation sum and snow cover. When looking at the influence of weather conditions and the number of trips made by the elderly respondents, only the daily precipitation sum seemed to have a significant (negative) effect, which is in line with the findings by Böcker et al (2013). For the other weather related factors there appeared to be no significant effects.

From the literature review it has also become evident that trip characteristics and the built environment factors might also influence mode choice and the number of trips. According to the analysis, trip distance seemed to have a significant negative effect on the number of trips and also seemed to significantly affect mode choice of the elderly respondents living in the study area (negative for active modes of transport and positive for public transportation compared to the car). When looking at trip motives, when trips were made for commute purposes this seemed to have a significant negative effect on walking as a transport mode, trip motives seemed to have no significant effects on the number of trips. When looking at the built environment factors, there appeared to be no significant effects on the number of trips. The type of residential environment, land-use diversity, address density, the percentage of green and highway access however, seemed to significantly influence elderly's mode choice.

From these results, it can be concluded that the findings to a large extent reflect the existing literature on the topic. This confirms that personal and household characteristics, built environment related factors and weather conditions might all influence elderly's mode choice and their number of trips. Although not all of the variables appeared to have significant effects, the direction of the effects appeared to be the same as in the literature in most of the cases.

5.2 Policy recommendations

Although it is not possible to make any statements about the entire study area, the results do indicate that policymakers should recognize and try to anticipate on potential problems related to population aging and mobility. A large number of studies (this study included) shows that the car is an important transport mode for the elderly, which could prove to be problematic at higher ages. Therefore policy could be aimed at monitoring and improving elderly driving skills, making them able to attain their mobility in a safe way. At the same time however, it is important to realize that research has shown that the elderly have becoming increasingly automobile. While it remains to be seen to what extent this trend continues, it is likely that in the future there will be a larger number of elderly who has both a driver's license and a car available. This could put additional stress on the road network as well as have important consequences regarding durability and climate change.

Therefore promoting the use of transport modes other than the car, public transport for example could prove to be a viable strategy (as it seems to be an important transport mode at higher ages). This could be done by planning for more sustainable forms of mobility (walking, cycling and public transport) and transit-oriented developments (TOD's), as research has shown that residents of a TOD-area tend to use of their cars less (Boschmann & Brady, 2013).

5.3 Strengths and limitations

This study confirmed some of the findings by other studies that there are a number of personal and household characteristics that might influence mobility of the elderly living in the greater Rotterdam area. The findings also indicate that weather conditions is possible to influence elderly's mode choice and their number of trips, providing evidence that it can be useful to include weather data into analyses concerning mobility characteristics of the elderly. This might also help to explain regional differences concerning the results of studies to elderly mobility characteristics (and factors that influence this mobility). Although in reality there are a large number of other factors that might also influence the mode choice and the number of trips of the elderly, the regression models appeared to be significant improvements for predicting elderly mobility characteristics and factors that might affect this mobility.

Despite these results, it is important to make a number of remarks concerning the research process. The first remark is related to the fact that the automobility of the elderly in comparable research is often illustrated by both the percentage of car ownership and the percentage of elderly in the possession of a driver's license. Unfortunately, the survey that was used for this study did not include a question concerning whether the respondents was in the possession of driver's license, therefore it was not possible to assess the influence of this variable (and if the variable could have been included this might have led to different results), although car availability seemed to have stronger effects then having a driver's license in other studies (Schwanen et al, 2001). Second, while this research recognized that the elderly are far from a homogenous group, it was not possible to do justice to this diversity (compare groups with the same lifestyles or health for example). A third limitation of the study is related to the fact that the sample as whole did not appear to be representative, meaning that the findings only relate the sample of the elderly respondents. Therefore it is not possible to translate the findings and to make any statements about to study area as a whole. The last remark that will be made here is related to the value of the regression models for predictive purposes. While the entire research process resulted in a reasonable model for mode choice, the explained variance for the number of trips remained relatively low, indicating that there might be other important variables for the number of trips made by the elderly that are not included in the present study. It is important to realize however, that the use of the models should not be underestimates as they still give a proper indication of factors that might influence elderly mobility characteristics.

Besides addressing the previously mentioned shortcomings, there are a number of possible directions for further research. First of all, this kind of research might benefit from replacing the self-administration of travel diaries by more advanced forms of data collection, such as GPS tracking, yielding more accurate results. In addition, it might be interesting to make different regression models for the different types of number of trips (number of walking trips, number of cycling trips) and for trips with certain motives (commute, leisure etc.) in order to assess the differences between these trips and variables that might affect them. Considering the effect of weather conditions, it might also be valuable to add respondents weather expectations, and weather conditions at the hourly level to assess their influence. These findings illustrate that there are ample opportunities for additional work concerning elderly mobility. It is hoped that the present study will stimulate further research to the topic.

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