Universiteit Utrecht

# Steps towards an active future

## A study on the influences on transport mode choice to school among Dutch adolescents

Master Thesis Urban Geography

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Supervisor: Marco Helbich

September 2016

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## Preface

Dear reader,

In front of you is my master thesis on active travel to school among Dutch adolescents. I wrote this thesis as a final step to conclude my master Urban Geography at Utrecht University. Writing my thesis was a long process filled with ups-and-downs. While there were times when it was stressful and difficult, I also learned a lot about the subject of my thesis and about independently writing and executing a research project from beginning to end.

Because walking and cycling are such an important part of everyday life, it was very interesting to approach these daily events from a scientific point of view. I also found adolescents to be an interesting group to study, for they behave very differently from children and adults. I am happy that my thesis focused on them, because I think that targeting this age group could result in actual change.

I would like to thank several people for their help and support throughout this process. First of all, I want to thank my supervisor Marco Helbich for his guidance and feedback. A special thanks goes to Willem, for all his patience and support during this time. Finally, I want to thank my family and friends for their support, pep-talks and welcome distractions.

Judith Soemers
September 2016

## Abstract

Obesity and overweight levels are rising and form a major health treat among adolescents. A way of counteracting and preventing this condition is by stimulating physical activity in the form of active commuting to school. Relatively little is known about what influences the mode choices to school among Dutch adolescents. Therefore, the aim of this research was to provide insights in the mode choice among Dutch adolescents between passive transport, walking and cycling to school. Data from the Dutch national travel survey ('Onderzoek Verplaatsingen in Nederland 2012 – OviN 2012 versie 2.0') was used for the analysis. Cycling was the most common transport mode among Dutch adolescents with 77,3% of the trips, 18,7% of the trips was made with a passive transport mode and walking was the least common transport mode with 4,0% of the trips. A multinomial logistic regression model was applied on a total of 5161 trips to school in order to find what characteristics were related to the mode choice to school among Dutch adolescents. The characteristics that were found to be related to mode choice were age, gender, ethnicity, household car ownership, household bicycle ownership, urban density of the municipality of residence, percentage of water, percentage of green, temperature, precipitation and distance. The most influential characteristic for walking and cycling was distance and the second most important predictor for walking was age and for cycling household bicycle ownership. In order to encourage active commuting to school, several policy recommendations were made, namely avoiding the merging of schools to serve a larger area in order to keep the distances from home to school as short as possible, teaching youths with a non-native ethnic background how to cycle and/or help them gain experience with cycling, setting up programs for subsidizing bicycles or a bicycle loan program, displacing the parking spaces for scooters or light motorcycles combined with education and regular communication with more vulnerable groups such as girls and non-native adolescents in order to isolate and address safety concerns.

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# 1.Introduction

## 1.1 Obesity and overweight

Obesity and overweight are a major health threat among adolescents as their levels are rising worldwide (Mendoza & Liu 2014). The World Health Organization (WHO) (2015) states that worldwide obesity rates have risen with nearly 50% among adolescents since 1980, with more than 22% of girls and nearly 24% of boys considered either overweight or obese in developed countries (Institute for Health Metrics and Evaluation 2015). Compared to global statistics the Netherlands has a lower number of overweight adolescents, namely 14% of the Dutch adolescents are considered overweight and 2% of this group is obese (Convenant Gezond Gewicht 2013). However, in 1980 the number of overweight adolescents was only 6%, which indicates that also in the Netherlands the number of overweight adolescents is more than doubled in this period of time (Nationaal Kompas Volksgezondheid 2014).

Overweight and obesity are defined by the WHO (2015) as abnormal or excessive fat accumulation that may impair health. The World Health Organization states that childhood obesity can cause type 2 diabetes, cardiovascular risk factors, hypertension, an increased risk of fractures, breathing difficulties, psychological effects, disability in adulthood and premature death. Overweight and obese youth are likely to take obesity into adulthood (Singh et al 2006), where it can lead to cardiovascular diseases (particularly stroke and heart disease), diabetes, musculoskeletal disorders and some cancers (breast, colon and endometrial) (WHO 2015). Moreover, obesity is thought to become the most influential cause of preventable diseases in the near future (Van der Horst-Nachtegaal 2009).

The main underlying cause of overweight and obesity is a long-term energy imbalance between the intake of calories and the calories that are expended (De Vet et al 2011; WHO 2015). The reasons for the rising worldwide levels of overweight and obesity among adolescents can be found in an increased intake of high fat energy-dense foods (WHO 2015) and a decrease of physical activity. This decline of physical activity is related to a general reduction of physical activity during youth and from youth to adulthood as well as the development of more sedentary behaviors among young people (De Vet et al 2011; Eyler et al 2008). During school hours there are less possibilities to be physically active and during non-school hours sedentary activities often have taken the place of physically active activities. These are activities such as watching TV and playing video games (Eyler et al 2008). Particularly computer use among children and adolescents has increased vastly (Singh et al 2006).

Obesity is difficult to treat and the treatment is often not effective in the long run (Singh et al 2006), however obesity and overweight are preventable according to the WHO (2015). Since obesity and overweight often start during youth (Singh et al 2006), it is important to focus on preventing and counteracting this it at a younger age (Elinder et al 2014). During adolescence, behavioral and cognitive skills are established, which makes this a useful age group to target when preventing overweight (Sing et al 2006). The recommendations that are made in order to prevent and counteract a raised BMI are a healthy diet and to engage in regular physical activity. More explicitly, this means for adolescents 60 minutes a day of moderate to vigorous physical activity (WHO 2015). However, only 35% of the adolescents in the Netherlands gets 60 minutes per day of physical activity and 22% is considered inactive on a daily basis (Convenant Gezond Gewicht 2013).

## 1.2 Active transport to school

Because of the severe consequences of overweight and obesity it is important to concentrate on counteracting this condition. This study will look at physical activity as a way of preventing and counteracting obesity and overweight among adolescents. The journey between home and school is gaining more and more attention as a source of physical activity for adolescents on a regular basis towards reaching the daily physical activity requirement of at least 60 minutes of moderate to vigorous physical activity per day (D'Haese et al 2011).

There are several advantages to focusing on active travel (which means walking and cycling) to school as a source for physical activity. First, active travel to school is an opportunity for implementing physical activity within the daily life of adolescents. This could add a form of physical activity on most days of the week which might be more difficult to avoid than physical activity in leisure time. Furthermore, active travel is cheap, easy, sustainable and is accessible for a large proportion of the population (Madsen 2013; Mäki-Opas et al 2014; Trapp et al 2012). Active transportation to school is as well associated with a higher overall levels of physical activity (Machado-Rodrigues et al 2014). Adolescents who actively commute, are approximately 20 additional minutes per weekday more physical active, separate from the commute itself, compared to adolescents that do not use active transportation (Bere et al 2011). Moreover, a high level of physical activity in between the ages of 9 to 18 predicts a higher level of physical activity in adulthood (D'Haese et al 2011). It is also connected with more energy expenditure, cardiovascular fitness (De Vries et al 2010) and lower adiposity levels (Mendoza & Liu 2014). The cardiovascular and metabolic profiles are better for youths who travel actively compared to adolescents who passively commute, independent of other physical activity (Machado-Rodigues et al 2014).

## 1.2 Relevance

Studies indicate that there is a worldwide decline in the amount of youths' physical activity, including active transportation (Dessing et al 2014; De Vries et al 2010). An increasing number of adolescents uses passive transportation (which means motorized transport, for example the car or public transport) to get to school (De Vries et al 2010). Despite the fact that active travel is relatively common in the Netherlands, the amount of walking and cycling to school is decreasing in the Netherlands as well (De Vries et al 2010). A number of strategies and initiatives with various approaches are already trying to stimulate active commuting among young people. They target for example secondary schools (DOiT 2015) and specific neighborhoods (JOGG 2015). This research can help, by concentrating on obtaining detailed knowledge about commuting habits of adolescents, to make strategies and policies more focused on the groups that are most likely to use a passive form of transport. By examining different modes of transport and analyzing the correlates that are of influence, this knowledge can contribute towards more specific and therefore more effective strategies to counteract and prevent obesity among adolescents.

From a scientific point of view it is also useful examine the mode choice to school among adolescents in the Netherlands, for this can add valuable information to the existing knowledge. Most studies about active commuting to school are conducted in the North America and Australia and a smaller amount in Europe (D'Haese et al 2011) with as most common focus the UK (Van Goeverden & De Boer 2013). Current

literature suggests that results of studies on young people and active commuting are country specific (De Vries et al 2010). There are distinctions between countries in their land-use and therefore infrastructure, such as street connectivity patterns (Aarts et al 2013), as well as different relationships between socio-economic characteristics and mode choice to school (Børrestad et al 2011). While North America, Australia and the UK are among the countries with the lowest levels of cycling, resulting in a relatively high amount of walking within active transport (Van Goeverden & De Boer 2013), the Netherlands is the country with the highest level of bicycle use in the industrialized world (Martens 2007). More than 27% of all trips are made on bike and the car is used relatively little with only 10% of the trips (Martens 2007). In the Netherlands, the land-use has a focus on the needs of cyclists and pedestrians (De Vries et al 2010). Furthermore, the environment in Dutch cities is suitable for cycling because of separate bicycle lanes and traffic calming measures in residential neighborhoods (Dessing et al 2014). Because of these high levels of bicycle use and the widely available bicycle infrastructure, the Netherlands represents a unique case (Martens 2007). Therefore, the correlates that for example are found in studies situated in the United States, Australia and the UK can differ with Dutch results (De Vries et al 2010). Because only a relatively small part of the existing literature about this topic concentrates on the Netherlands, this study can add to the current knowledge.

Another important point in which this study can add to existing knowledge about active transport among adolescents in the Netherlands is that this is a nationwide research. Up till now studies on this subject were situated in one city such as Amsterdam (Mäki-Opas et al 2014) or Rotterdam (Bere et al 2011; Prins et al 2009; Van der Horst Nachtegaal 2009). The studies about Dutch adolescents that were conducted on a national level either focused solely on ethnicity (Van Dommelen et al 2015), included cycling and not walking (De Bruijn et al 2005) or only discussed Dutch adolescents as a subcategory (Van Goeverden & De Boer 2013). A nationwide approach focusing on mode choice to school among adolescents is an important addition to the current knowledge. Due to the scale of this study the results can be generalized, which can provide new useful insights. Additionally, because this research is not limited to one single city it can help understand mode choice for school travel within the context of diverse geographic locations such as more rural regions and highly urban areas.

Furthermore, another important contribution this study can make is its focus on adolescents. Adolescents behave differently from adults regarding transportation for they have different activity patterns (Prins et al 2009). Their situation is also different from younger children because they are more independent and the distance from their home to school is often longer (Van Goeverden & De Boer 2013). Therefore, it is useful to consider adolescents as a separate group. This study can add knowledge that can be generalized to Dutch adolescents in general.

This research will also focus on the difference between walking and cycling. Relatively few studies acknowledge the distinction between the two transport modes (Bere et al 2011). Dessing et al (2014) recognize that these forms of transport should be separated in analyses because they have been associated with different correlates in previous research. While walking is only a practical transport mode for short distances (Van Goeverden & De Boer 2013), cycling can enable active transport for longer distances (Trapp et al 2011). In addition, cycling appears to be more energy intensive than walking (Bere et al 2011) and therefore should be considered separately from walking. This is particularly useful in this study with its focus is on preventing and counteracting overweight.

## 1.3 Research questions and objectives

In order to create effective strategies to prevent and counteract overweight and obesity, it is essential to have knowledge of who chooses particular (active or passive) transport modes and which elements affect this choice (D'Haese et al 2011). This is why the focus of this research will be on the choice for either passive transport, walking or cycling to school and consequently which variables influence this decision. Adolescents are a useful group to focus on within this study, for this particular group is young enough to prevent overweight and to teach them healthy habits (Singh et al 2006), but old enough to travel independently and make their own choices (Johansson et al 2011). Therefore, the following research aim is formulated:

*The aim of this research is to provide insights in the mode choice among Dutch adolescents between passive transport, walking and cycling to school.*

This research aim is broken down into the following research questions:

1. *To what extent is the choice between passive transport, walking and cycling to school by Dutch adolescents influenced by individual and household characteristics?*

2. *To what extent is the choice between passive transport, walking and cycling to school by Dutch adolescents influenced by other characteristics?*

## 1.5 Reading guide

This research consists of four parts in addition to this introduction chapter, which are a literature review, a chapter about the research design, a results and discussion chapter and the conclusions. In the following chapter a review is given of the existing literature about active travel among adolescents. By analyzing the literature and consequently researching which variables could be related to the choice for a particular transport mode, a conceptual model is formed which is presented in the next chapter. This chapter focuses on the research design of this study. In this part is explained what research design is chosen, what methods are used and how the relevant data was obtained. Consequently, the results and discussion chapter provides the results for the various correlates and their connection with active travel combined with possible explanations based on previous research. This leads to the final chapter, in which the research questions are answered. Finally, several policy recommendations are suggested order to stimulate adolescents into using active travel to school.

# 2. Literature review

Because of the rising levels of obesity and overweight (Mendoza & Liu 2014; Nationaal Kompas Volksgezondheid 2014; WHO 2015) and the severe consequences of this condition, it is useful to look at active commuting to school as a way of preventing and counteracting this problem. By analyzing existing literature related to active travel among youth, the different elements can be identified which, to the current knowledge, are assumed to influence the choice for a particular travel mode to school. These characteristics are related to the youth itself, such as age and gender as well as the person's household, with elements such as the social economic status of the household and car ownership. In addition, the environment in which the trip to school takes place is expected to have an impact on the mode choice. This includes the built environment, the natural environment as well as safety. Another angle from which to approach the choice for a particular mode to school are the characteristics of the trip itself, such as the distance from home to school.

In this chapter an overview will be given of literature concerning active transport to school among adolescents. The objective is to identify the variables that may influence the choice between passive transport, cycling and walking to school. These findings can help answer the research questions of this study, by providing a theoretical framework. First, individual characteristics are discussed followed by household characteristics. In addition, environmental characteristics are explained and finally trip characteristics. In table 2.1 an overview is given of the literature concerning active travel among youths which was used for this review. The papers are sorted by country and for each paper several key characteristics are listed.

It should be noted that, as previously mentioned, the research related to this subject is for an important part focused on North America and Australia (D'Haese et al 2011). Findings from studies situated outside Europe might not be relevant for the Dutch situation, because of the very different geographies (Aarts et al 2013). European cities are often much more compact have different forms of land use compared to North America and Australia. Another important difference is the lower dependency on cars in Europe. In addition, the Netherlands seems to be different from many other European countries, due to its specific bicycle culture. Cycling is not only used for leisure, but often as a way of transport (Helbich et al 2016). Therefore, while findings from other countries are used to provide general insights, the conclusions are specified for the Netherlands where possible.

## 2.1 Individual characteristics

Individual characteristics are recognized to be one of the most important groups of variables when explaining travel mode choices among youths (Mitra 2013). This category contains characteristics which are specifically related to the individual. First, age is discussed, followed by gender and subsequently ethnicity.

*Table 2.1 Sources active transport used for literature review*

| Author (year) | Sample size | Age group | Country (locality) | Research aim (as formulated by author(s)) | Data source | Recall period |
|---|---|---|---|---|---|---|
| **Leslie et al (2010)** | 2961 | 10-14 | Australia | Examining the associations between personal, social and environmental variables and active travel to and from school | Self-report | Usual travel |
| **Robertson-Wilson et al (2008)** | 21345 | 14-18 | Canada (Ontario) | Exploring the relationships between demographic, behavioral, social/psychological, and environmental correlates of active commuting to school | Self-report | Previous week |
| **Broberg & Sarjala (2015)** | 202 | 11-14 | Finland (Helsinki region) | Identifying and investigating the elements of urban structure around homes en route to school that promote children's ability to walk or cycle to school | Self-report | Usual travel |
| **Sarjala et al (2015)** | 1037 | 11-12, 14-15 | Finland (Helsinki metropolitan region and Tampere) | Composing multivariate environment types using principal component analysis that takes notice of the inter-correlations between physical-environment variables | Self-report | Usual travel |
| **Yang et al (2014)** | 2178 | 9-18 | Finland (Helsinki, Kuopio, Oulu, Tampere and Turku) | Describing the stability of active commuting behavior over 27 years and examining the relationship between active commuting and physical activity from youth to early midlife | Self-report | Usual travel per season |
| **Nelson & Woods (2010)** | 2159 | 15-17 | Ireland | Examining perceptions of the physical environment as a correlate of active commuting | Self-report | Usual travel |
| **Aarts et al (2013)** | 5963 | 4 -12 | Netherlands (4 medium sized cities in the southern part of the Netherlands) | Exploring the association between physical and social environmental characteristics in the home, neighborhood, and school environment and walking and bicycling to school | Reported by parents | Usual travel |
| **Bere et al (2011)** | 1361 (Netherlands) /1197 (Norway) | 12-15 | Netherlands (Rotterdam)/Norway (Kristiansand) | Assessing the potential association between cycling to school and weight status | Self-report | Usual travel |
| **De Bruijn et al (2005)** | 3859 | 12-18 | Netherlands | Testing how well a conceptual model, combining features from the theory of planned behavior and the theory of triadic influence explained two behaviors related to energy balance, namely bicycle use for transportation and snacking behavior | Self-report | Usual travel |
| **Dessing et al (2014)** | 79 | 6 -11 | Netherlands (Amersfoort, Haarlem, Hengelo, Rotterdam, Vlaardingen) | Exploring active transport to school in relation to the distance between home and school | GPS recordings | 1 week |
| **De Vries et al (2010)** | 448 | 6-11 | Netherlands (Amersfoort, Haarlem, Hengelo, | Examining built environmental correlates of children's walking and cycling behavior | Self-report together with parents | 1 week |

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|---|---|---|---|---|---|---|
| | | | Rotterdam, Schiedam, Vlaardingen) | | | |
| **Fishman et al (2015)** | 71465 | 18-99 | Netherlands | Determining the degree to which Dutch walking and cycling contributes to meeting minimum level of physical activity of 150 minutes of moderately intensity aerobic activity throughout the week | Self-report | 1 day |
| **Helbich et al (2016)** | 623 | 6-11 | Netherlands (Amersfoort, Haarlem, Hengelo, Rotterdam, Vlaardingen) | Examining how natural and built environments influence mode choice among Dutch children | GPS recordings | 8 days |
| **Mäki-Opas et al (2014)** | 697 | 10-18 | Netherlands (Amsterdam) | Examining the effect of the physical environment on cycling to and from school among boys and girls of Turkish and Moroccan origin | Self-report | Usual travel in 1 week |
| **Prins et al (2009)** | 654 | 12-15 | Netherlands (Rotterdam) | Examining the associations of the perceived and objective environment with adolescent engagement in sports activities and walking and cycling in leisure time as well as exploring the degree of agreement between objective and perceived availability of physical activity facilities in neighborhoods | Self-report | Usual travel in 1 week |
| **Van der Horst-Nachtegaal (2009)** | 1361 | 12-15 | Netherlands (Rotterdam) | Examining important individual and environmental correlates of presumed energy balance-related behaviors and investigating the associations with and the interactions between these correlates and energy balance-related behaviors | Self-report | Usual travel |
| **Van Dommelen et al (2015)** | 2223 (Turkish)/ 2204 (Moroccan) (1997) 2148 (Turkish)/2181 (Moroccan) (2009) 883 (Turkish)/896 (Moroccan) (2009) (Questionnaire) | 2-20 (1997) 2-25 (2009) 2-18 (2009) (Questionnaire) | Netherlands | Assessing the trend in overweight and obesity in Turkish and Moroccan children since 1997 and to monitor the levels of lifestyle-related behaviors in 2009 | Self-report or reported by parents and measurements | Previous day |
| **Van Goeverden & De Boer (2013)** | 5621/1108 | 5-17 | Netherlands and Flanders | Analyzing two aspects of school travel behavior: home-to-school distances and modal choice | Self-report | 1 day |
| **Van Kann et al (2014)** | 3438 | 5-12 | Netherlands (Heerlen, Sittard-Geleen, Maastricht, Kerkrade, Meerssen) | Examining the relationship between the physical environment characteristics of primary schools and active school transport among primary school children | Self-report and observations | Two times 90 minutes of observations within two weeks per school |

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|---|---|---|---|---|---|---|
| **Oliver et al (2014)** | 217 | 6-15 | New Zealand | Gaining a better understanding of associates of children's active transport to school, by considering the effects of daily weather patterns and neighborhood walkability and neighborhood preferences on this behavior | Reported by parents | Previous week |
| **Børrestad et al (2011)** | 1339 | 10 -12 | Norway (Hedmark and Telemark) | Reporting prevalence of commuting to school with regard to season, gender, parental education level, ethnicity and distance to school | Self-report and reported by parents | Usual travel per season |
| **Machado-Rodrigues et al (2014)** | 665 | 7- 9 | Portugal | Analyzing the associations between blood pressure and adiposity risk and active travel to school | Reported by parents and measurements | Usual travel |
| **Johannson et al (2011)** | 4415 (Sweden) /1008 (Stockholm County) | 11-15 and 13 | Sweden (National and Stockholm county) | Investigating the prevalence of active commuting to school and how active commuting varies according to sociodemographic and socio-economic characteristics | Self-report | Usual travel in 1 week |
| **Bringolf-Isler et al (2008)** | 1345 | 6-7, 9-10 and 13-14 | Switzerland (Bern, Payerne and Biel/Bienne) | Assessing whether prevalence of active commuting and regular car trips to school vary across communities and language regions and to determine personal and environmental correlates | Reported by parents | Usual travel per season |
| **Collins et al (2015)** | 75 | 13-14 | United Kingdom (Central England) | Accurately measuring the commute home to school and how this contributes to total free-living moderate-to-vigorous physical activity | GPS device and self-report | 4 days |
| **Harrison et al (2014)** | 283 | 9-10, 10-11 and 13-14 | United Kingdom (Norfolk) | Examining the relationship between rainfall and physical activity in a longitudinal cohort | Accelerometer recordings and reported by parents | 1 week |
| **Babey et al (2009)** | 3451 | 12 -17 | United States (California) | Examining socio-demographic, family, and environmental characteristics associated with active commuting to or from school | Reported by adult in household | Previous week |
| **Chillón et al (2014)** | 1107 (parents)/1219 (children) | 9-11 | United States (Florida, North Carolina, Texas, Colorado, California, Alaska, Minnesota, Pennsylvania and New Jersey) | Examining associations between active school travel and variables hypothesized as correlates (demographics, physical environment, perceived barriers and norms) | Self-report and reported by parents | Previous week |
| **Dalton et al (2011)** | 1552 | 12-17 | United States (New Hampshire & Vermont) | Describing active travel to school in two predominantly rural states and determining if school neighborhood built environment characteristics predict active travel to school after adjusting for school and individual characteristics | Self-report and reported by parents | Usual travel per week per season |
| **Kerr et al (2006)** | 259 | 5-18 | United States (Seattle) | Examining the association of objective and perceived neighborhood environmental characteristics and parent concerns with active commuting to school and | Reported by parents | Usual travel in 1 week |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | investigating whether parental concerns varied by environmental characteristics, and comparing the association of the perceived environment, parental concerns, and objective environment on the outcome active commuting to school | | |
| **McDonald (2012)** | 3297 (to school)/3120 (from school) (1977) -1295 (to school)/1199 (from school) (1983) -4048 (to school)/4105 (from school) (1990) -8398 (to school) /7812 (from school) (1995) -12426 (to school)/11681 (from school) (2001) -19363 (to school) /18100 (from school) (2009) | 5-18 | United states | Examining sex differences in school travel and how they have changed over time | Reported by adult in household | Usual travel |
| **Davison et al (2008)** | --- | <18 | --- | Summarizing research on predictors and health consequences of active commuting to school and outlining and evaluating programs specific to children's walking and bicycling to school | Published articles | --- |
| **Mitra (2013)** | --- | <18 | --- | Reviewing transportation, urban planning, health and environmental psychology literatures to explore current understanding of school travel behavior | Published articles | --- |
| **Panter et al (2008)** | --- | 5-18 | --- | Providing a review of the available literature and present a novel theoretical framework that integrates the environment into the wider decision making process around travel choices for children and adolescents | Published articles | --- |
| **Pont et al (2009)** | --- | 5-18 | --- | Investigating the environmental (physical, economic, socio-cultural and political) correlates of active transportation among young people | Published articles | --- |
| **Wong et al (2011)** | --- | 5-18 | --- | Examining and summarizing the relationships between objectively measured built environment features and active school transportation and to critically discuss GIS methodologies used in this context | Published articles | --- |

### 2.1.1 Age

**I**t is generally agreed upon within literature concerning transport to school, that age is an important determinant for mode choice (McDonald 2012; Mitra 2013; Panter et al 2008; Van Goeverden & De Boer 2013). However, it is not clear in what way age is related travel mode choice, for the results are inconsistent (Davison et al 2008; Johansson et al 2011). A higher age seems to indicate more active travel according to Aarts et al (2012) and Babey et al (2009), whereas Robertson-Wilson et al (2008) and Van Goeverden & De Boer (2013) state that age is negatively related to active travel. Additionally, Davison et al (2008) suggest that the relationship between walking or cycling to school might not be linear. Moreover, Wong et al (2011) propose that narrow age groups should be distinguished when examining their travel behavior, for they behave in their own distinctive ways. The age groups that should be recognized according to Wong et al (2011) are early elementary, late elementary, middle school and high school students able to drive. Furthermore, McDonald (2012) states that different results in literature may be affected by the studying of different age groups.

Several things might change in older age groups. For instance, when youth gets older, they become more independent from their parents, which means that adolescents acquire a greater control over their mobility decisions (Mitra 2013). While their parents might have preferred cycling and encouraged them to use this form of active transport in the past, adolescents might favor passive transportation such as a motorcycle (Van Goeverden & De Boer 2013). In addition, cognitive and physical development contribute to a youth's independence, for they are increasingly better able to independently handle themselves (Mitra 2013). Moreover, adolescents often have less concern about personal and road safety compared to younger youths. Therefore, elements such the physical environment may influence various age groups in specific ways (McDonald 2012).

Another particular effect related to age, is that schools tend to be further away when youths grow older (Mäki-Opas et al 2014). For example, generally around the age of 12 adolescents go from primary school to a secondary school and later a number of youths go to a vocational school. Due to the lower densities of these schools compared to primary schools, the journey to school often gets longer, which may impact the mode choice (Bringolf-Isler et al 2008; Van Goeverden & De Boer 2013). A consequence of a longer route to school is the raised probability of encountering potentially dangerous traffic situations such as the crossing of major roads, which may influence the type of transport which is chosen (Bringolf-Isler et al 2008).

According to Johansson et al (2011), active transport to school is most common among 10 to 12 year olds relative to younger as well as older youths. A possible reason for the decrease of active commuting after the age of 12 is the replacement of active travel by public transport. It is presumed that this different way of going to school is due to on the one hand a greater distance to school, for secondary schools are often located further away than primary schools and an increased independence. Yang et al (2014) complement this by stating that active commuting to school in Finland severely declines after age 12 and further declines from the age of 15. The decreased amount of active cycling and walking to school from age 12 could be related to the previously mentioned school transitions and increased independence. Moreover, age 15 is the age when Finnish adolescents are allowed to ride light motorcycles. This is comparable to the age of 16 in the Netherlands, for from that age onwards adolescents are allowed to ride a light motorcycle or a scooter (Rijksoverheid 2015b). This form of passive transport might replace active commuting. Additionally, for Dutch adolescents the use of passive transport seems to rise with increasing age at cost of cycling to school (Van Goeverden & De Boer et al 2013).

### 2.1.2 Gender

Several studies indicate that gender is associated with travel mode choices (Babey et al 2009; Børrestad et al 2011; Davison et al 2008; De Bruijn et al 2005; Johansson et al 2011; Leslie et al 2010; McDonald 2012; Nelson & Woods 2010; Panter et al 2008; Robertson-Wilson et al 2008). However, the way gender is expected to affect the mode choice differs. In a number of studies, it is concluded that a higher proportion of boys use active travel as main mode of travel to school (Babey et al 2009; Davison et al 2008; Leslie et al 2010; Johansson et al 2011; Nelson & Woods 2010; Robertson-Wilson et al 2008). Specifically, boys seem to cycle more than girls, while girls are more likely to walk or use a form of passive transport to school. (Leslie et al 2010); Nelson & Woods 2010). Other studies give slightly different results which say that while boys are more likely to commute actively to school (particular cycling), girls tend to walk more (Børrestad et al 2011; Johansson et al 2011).

Traditionally, in research on the subject of gender and travel it is thought that girls are traveling less independently than boys. Girls are supposed to have a lower degree travel freedom which is connected to a smaller amount of active travel than boys. The traditional argumentation is that parents are more protective of girls than of boys and that girls have greater responsibilities within the household. Parents were particularly concerned about sexual molestation of girls since boys were thought to be less vulnerable to strangers than girls. While these ideas might be changing, for parents are increasingly concerned with the safety of girls as well as boys in public spaces, gendered practices may still have influence on travel mode choice today (McDonald 2012). Generally, higher rates of active travel are found among boys than girls, which might reflect the tendencies that parents have to be more protective of their daughters than their sons (Davison et al 2008; Collins et al 2015). In addition, parents are less likely to give their permission for traveling alone to girls compared to boys of the same age. However, the amount of time the caregivers spent walking appears to have a weakening effect on the differences between the sexes (McDonald 2012). A possible explanation for this effect might be that as parents walk in their neighborhood they know the area better and have therefore more knowledge about the actual safety of this region instead of prejudices. This makes encouraging their children to use an active form of transport more probable.

The gender differences might additionally be explained by underlying differences in perception of the environment (Panter et al 2008; Nelson & Wood 2010). An example is that girls are more likely to walk when they perceive their neighborhood as safe and have many friends in that area, while they are less likely to use a form of active transport when there are parks near where they live (Panter et al 2008). This might be because parks could be perceived as unsafe locations. Looking at places in different ways could cause distinct behavior. A possible explanation for gendered perceptions of the environment is suggested by Nelson & Woods (2010). The traditional protectiveness surrounding girls might lead to increased fear in the physical environment, which means they are more influenced by (traffic) safety issues.

Johansson et al (2011) found that boys are more likely to use a form of active travel to school than girls, and in particular more cycling. While in the metropolitan area which was researched in this paper, namely Stockholm, adolescents cycled less in general and there were no overall differences between the genders regarding active transport, boys cycled significantly more than girls. A possible explanation for this distinction between the sexes is connected to the heavy traffic in metropolitan areas which might discourage adolescents to cycle. Possibly due to a traditional distinction between genders, boys could be encouraged to engage more in risky behavior. This tendency is mentioned as well by Yang e.a (2014) in a Finnish study. As previously mentioned, Finnish adolescents are allowed to ride light

motorcycles form age 15 onwards. Typically, particularly boys choose to do this. This might as well point to an inclination for boys to employ riskier behavior.

McDonald (2012) and Johansson et al (2011) state that while there are strong differences between boys and girls in the literature concerning cycling as a transport mode to school, this is might not be the case in countries where cycling is more common. Therefore, in the Netherlands where a strong bicycle culture is present (Martens 2007), the gender divide might be minimal. Mäki-Opas et al (2014) discovered no significant gender divide in relation to the connection between the physical environment and cycling to school in addition to Van Goeverden & De Boer (2013) who found no relationship between gender and travel mode. Concluding, while in general gender seems to affect the transport mode choice, this effect might be minimal in the Netherlands.

### 2.1.3 Ethnicity

Ethnicity is another individual characteristic which is expected to be related to travel mode choice. Previous research provides mixed results regarding the relationship between ethnicity and travel mode (Børrestad et al 2011). Moreover, while according to some papers a connection is expected (Davison et al 2008; Mitra 2013; Pont et al 2009), others report no significant association between ethnicity and transportation mode (Børrestad et al 2011; Johansson et al 2011). However, in the Netherlands a clear connection between ethnicity and mode choice among adolescents is consistently reported (Bere et al 2011; De Bruijn et al 2005; Van der Horst-Nachtegaal 2009).

In the Netherlands differences in transport mode choice were observed between adolescents from Dutch and non-western ethnic backgrounds. Among native Dutch adolescents, cycling was the main transport mode to school while for adolescents from a non-western ethnicity, passive transport modes were the most prevalent (Van der Horst-Nachtegaal 2009). Native Dutch adolescents were nearly three times as likely to cycle to school than youths with a non-western ethnicity. Walking was found to be the second most frequent transport mode for youths with a non-western ethnicity (Van der Horst-Nachtegaal 2009; De Bruijn et al 2005).

The disparities between the ethnicities can be explained by cultural differences. The bicycle is traditionally used as an important way of transport for in the Netherlands (De Bruijn et al 2005). A result of this cultural phenomenon is that most native Dutch children learn to ride a bike at a young age. This is less common among non-western migrants for the cycling is not a part of their original culture (Mäki-Opas et al 2014). When parents cannot ride a bike, this has also consequences for their children's' transport mode choice. On the one hand when they cannot learn to cycle from their parents they may learn it at an older age and gain less experience (Ministerie van Verkeer en Waterstaat 2009) or they might in general be less inclined to choose to cycle. Furthermore, an effect of these diverse cultural backgrounds is a difference in bike ownership for households. Most native Dutch households have bikes at their disposal (De Bruijn et al 2005), namely 83% of the Dutch households have at least one bicycle, compared to only 47% of the non-western immigrants and 67% of the western immigrants (Van der Horst-Nachtegaal 2009).

*Paragraph summary*

*Age is expected to be of influence on travel mode choice. Narrow age groups should be studied to get useful results and there might be a decrease of active travel with increasing age and specifically after the age of 16, when Dutch teenagers are allowed to ride a light motorcycle. While gender differences are traditionally strongly associated with transport mode, these differences might be minimal in the Netherlands, because of the prevalent bicycle culture. In addition, ethnicity is assumed to be related to travel mode choice as native Dutch adolescents might travel more actively than youths with a non-western ethnicity. This difference seems particularly pronounced for cycling, for it is expected that adolescents with a non-western ethnicity cycle less than native Dutch teenagers*.

## 2.2 Household characteristics

In addition to individual characteristics, household characteristics are as well thought to be one of the most important groups of variables for understanding the choices for particular travel modes among youths (Mitra 2013). In this paragraph several features related to the individual's household which are expected to influence the travel mode choice are discussed. First, the possible effect of household composition on school travel is explained. Subsequently, an overview of the impact of household social economic status and household car ownership is given.

### 2.2.1 Household composition

Household composition may be another characteristic which influences the travel mode to school among adolescents (Aarts et al 2012; Babey et al 2009; Pont et al 2009; Van der Horst-Nachtegaal 2009; Van Goeverden & De Boer 2013). Pont et al (2009) found in a literature review that youths with one parent living at home relative to youth living in a two parent household were more likely travel in an active way to school. Furthermore, a connection was observed between the parental marital status and active commuting, although it was non-significant. However, Van der Horst-Nachtegaal (2009) obtained contrasting findings, namely that youths with at least one parent without a paid job, are less likely to cycle to school and more likely to choose a passive form of transport than adolescents with two working parents. These findings might be different from Pont et al (2009) for this research is specifically focused on the Netherlands which has a particular cycling culture (Martens 2007). In a more practical way, the relationship between mode choice and household composition could be connected with the availability of bicycles per household. 73% of the households with two working parents has (a) bike(s) available at home and 53% of the households with at least one parent without a paid job owns (a) bicycle(s) (Van der Horst-Nachtegaal 2009).

Another characteristic related to household composition is siblings. Youths who had siblings living within the same household were more likely to travel actively to school (Aarts et al 2012; Babey et al 2009; Van Goeverden & De Boer 2013). The larger a household, the higher the likelihood of walking instead of cycling, and cycling at cost of transport by car. A possible explanation for this shift in transport modes in larger families is the increased difficulty of organizing transport to schools that are further away. When youths can travel together to school there is less need for escorting to school by their parents and therefore possibly passive transport (Van Goeverden & De Boer 2013) due to safety in numbers when they travel together (Aarts et al 2012). If they should go to different schools, escorting might be more difficult to arrange, which decreases the chance of passive commuting with

their parents as well. Moreover, a negative association is found between household size and travel by car (Van Goeverden & De Boer et al 2013).

### 2.2.2 Social economic status

Another element that seems to influence travel mode choice among adolescents is social economic status (De Bruijn et al 2005; De Vet et al 2011; Davison et al 2008; Johansson 2011; Van der Horst-Nachtegaal 2009), which is supported by Babey et al (2009) and Pont et al (2009) who indicate that household income is a factor in travel mode choice. Davison et al (2008) define social economic status as a measure of economic status based on household income, home ownership, neighborhood level and whether a household receives welfare.

Outside the Netherlands is often found that when youth have a lower social economic status, they are more likely to use an active transport than youth with a higher social economic background (Babey et al 2009; Davison et al 2008; Johansson et al 2011; Pont et al 2009). However, in the Netherlands this relationship seems to be reversed. Adolescents with a higher social economic background in the Netherlands generally travel more actively than youths with a lower social economic background (De Bruijn et al 2005; Van der Horst-Nachtegaal 2009). An explanation for this difference might be found in reputation of active travel. In other countries active travel may represent a low social status, for it seems that the person is not able to travel passively due to for example fewer vehicles available per household or not being able to buy a car (Babey et al 2009; Ministerie van Verkeer en Waterstaat 2009). In the Netherlands, active travel and particularly cycling have a reputation of a sporty, environmentally aware lifestyle (Ministerie van Verkeer en Waterstaat 2009). Furthermore, differences in levels of cycling in the Netherlands could be related to bike availability at home. Households with a lower social economic status might own less bicycles (Van der Horst-Nachtegaal 2009), which could limit the possibilities of using a bicycle as travel mode.

On the other hand, in higher income households more value could be given to the quality of schools, for people with more income are often highly educated themselves. If importance is given to the quality of a school, a different school might be chosen than the nearest one. This could lead to larger distances and therefore an increased likelihood of passive transport. In addition, a higher income could enable traveling with motorized modes which are relatively expansive. Distance seems to be less of a barrier for travel in high social economic households (Van Goeverden & De Boer 2013).

Another argument which came up in previous research for the relationship between travel mode choice and social economic status was self-selection (Madsen 2013; Oliver et al 2014). With self-selection is meant that people who prefer active forms of transportation over passive forms choose to live in areas that are more suitable for walking and cycling (Madsen 2013). Specific neighborhoods often contain households with similar social economic statuses, which may contribute to the relationship between social economic background and choices for particular forms of travel. In this theory it is assumed that parents have an important role in the travel behavior of their child and that their choices for living in a particular neighborhood are a determinant for their children's way of transport (Oliver et al 2014).

### 2.2.3 Car ownership

Related to social economic status is the number of cars per household, which may be a factor in travel

mode choice as well. However, while this potential relationship is not confirmed in previous research specifically for Dutch adolescents, it seems to be a factor for youths in other countries (Aarts et al 2012; Johansson et al 2011; Mitra 2013; Panter et al 2008; Pont et al 2009). Therefore, car ownership is discussed for it might be a relevant influence for Dutch teenagers on their choices for particular transport modes. Owning a car or cars could enable choosing a more distant school and consequently encourage passive commuting (Van Goeverden & De Boer 2013). A side note is that Dutch teenagers are only allowed to drive independently from the age of 18 onwards (Rijksoverheid 2015a), which means that the target group for this thesis only travels by car as a passenger.

According to several papers the number of cars per household is negatively connected with active commuting to school (Aarts et al 2012; Johansson et al 2011; Pont et al 2009). This means that the more cars there are available for a household, the less likely it might be that a youth chooses a form of active travel to school (Pont et al 2009). Not having access to a car can be a direct motivation to use a form of active travel to school (Panter et al 2008). The availability of a car enables driving, or in this case being driven to school, and might consequently encourage passive travel (Mitra 2013; Van Goeverden & De Boer 2013). Therefore, access to a car for a household may influence choices for particular ways of travel (Mitra 2013).

Furthermore, this tendency seems to be especially relevant when the household has more than one car available (Johansson et al 2011). This might be because while some households do own a car, they do not use it regularly. This seems to be less likely in households with multiple cars. It is assumed that active travel forms are more frequently employed in households where the available car is not frequently used, for this could lead to parents knowing their neighborhood better than persons who commonly travel passively. A possible result might be that they are more likely to judge the area safe for active travel for their children, because they have more experience with active traveling in the neighborhood themselves. This in contrast to the parents who are less inclined to use an active mode and travel by car. They may perceive the area as unsuitable for active travel due to lack of awareness (Panter et al 2008). Consequently, while the number of cars per household may be of influence on travel mode choice, this is particularly applicable when there is more than one car available.

*Paragraph summary*

*Household composition might be of influence on the choice for particular travel modes, specifically the distinction between one and two parent families. When two parents are living at home it is more likely for a youth to choose an active form of transport than in families with one parent living at home. In addition, the number of siblings could be positively related to active commuting. In contrast to many other countries, in the Netherlands it seems more likely for youths from households with a higher social economic status to choose forms of active transport compared to youths from families with a lower social economic status. Even though car ownership is not confirmed in literature specifically for Dutch adolescents as to be related to travel mode choice to school, it might be of influence for it is identified as an important factor for youths in other countries. It is thought that with an increasing number of cars per household the amount of active transport decreases, especially when there is more than one car available for the household. Furthermore, another element which was not explained separately but has emerged multiple times as a relevant factor in this as well as the previous paragraph is bicycle ownership. Less bicycles available per household seems to be related to less cycling to school.*

## 2.3 Environmental characteristics

Environmental factors are considered to have an important influence on the transport mode choice among adolescents (De Bruijn et al 2005; Mäki-Opas et al 2014; Mitra 2013; Panter et al 2008; Prins et al 2009). The general term environmental characteristics include built environmental features such as urban density and land-use diversity, natural environmental characteristics, for example green and weather conditions and safety. Some environmental characteristics are thought encourage active travel while other elements may form barriers (Nelson & Woods 2010). First, some general information is given about the way the environment is thought to affect travel mode choices, followed by the how the built environment and the natural environment are expected to influence travel mode choice and finally safety will be discussed.

The effect of the environment on transport modes can be direct as well as indirect. For example, elements from the objective physical environment may encourage or obstruct certain travel behavior (Nelson & Woods 2010). For instance, the presence of bicycle paths encourages cycling (Pucher & Buehler 2008). Subsequently, with indirect influence is meant that the physical environment is expected to affect perceptions of the environment. These perceptions may play an important part when forming a decision and therefore making a particular transport mode choice. The perceptions help decide whether or not the environment is suitable for active travel (Panter et al 2008). There may be differences between the relationship between the objective environment and active travel behavior and the perceived environment and active travel behavior. Perceptions might even be more strongly associated with physical activity than the objective environment (Prins et al 2009).

Prins et al (2009) explain perceptions to be the result of the interpretation of the objective environment combined with cognitive processes. Not merely the physical environment is expected to contribute to perception, but additionally for example the social or cultural environment, which means the behavior of friends and what is socially accepted. Furthermore, pre-existing opinions may impact perceptions of the environment as well as attitudes. For instance, adolescents with a positive attitude towards walking may perceive their environment as more suitable for walking and subsequently active transport than peers with a less positive attitude (Panter et al 2008). However, it should be mentioned that it is unclear whether perceptions of the environment lead to active travel or if people that use active forms of transport have different perceptions of the environment because they are more aware of certain environmental characteristics (Nelson & Woods 2010).

Individuals may perceive the same objective environment in distinctive ways (Prins et al 2009). It is expected that the relationship between the perceived environment and active travel behavior can differ between subgroups in the population (Nelson & Woods 2010) An example of these different perceptions of the same environment can be found in the previously discussed individual and household characteristics. Boys and girls may perceive environments in separate ways, for the girls perceived the same environment as less safe than the boys (Johansson et al 2011). While the physical environment is the same, the perceptions differ due to different attitudes and another social environment.

Not merely the perceptions of the youth itself are important when deciding on a particular travel mode, for the parents´ perception may be relevant as well. While parents´ perceptions are to a greater extent associated with the travel behavior of younger children, they may as well be related to the transport mode choices of adolescents (Babey et al 2009; Panter et al 2008). There is expected to be a dialogue between the parents and their children during the decision making process. Parents may influence the attitudes of their children and the other way around. For example, when parents perceive

the environment as suitable for active transport and they have a positive attitude towards active travel they are more likely to encourage their children to travel actively (Panter et al 2008).

### 2.3.1 Built environmental characteristics

Built environmental characteristics are thought to influence travel mode choices (Aarts et al 2013; Broberg & Sarjala 2015; Dalton et al 2011; De Vries et al 2010; Helbich et al 2016; Kerr et al 2006; Mitra 2013; Nelson & Woods 2010; Panter et al 2008; Sarjala et al 2015; Van Kann et al 2014; Wong et al 2011). A common division which is used to explain built environmental characteristics is by means of the 'three Ds', namely density, diversity and design measures (Ewing & Cervero 2010; Helbich et al 2016). Density, diversity and design could impact the travel mode choice in various ways. For example, a high density is expected to decrease the distances between destinations, which could result in relatively short trip distances (Helbich et al 2016). Shorter distances are associated with an increase of active travel (Madsen 2013; Wong et al 2011). This is particularly relevant when there is a higher land use mix, or more diversity. When multiple destinations, such as for instance shops or schools, are close together, the trip distances decreases. Because of the shorter distances between destinations, it is expected to be more attractive to travel by active transport modes. In addition, it is easier in areas with a high diversity to make trips with multiple destinations in one time by means of active transport. Additionally, the third 'D', namely design is associated with the street layout of an area. For example, more intersections result in a higher street connectivity, which could positively impact the route distance towards destinations and therefore increase active travel. However, a high street connectivity could also lead to busier traffic (Helbich et al 2016), which might discourage active travel on these streets (Bringolf-Isler et al 2008; Mitra 2013).

#### *Urban density*

It is expected that the level of urban density, or urbanicity, is related to travel mode choice to school among youths (Babey et al 2009; Broberg and Sarjala 2015; Davison et al 2008; De Bruijn et al 2005; Johansson et al 2011; Mitra 2013; Robertson-Wilson et al 2012). Urban density is way of assessing the concentration of human activities in a specific area by looking at address density (Centraal Bureau voor de Statistiek 2016d).

Walking or cycling to school seems to be more common in urban areas than in rural locations or non-urban areas (Babey et al 2009; Davison et al 2008; Mitra 2013; Robertson-Wilson et al 2012). One explanation for this phenomenon is that youths in non-urban areas tend to live further away from their school, which increases the likelihood of passive forms of transport such as traveling by bus (Davison et al 2008; Robertson-Wilson et al 2012). This could be related to the schools that are situated in these areas. When the population density in an area is low, the school density is also expected to be low (Van Goeverden & De Boer 2013). Additionally, there may be less infrastructure for walking available in rural areas, which decreases the probability of walking to school (Davison et al 2008).

In addition, larger satellite schools are often positioned outside residential areas and therefore in places with a lower population density. These schools attract a greater number of students from a broader geographical area. The distance these students travel is often further and as a result the likelihood of active commuting diminishes (Davison et al 2008). In the Netherlands, secondary schools are usually located in cities that have a central function on a regional level. The area these schools serve has a radius of about fifteen kilometers around the city. Moreover, school types that are less

common are often only located in larger cities, which can result in a longer commute (Van Goeverden & De Boer 2013). Because of the longer expected distances, youths who go to smaller neighborhood schools are more likely to use an active form of transport, compared to students who attend larger magnet schools. (Mitra 2013).

Furthermore, living in a city center neighborhood seems to be positively associated with walking to school. (Aarts et al 2012). A greater urban density within 0,5 miles from the school is related to higher rates of active commuting (Davison et al 2008). High density residential blocks tend to correspond with more walking (Mitra 2013). This could be related to the proximity of facilities within the neighborhoods, and therefore these areas are considered more attractive for walking. In addition, within city center neighborhoods commuting by car can be unappealing, due to the difficulty of parking in the city center (Aarts et al 2012). Specifically, for the Netherlands, cycling is used often as a transport mode because the cities tend to be compact. This results in short distances between destinations which leads to lots of short trips within the city. The more often short trips are made, the more active transport, and particularly cycling, is used (Ministerie van Verkeer en Waterstaat 2009).

However, transport mode choice and urban density may not be connected in a linear way. In larger, denser cities, there seems to be increased use of public transport and more walking instead of cycling (Ministerie van Verkeer en Waterstaat 2009; Van Goeverden & De Boer 2013). De Bruijn et al (2005) concluded that students in a less urbanized town are two times as likely to cycle to school than students who are living in a more urbanized town. An explanation for this finding is that highly urbanized towns tend to have more traffic that moves with a higher speed. This may decrease the feeling of safety for cyclists and therefore result in cycling as a form of transport being less appealing. Johansson et al (2011) found the same results for the Swedish Stockholm metropolitan area. Cycling is in this region less common among youths compared to adolescents in medium sized cities, which could partly be related to the heavy traffic in this area. Another speculation concerning these differences in travel mode choice is that adolescents in metropolitan areas may have a wider choice of schools and can therefore attend schools further from home. The potentially greater distances combined with the heavy traffic can form a barrier for choosing an active transport mode (Johansson et al 2011). Furthermore, in more urbanized cities often a better public transportation system is available which may encourage passive commuting (Van Goeverden & De Boer 2013). Additionally, a higher level of urbanicity is related to greater building densities in the residential area. This great volume of buildings might lead to reduced feelings of personal safety (Broberg and Sarjala 2015), which may discourage active transport.

### *Land use diversity*

Another concept connected with the built environment which might be related to transport mode choice among adolescents is land use diversity (Panter et al 2008). The results found in previous research are however not consistent. While some in some papers a negative relationship was found between active travel and land use mix (Broberg & Sarjala 2015; Wong et al 2011), in other studies no association was found (Mitra 2013; Wong et al 2011) or a positive correlation (Madsen 2013; Mitra 2013).

A possible reason for the negative relationship between active travel and land use mix is that a diverse landscape could be connected to a less organized and busier built environment. This may be a less attractive environment for attractive travel (Broberg & Sarjala 2015). On the other hand, a more diverse environment could encourage active travel. A possible explanation for this contrasting view is

that diverse land-use decreases the distances between different destinations. The shorter distances may encourage the use of active forms of transport such as walking and cycling (Madsen 2013; Wong et al 2011). In addition, the multitude of possible destinations would make it more convenient to make 'trip chains' across multiple activities using active modes of travel (Wong et al 2011).

Moreover, it might be important to look at the quality of the land use mix. For example, smaller residential blocks and street-level retail within a neighborhood may increase feelings of safety because there are 'eyes on the street'. A perceived safe environment might encourage walking and cycling (Mitra 2013). This is further illustrated by the finding that the probability of active commuting increases with the proportion of single-family housing in an area, which is often connected with smaller blocks and therefore a more attractive environment for walking and cycling (Broberg & Sarjala 2015; Sarjala et al 2015). The perceived safety may be less with larger retail centers and employment districts, which can form a barrier for active commuting (Mitra 2013). Traffic-dominated environments and mixed-use business districts are most often reached by passive transport (Sarjala et al 2015

Furthermore, it might be that different types of land use are relevant for particular age groups (Broberg & Sarjala 2015; Panter et al 2008). This could be because different destinations are relevant for individuals in separate age groups. For example, while schools and particular recreational spaces might be important for adolescents, this might be less relevant for adults. Panter et al (2008) identified a higher residential density, the presence of at least one recreational space and having at least one commercial land use as important for adolescents.

### *Walkability and bikeability*

Closely related to land use diversity is neighborhood walkability. A walkable neighborhood is by Panter et al (2008) defined as an environment which supports walking for travel purposes. Neighborhood walkability is slightly different defined by Babey et al (2009) who state that it means how friendly the built environment is for people to live, shop, visit or enjoy spending time in a specific area. Several characteristics are named in order to measure this concept, namely street connectivity, residential density (Babey et al 2009; Kerr et al 2006; Madsen 2013), land use mix (Babey et al 2009; Madsen 2013), destinations near homes (Kerr et al 2006), pedestrian oriented retail design (Babey et al 2009) and high retail floor area ratios (Madsen 2013). Because facilities such as commercial areas, schools and recreational locations closer together, the overall trip distances are expected to be shorter. Therefore, it is likely that more trips are made with an active transport mode (Kerr et al 2006; Panter et al 2008; Pucher & Buehler 2008). Additionally, the probability of active travel was higher in areas that were perceived to be walkable. Characteristic for these neighborhood is that they often have a sense of community and people walk in these areas. (Mitra 2013). Furthermore, neighborhoods where children live are often perceived as more walkable (Davison et al 2008). Youth who live in more walkable neighborhoods have a higher probability of traveling actively to school (Wong et al 2011).

The characteristics that were used to define walkability are also thought to influence cycling. People who live in highly walkable neighborhoods tend to cycle more than people living in less walkable areas (Madsen 2013). This might be because the trip distances are often shorter then in neighborhoods with low walkability. And shorter trip distances are expected to lead to more active transport (Kerr et al 2006; Panter et al 2008; Pucher & Buehler 2008). However, in addition to a walkability index, there is also a bikeability index. Comparable with the walkability are the characteristics street connectivity, residential density, land use mix and retail floor ratio. These features are complemented with topography, namely the slope and cycle path density (Madsen 2013).

Cycle facilities are important for a bicycle-friendly infrastructure (Mäki-Opas et al 2014), for more cycling facilities are related to an increase in cycling. This might be due to the safety and continuity this infrastructure provides (Madsen 2013). Cycling lanes contribute to a comfortable and convenient environment for cycling (Pucher & Buehler 2008). However, quiet residential streets seem to be more attractive to cyclists than autonomous bicycle paths alongside busy roads (Ministerie van Verkeer en Waterstaat 2009). Most people prefer to cycle in areas with low volumes of traffic or entirely away from motor traffic (Elinder 2015). Aarts et al (2012) found that in the Netherlands quality sidewalks and bike lanes were not significantly related to active travel. This might be because the specific Dutch infrastructure already provides a suitable environment for walking and cycling. However, according to Mäki-Opas et al (2014) a bicycle-friendly infrastructure is positively related to cycling to and from school among adolescents. Consequently, it is unclear to what extent a bicycle-friendly infrastructure is related to active commuting to school among Dutch adolescents.

### 2.3.2 Natural environment

In addition to the built environment, the natural environment might be of influence on the mode choice for the commute to school as well. The natural environment includes green, water, slopes, weather conditions and seasonality.

Green spaces could be related to the choice between active and passive travel among adolescents (Leslie et al 2010; Wong et al 2011). However, the way green spaces could influence travel mode choices are unclear for there are positive connections found between active commuting and green space (De Vries et al 2011; Leslie et al 2010; Wong et al 2011) as well as a negative relationship (De Vries et al 2011; Panter et al 2008).

A positive relationship was found between the presence of parks near the home and active travel (Leslie et al 2010) as well as a positive correlation between the number of trees in the street that are situated five meters or less from the road edge and active travel to school (Wong et al 2011). It is thought that green areas might encourage active commuting because natural environments are often perceived as more attractive than built environments (De Vries et al 2011; Van Kann et al 2014). De Bruijn et al (2005) suggest that an attractive environment has in indirect positive influence on the intention to be physically active among adolescents. Furthermore, an aesthetically pleasing environment might have an encouraging effect on active commuting (Van Kann et al 2014). Van Kann et al (2014) found that particularly the presence of parks was related to active travel. Additionally, green areas such as parks are often used as an alternative route for active transport. This might be to avoid streets with heavy traffic of because of a lack of traffic lights and therefore more continuity (De Vries et al 2011).

A contrasting finding is a decrease in active travel when there was more green in the area (De Vries et al 2011; Fishman et al 2015; Panter et al 2008). A possible reason for this association is that a consequence of more green in a neighborhood is a possible reduced density of facilities. When facilities in areas are more widespread the amount of active commuting might be less compared to neighborhoods with almost no green, where there is a high density of facilities. Fishman et al suggest in a Dutch study that a lack of green could represent highly urbanized areas. These areas are in the Netherlands often relatively attractive for active travel, because of their compact designs which results in car-unfriendly areas and shorter distances between destinations. Additionally, Panter et al (2008) found that active forms of transport were less common when there were parks in the neighborhood for girls. This might be because parks could be perceived as unsafe areas due to the lack of ‘eyes on

the street'. Another reason for a reduced amount of active commuting when there is more green, might be that a high amount of green space could indicate agricultural areas (De Vries et al 2011). In these areas the commuting distances may be longer, which could discourage active forms of travel.

Another natural environment characteristic which may influence the travel mode choice is slopes. Steep slopes can be connected to the choice between active and passive travel (Davison et al 2008; Mitra 2013; Van Kann et al 2014; Wong et al 2011), because walking and cycling is easier on a flat area than in a hilly environment (Ministerie van Verkeer en Waterstaat 2009) and additionally they might be perceived as a barrier for active travel (Van Kann et al 2014). A more challenging environment for active forms of travel may discourage walking or cycling.

Additionally, a specific natural characteristic which might influence travel mode choice in the Netherlands is water. It is common in the Netherlands that canals or rivers separate different areas from each other. These waterways can act as barriers for active travel for they can only crossed on specific points when there are bridges suitable for walking or cycling (Ministerie van Verkeer en Waterstaat 2009). On the other hand, it could be speculated that water may add to the attractiveness of an area, which could encourage active commuting (De Vries et al 2011). It is however unclear if there is a positive connection between active forms of travel and the presence of water in the area.

### *Weather conditions*

Weather conditions might also be of importance in relation to travel mode choice (Børrestad et al 2011; Bringolf-Isler et al 2008; Chillón et al 2014; Madsen 2013; Mitra 2013; Van Goeverden & De Boer 2013). More specifically it is expected that bad weather is a disincentive for active forms of travel (Børrestad et al 2011; Chillón et al 2014; Madsen 2013) and is one of the most important determinants for choosing a passive transport mode over walking or cycling (Bringolf-Isler et al 2008; Mitra 2013; Van Goeverden & De Boer 2013). Mitra (2013) identified weather as one of the most important reasons for parents to bring their child to school by car. Bad weather includes conditions such as rain, snow, wind and cold temperatures (Yang et al 2014). The active transport modes are the most vulnerable to weather conditions (Sabir 2011) and particularly cycling is sensitive to weather conditions in comparison to other forms of transport (Chillón et al 2014; Madsen 2013; Sabir 2011; Van Goeverden & De Boer 2013). Especially extreme weather conditions have an impact on the mode choice (Sabir 2011).

Not merely weather conditions at the time of travel are thought to influence the transport mode to school. Extreme weather conditions on the same day as the trip may act as a barrier for active commuting (Machado-Rodrigues et al 2014; Mitra 2013). Moreover, predicted weather patterns or heavy rainfall in the early morning could influence travel plans for later that day, regardless of the weather at the time of the trip (Oliver et al 2014).

However, not all studies are consistent regarding the relationship between weather conditions and active transport to school (Chillón et al 2014). Robertson-Wilson (2008) found that temperature and precipitation were no predictors of active travel to school. Oliver et al (2014) as well state that there is no significant relationship between daily weather patterns and active travel in addition to Davison et al (2008) who found no correlation between weather and active transport rates. It should be noted that Oliver et al (2014) as well as Davison et al (2008) provided explanations for the lack of correlation between weather conditions and active travel which were related to unrepresentative data (Oliver et al 2014) and imprecise data (Davison et al 2008). Therefore, it is uncertain if there actually was no relationship between weather and transport mode or if this was related to the available data.

### *Temperature*

While temperature might be related to travel mode choice (Sabir 2011; Van Goeverden & De Boer 2013), the results in previous research are not consistent (Robertson-Wilson 2008). Van Goeverden & De Boer (2013) state that temperature is the weather condition with the most influence on travel behavior in the Netherlands. However, Roberson-Wilson (2008) found no relationship between temperature and active travel to school among adolescents. This study took place in Canada, and therefore it is not clear whether this is applicable for the Netherlands.

The assumed connection between temperature and travel mode choice indicates that people are thought to cycle less in very low temperatures and more in warm weather. During extremely cold temperatures the amount of cycling decreases compared to when the temperatures are between 0˚C and 10 ˚C. Cycling seems to be substituted by passive transport modes as well as walking. This shift might take place due to that cyclists are more sensitive to extreme weather conditions than people who walk or travel with passive transport forms (Sabir 2011). The likelihood of cycling for an educational purpose increases at the cost of passive transport modes when the temperatures are between 10˚C and 20 ˚C compared to 0˚C and 10 ˚C and even further when it was warmer (Sabir 2011; Van Goeverden & De Boer 2013).

### *Precipitation*

Precipitation is according to Harrison et al (2015) and Madsen (2013) the most common barrier for travel However, Harrison et al (2015) found no significant relationship between travel mode choice for commuting to school among adolescents and precipitation. A possible explanation for this absence of a significant correlation is that adolescents may lack suitable alternatives for transportation (Sabir 2011).

The term precipitation includes various forms of weather such as rain, snow, hail and sleet (Sabir 2011). For instance, rain can be perceived as a reason not to cycle (Madsen 2013). The presence of precipitation can lead to people choosing different transport modes such as public transport or the car (Sabir 2011). Sabir (2011) found that in the hour of departure before a trip, ten minutes of rain can lead to a decreased likelihood of cycling and a higher probability of car use. There appears to be an association between the amount of precipitation and travel mode choice, for while the likelihood of cycling is lower during average precipitation than during dry weather, this decreases further in the presence of extreme precipitation conditions. Moreover, possible explanations for the discouraging effect of precipitation are less comfortable and more challenging conditions as well as safety concerns. This is illustrated by that during precipitation the amount of traffic accidents rises. Particularly snow can lead to safety risks (Sabir 2011). The effects of precipitation on transport mode choice seem to be more relevant for cycling than for walking. This might be because it is easier to find shelter against precipitation when walking than during cycling, by for example using an umbrella or walking under the covering of a building (Fishman et al 2015). Therefore, the effects of the precipitation might be more strong for cycling than walking.

### *Wind*

Additionally, wind might impact the choice for active or passive transport. Although Sabir (2011) found no significant correlation between educational trips and strong wind, there seems to be a small connection between strong wind and the increased choice of passive transport forms. Strong wind

might influence the travel mode choice due to decreased safety. Wind affects moving vehicles such as bikes, which makes it more challenging to cycle in these weather conditions (Sabir 2011). Cycling seems to be more affected than walking by strong wind, probably because cyclists are more exposed to strong wind than pedestrians (Fishman et al 2015). Furthermore, a strong wind could lead to obstacles in the form of for example falling branches or blowing snow or sand (Sabir 2011).

#### *Seasons*

Closely related to weather conditions are the seasons which might influence the travel mode choice (Børrestad et al 2011; Dalton et al 2011; Harrison et al 2015; Madsen 2013; Sabir 2011; Yang et al 2014). Dalton et al (2011) found seasonal variation to be a significant predictor for active travel among adolescents. The results of their research indicated that the amount of active transport was almost double in fall and spring compared to winter. In addition, Børrestad et al (2011) stated that cycling was the most used travel mode in fall and spring, while walking was the most common in the winter months. While these studies were respectively situated in the United States and in Norway, the results might not be directly applicable to the Netherlands, however the findings are confirmed in a Dutch paper. Sabir (2011) found that there were less bicycle trips during the winter and more during the summer.

Furthermore, concurrent with the results of weather, the findings were inconsistent. In some papers no significant relationship between seasons and active travel among youth was found (Machado-Rodrigues et al 2014; Mitra 2013; Robertson-Wilson et al 2012). Mitra (2013) suggests that the usual school travel mode may not differ between seasons for there is no correlation between seasonal climate and travel mode choice. Extreme weather conditions on the day of the school trip itself might be more important for the choice for a particular transport mode than general climate conditions in the different seasons.

Explanations for a possible association between transport mode and seasonality are found in the changing weather conditions (Børrestad et al 2011; Harrison et al 2015) as well as in the difference of day length (Aarts et al 2012; Dessing et al 2014; Harrison et al 2015; Madsen 2013; Yang et al 2014). Decreased temperatures during winter may discourage cycling (Børrestad et al 2011; Madsen 2013). Moreover, precipitations such as snow and rain might form a barrier for cycling as well as strong wind. These weather conditions during winter make cycling more challenging and might therefore lead to an increase in walking or passive forms of transport. These circumstances can be aggravated by problems specific for the winter such as the poor removal of snow (Børrestad et al 2011).

In addition, another consequence of the changing seasons is the difference in day length. Particularly during the winter there are less hours of daylight which is associated with darkness in the mornings and late in the afternoon. Darkness in the mornings may influence traffic safety as well as personal safety (Dessing et al 2014) and therefore discourage active travel to school (Madsen 2013; Yang et al 2014). Moreover, this could lead to differences in transport mode between the morning, when it is still dark, and the afternoon (Aarts et al 2012). It should be noted that daily commuters might be less influenced by seasonal changes than other cyclists, because they might have no other option than using their bike for transportation (Madsen 2013).

### 2.3.3 Safety

Closely related to the previously discussed environmental characteristics is safety. It is thought that a

higher perceived safety is a predictor for active travel (Leslie et al 2010). In addition, it is expected that increased safety encourages more cycling (Pucher & Buehler 2008). Furthermore, concerns about safety may form a barrier to active transport. The concept of safety can be divided into personal and traffic safety (Panter et al 2008).

It is assumed that the feeling of personal safety might be related to active travel (Babey et al 2009; Broberg & Sarjala 2015). The lack of eyes on the street as well as stranger danger may increase personal safety concerns. Small residential blocks and the presence of retail on street-level in the neighborhood 'places eyes on the street', which increases feelings of personal safety and therefore encourages active travel (Mitra 2013). Bigger building densities, which are often related to employment districts or larger retail centers may discourage forms of active transport by providing an environment which is perceived as less safe (Broberg and Sarjala 2015; Mitra 2013). Personal safety concerns may be increased by darkness in the morning or the evening, which can make walking or cycling seem more dangerous (Dessing et al 2014). Furthermore, elements such as vandalism might impact the feeling of personal safety and discourage active travel (Van Kann et al 2014).

In addition, traffic safety is an important predictor for active commuting (Aarts et al 2012; De Vet et al 2011; De Vries et al 2010; Nelson & Woods 2010). Perceived traffic danger may discourage for instance cycling (Pucher & Buehler). Several elements that might lead to traffic safety concerns were identified in previous research. An important barrier to active commuting is high traffic volume. Additionally, major street crossings may discourage walking or cycling (Bringolf-Isler et al 2008; Mitra 2013) and are according to Aarts et al (2012) significantly correlated with passive commuting. Moreover, busy intersections can form barriers for active travel (Mitra 2013). Similar as with personal safety concerns, perceived traffic safety concerns might be increased by darkness (Dessing et al 2014).

Furthermore, there are some characteristics which may enhance the perception of traffic safety, such as the presence of sidewalks (Mitra 2013). Also, separate cycling facilities along busy roads and intersections (Pucher & Buehler 2008) and pedestrian crossings are correlated to active walking or cycling to school (De Vries et al 2010). Traffic calming measures in residential neighborhoods have a positive influence on traffic safety as well (De Vries et al 2010; Pucher & Buehler 2008). These measures imply that cars have speed limit of 30 kilometers per hour in residential zones. Related to this is the influence of parallel parking spaces. Parked cars act as a barrier between the sidewalk and the street as well as that parallel parking is most often found in narrow streets, where vehicles drive generally slower (De Vies et al 2010).

Subsequently, similar to the previously discussed perceptions, the parents' perception of safety might be of influence on their children's transport mode choice (Panter et al 2008). Particularly traffic safety concerns could be of influence for parents on the transport mode choice of their children (Bringolf-Isler et al 2008). Parents perceived that the road was safe if the speed of vehicles was slow and the traffic volume was low (Panter et al 2008). However, while Panter et al (2008) state that parental safety concerns may be of influence on their child's travel mode choice, Babey et al (2009) write that parental perceptions of neighborhood safety were not related to active travel among adolescents. Therefore, it is unclear if parental safety perceptions influence adolescent's travel mode.

In the Netherlands several particular elements enhance the traffic safety. A specific characteristic in the Netherlands is the great number of cyclists (Dessing et al 2014). It is thought that cycling is safer in countries with a higher amount of bicycle use (Pucher & Buehler 2008; Verkeer en Waterstaat 2009). The reason for this increased road safety is thought to be 'safety in numbers' (Dessing et al 2014; Pucher & Buehler 2008). The greater number of cyclists on the roads increases the road safety because automobilists adjust their behavior because they expect cyclists (Dessing et al 2014).

Additionally, in the Netherlands some specific measures are taken to ensure the safety of cyclists, such as extensive traffic calming measures in residential neighborhoods. Not only is the speed limit lowered to 30 kilometers per hour, the measures are usually area wide instead of targeted to specific streets. Therefore, traffic is not shifted from one residential street to another but is predominantly placed on main roads that are made for that purpose. Furthermore, the streets themselves are modified in several ways to enhance the traffic safety. Some roads are narrowed, crosswalks and traffic circles are added, some roads have extra curves, zigzag routes, speed humps and raised intersections and some artificial dead ends are added by placing street closures (Pucher and Buehler 2008). These characteristics may increase the perceived traffic safety in the Netherlands.

*Paragraph summary*

*The environment is expected to influence the transport mode choices of adolescents in a direct as well as in an indirect way. Environmental characteristics can either encourage or form a barrier for particular transport choices. In addition, perceptions seem to be a factor for many specific environmental characteristics for this helps explain why these characteristics are related to specific choices. Furthermore, several built environmental characteristics might impact travel mode choice. Urban density is expected to be related to choosing either active or passive commuting. In rural areas there is thought to be less active travel than in more urban areas, but the amount of active transport may decrease in highly urbanized towns. Land use mix might be related to either active or passive travel, however the direction of this relationship is unclear. The quality of the land use mix seems to be of importance for specific kinds of land use encourage active travel while others discourage walking and cycling. In addition, a more walkable or bikeable neighborhood might encourage active forms of travel. However, it is not clear if this is applicable for Dutch adolescents. Subsequently, apart from the built environment, the natural environment is also expected to influence travel mode choice. Green spaces might influence travel behavior, but also with this characteristic the direction of the connection is unclear. In addition, the presence of slopes is expected to discourage travel for walking or cycling in a hilly environment is more difficult than on a flat surface. Furthermore, the presence of water could influence travel mode choice, although also with this the direction of the relationship was not clear. In addition, weather might influence the travel mode choice, although in some papers no connection was found. Active travel modes are particularly sensitive to weather conditions, specifically cycling. Bad weather might be one of the most important determinants for choosing passive instead of active transportation. Precipitation can lead to less active commuting and this might increase when there is more precipitation. Furthermore, cold temperatures may discourage cycling which is replaced by walking or passive transport. The likelihood of cycling increases when the temperatures are warmer. Strong wind might increase the probability of choosing a passive travel mode. Moreover, extreme weather on day of the trip could be more important than seasonality. Subsequently, the probability of active commuting and particularly cycling seems to decrease during winter compared to spring and fall and increase during summer. However, these seasonal effects might be less strong among daily commuters. Lastly, personal and traffic safety might encourage active travel, while feelings of unsafety can act as a barrier.*

## 2.4 Trip characteristics

In addition to household, personal and environmental characteristics, features related to the trip itself might as well have influence on the travel mode choice. The characteristics that are discussed in this paragraph are distance and time of day.

### 2.4.1 Distance

The relationship between distance from home to school and active transport is the most consistently agreed on predictor of travel behavior within existing literature (Aarts et al 2012; Babey et al 2009; Børrestad et al 2011; Bringolf-Isler et al 2008; Broberg & Sarjala 2015; Collins et al 2015; Davison et al 2008; Dessing et al 2014; Johansson et al 2011; Madsen 2013; Mitra 2013; Panter et al 2008; Pont et al 2009; Van Goeverden & De Boer 2013; Wong et al 2011). It is thought that when the journey between home and school is shorter, the more likely it is that it is that the trip is made with an active form of travel (Børrestad et al 2011; Dessing et al 2014; Panter et al 2008) and when the distance increases, youths are less likely to walk or cycle (Babey et al 2009; Broberg & Sarjala 2015; Mitra 2013; Van Goeverden & De Boer 2013).

Around three kilometers lies the expected maximum distance that youth choose to walk as a form of transportation. This particular distance is as well the point that the positive correlation between distance and cycling turns into a negative relationship. An increased distance is thought to lower the probability of using an active travel mode and increases the likelihood of choosing for passive transport (Van Goeverden & De Boer 2013). Distance can act as a barrier to choose an active transport mode and is the strongest predictor for youths to walk or bike to school (Babey et al 2009; Davison et al 2008; Van Goeverden & De Boer 2012) or use a form of passive transport (Bringolf-Isler et al 2008; Van Goeverden & De Boer 2013).

Van Goeverden & De Boer et al (2013) explain that the distance an adolescent has to commute is determined by the choice for a particular school. Reasons for choosing a school can be divided in academic, which means the level of education, situational, which includes criteria such as proximity and if friends are going to the same school, organizational (this includes the size of the school, if there are specific rules and school management), selective (these are characteristics such as religion, ability and gender) and security, which entails discipline, safety and welfare. Consequently, the choice for a particular school, and therefore the commuting distance, is the result of the proximity of the nearest suitable school combined with how selective the youth and/or the parents are. It is assumed that the nearest school is chosen, unless a more distant school provides a certain higher quality. Whether the higher quality of the school is perceived as important might be related to personal and household characteristics. For example, when parents are highly educated themselves, they might be more likely to choose a particular school for their children that is not necessarily the nearest (Van Goeverden & De Boer).

The effect of distance as a predictor of active travel seems to be particularly strong in urban areas compared to more rural regions (Bringolf-Isler et al 2008; Johansson et al 2011). In rural areas it is less likely that active transport is chosen (Robertson-Wilson et al 2012; Van Goeverden & De Boer 2013), which might be due to the generally greater distances between home and school. More forms of passive transportation, such as travel by bus, are employed in these areas (Robertson-Wilson et al 2012). Furthermore, even when looking at relatively short distances such as 500 meters, youths in urban areas seem to be more likely to walk or cycle to school than youths in rural areas (Bringolf-Isler

et al 2008). This is probably related to the differences in urban density between more rural and urban regions. A higher urban density is connected with increased rates of active commuting (Davison et al 2008). As explained earlier, it is thought that in areas with a higher urban density a multitude of destinations, such as school and shops, are close together, which increases the number of short trips. This phenomenon is illustrated by that while individuals who live maximally three kilometers from a central part of a city make 27% of their trips over short distances, people living further away from the central part of the city or in smaller municipalities have 22% of their total number of trips over a short distance. The more short trips are made, the likelier it becomes that an active form of travel, such as cycling, is chosen (Ministerie van Verkeer en Waterstaat 2009).

The effect of distance on travel mode is thought to be different for particular groups (Bringolf-Isler et al 2008; Wong et al 2011). For example, Mäki-Opas et al (2014) identified distance as the most relevant factor in connection to cycling among adolescents from ethnical backgrounds where cycling was not traditional. A longer distance from home to school might form a barrier for these youths for biking, while the same distance might not be discouraging for adolescents who are used to cycling. People who regularly use the bike for commuting are less likely to be discouraged when it comes to longer distances, however a non-cyclist might perceive this distance as a barrier (Madsen 2013). In the Netherlands the actively commuting of relatively long distances is normal. Van der Horst-Nachtegaal (2009) found that Dutch adolescents walk at least up to three kilometers and they cycle up to ten kilometers. These relative long distances in which active transport is chosen, may in addition to the strong bicycle culture be related to the flat landscape of the Netherlands which is very suitable for walking and cycling.

### 2.4.2 Time of day

Another trip characteristic that might influence the travel mode choice is the time of day (Aarts et al 2012; Dessing et al 2014; Wong et al 2011). The time of day could be relevant due to darkness (Aarts et al 2012; Dessing et al 2014; Madsen 2013; Yang et al 2014) as well as the possibility for parents of bringing their children to school (Aarts et al 2012; Dessing et al 2014; Mitra 2013; Wong et al 2011). Traffic safety as well as personal safety is influenced by darkness (Dessing et al 2014), possibly due to restricted visibility. Furthermore, when it is dark there might be less eyes on the street which can enhance feelings of unsafety (Mitra 2013). Darkness during for example winter mornings could discourage active travel to school (Madsen 2013; Yang et al 2014). In addition, this could result in a change of transport modes between the dark mornings and the afternoon when daylight is present.

Additionally, in previous research is indicated that the youths' transport mode choice can be associated with their parents' works schedule. The parental work-travel characteristics are related to escorted school trips. When parents are available in the morning for escorting to school, the chance of passive commuting to school increases. If youth is not escorted to school by an adult caregiver, walking or cycling is more likely (Mitra 2013). Parents may be available to drive their children to school on the way to their workplace. However, they might not be able to drive them home after school, due to the difference in time schedules between them and their children (Dessing et al 2014; Wong et al 2011). This can possibly lead to a mode shift from passive transport in the mornings to active travel in the afternoon (Aarts et al 2012; Wong et al 2011). Additionally, the choice for either active or passive transport to school is related to their caregivers' convenience. When youths' active travel is difficult to combine with the parents' work schedules or with their after school commitments, they are less likely to use an active transport mode (Davison et al 2008). However, Helbich et al (2016) found that in the

Netherlands the same mode choice is often made for the way to school as well as back home. It should be noted though that this study focusses on younger children, and therefore the results might be different for adolescents for they are more independent. They might be more encouraged or able to travel back home with another transport mode independent from their parents.

*Paragraph summary*

*Distance is the most consistently agreed on predictor for active or passive travel to school. The commuting distance is a result from the choice for a particular school, which might be related to personal and household characteristics. It is thought that distance can form a barrier for active travel. The shorter the distance, the higher the probability of active commuting is and the longer the distance the higher is the likelihood of passive travel. Walking is used for shorter distances and cycling for slightly longer trips. This effect seems to be particularly strong in urban areas compared to rural regions, where it seems to be more likely that passive transport modes are chosen. In addition, the effect of distance might be different for different groups. Time of day might as well influence the travel mode choice due to darkness and the possibility of parents driving their children to school. Darkness might discourage active travel, which could lead to less walking and cycling on winter mornings. Subsequently, the chance of passive commuting might be increased when it is convenient for parents drive their children to school, which could result in separate transport modes in the morning to school and back home in the afternoon. However, this might not be common in the Netherlands.*

# 3. Research design

In this chapter is explained how the practical research is executed and what choices were made in the process. First, the findings from the literature review are represented in a conceptual model, followed by some information regarding the geographical context of this research. Furthermore, the research design and data collection are discussed and subsequently the methods that are employed for the statistical analyses in this research. The final paragraph contains the operationalization of the relevant dependent and independent variables.

## 3.1 Conceptual model

The literature review has resulted in a variety of factors that according to previous research papers are related to various modes of transportation to school by adolescents. A general distinction can be made between individual characteristics, household characteristics, environmental characteristics and trip characteristics. Based on the factors described in the previous chapter, the following conceptual model is constructed (figure 3.1). This model is a schematic rendering of the expected connections between the characteristics and the choices for specific transport modes. It is shown in the model that these attributes are expected to be connected with the choice between passive transport walking and cycling. This conceptual model will be a useful tool for the actual analysis as it presents a clear picture of a complex situation and therefore a practical starting point for examining the transport mode choices of Dutch adolescents.

The choice has been made to exclude certain factors from the conceptual model (and consequently from this study) which did come forward in the previous chapter as variables that are potentially related to the decision of using a specific transport mode. Some examples of characteristics which are not included in this thesis are built environmental characteristics such as the presence of sidewalks and intersections. A reason for deciding to leave out several variables is to keep the analysis focused on the main research questions. In addition, later in this chapter will be more extensively explained, why it is chosen to include certain characteristics and exclude other variables from this research.

## 3.2 Study area

The geographical area covered in this research is the Netherlands. Since the target population of the analysis is situated in this country it is useful to provide some background information for this area. Some general facts about the region will be presented in order to establish a geographical context for the thesis. In addition, some aspects that are particularly relevant with regard to the research questions will be briefly explained in the next part of the chapter. It is for instance expected that elevation (Wong et al 2011) and population density have consequences for travel mode choices (Mitra 2013). Furthermore, the population will be briefly discussed.

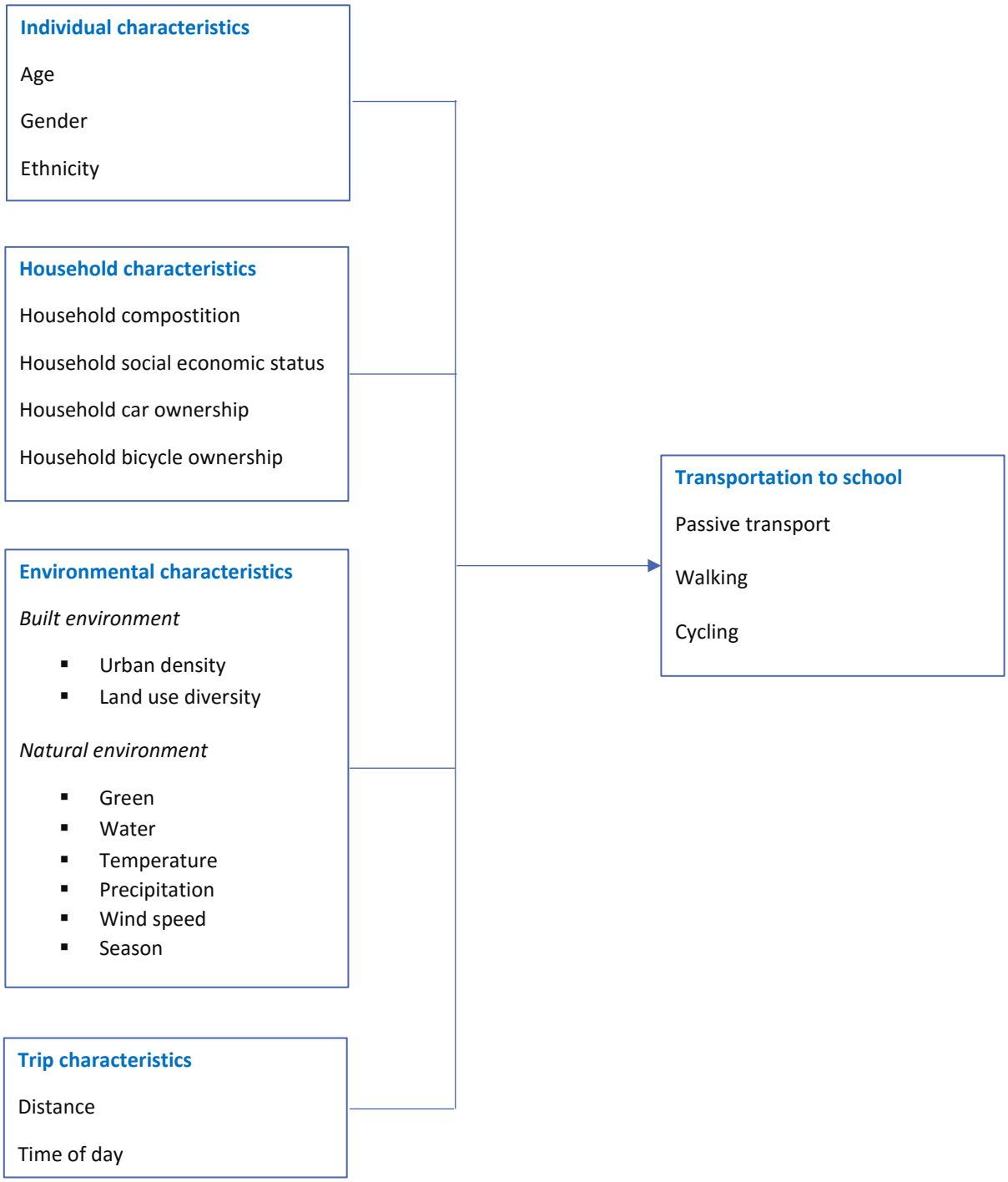


*Figure 3.1 Conceptual model*

### 3.2.1 Geography

The Netherlands is located in the western part of Europe and borders to Belgium on the south and Germany on the east and north. The western side of the country is positioned along a coastline bordering the North Sea. The surface of the country is 41.543 square kilometers of which 33.893 square kilometers are land and 7.650 square kilometers consist of water (Central Intelligence Agency 2016). Water, including numerous canals and lakes, is an important element which characterizes the nations landscape. Almost 25% of the land lies at or below sea level and almost half of the land is elevated just above sea level. This part has in addition to a low elevation a very flat appearance (World atlas, 2015). In some parts of the country more elevation is present, such as in the central area where a number of low rolling hills are situated. In the eastern part of the country an elevation of more than 100 meters is reached and in the far south, bordering the Ardennes, is the only place in the Netherlands where heights of more than 105 meters are measured (Encyclopedia Britannica 2016).

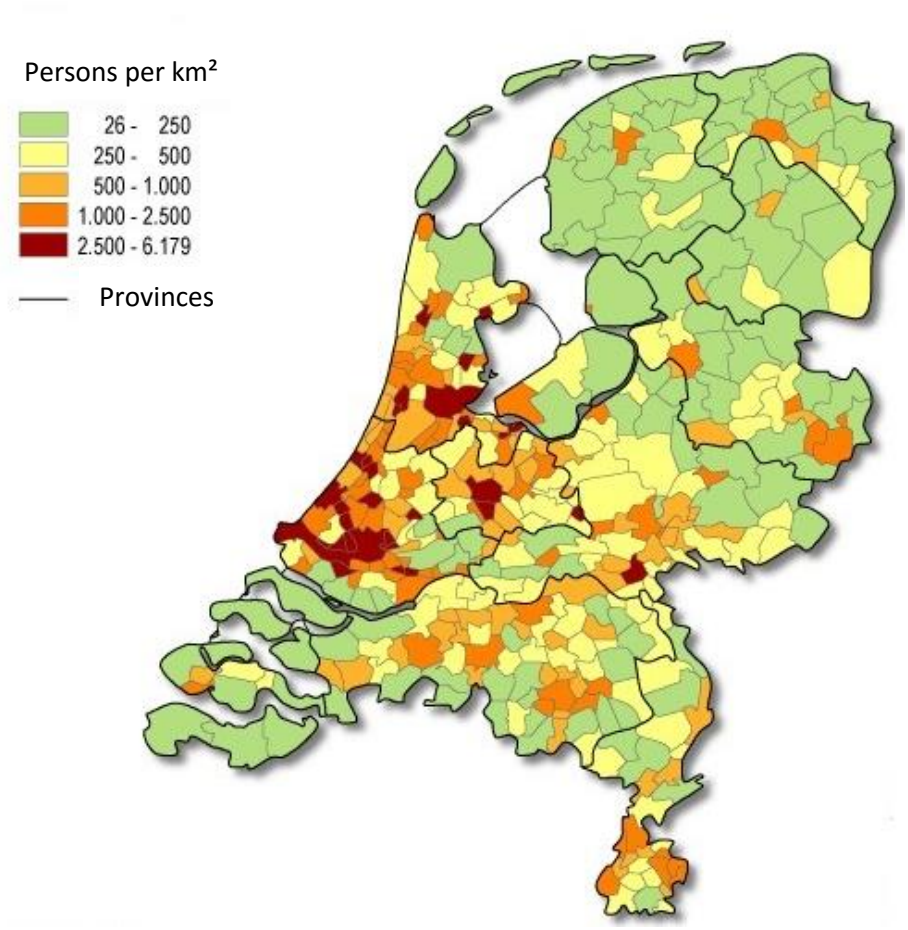


*Figure 3.2 Population density per municipality in the Netherlands (2013)*
*(Source: Rijksinstituut voor Volksgezondheid en Milieu 2014)*

The Netherlands are divided into multiple organizational entities of which a commonly used division is the twelve provinces, namely Drenthe, Flevoland, Friesland, Gelderland, Groningen, Limburg, Noord-Brabant, Noord-Holland, Overijssel, Utrecht, Zeeland and Zuid-Holland. Moreover, the country consists of 390 separate municipalities (figure 3.2) (Centraal Bureau voor de Statistiek 2016). The nation's two largest cities are Amsterdam, which has a population of 837.155 and Rotterdam which has 630.383 inhabitants. Other major cities include The Hague with 520.321 people and Utrecht which has 339.852 residents (Centraal Bureau voor de Statistiek 2016b).

### 3.2.2 Population

The number of inhabitants in the Netherlands, measured in November of 2015, was 16.900.726 (Centraal Bureau voor de Statistiek 2015). The nation has an average population density of 500 persons per square kilometer (Centraal Bureau voor de Statistiek 2015), which makes the Netherlands the most densely populated country in the European Union (with exception of the very small countries such as Malta) (Migration Watch UK 2015). The majority of the people in the Netherlands live in urban areas which are densely populated (Nations Encyclopedia 2016). The most populated area is located in the western part of the country (Figure 3.3) and includes the cities of Amsterdam, Rotterdam, Utrecht and The Hague (Organization for Economic Co-operation and Development 2007). The northern and the south western part of the country are more sparsely populated and have generally a more rural function.

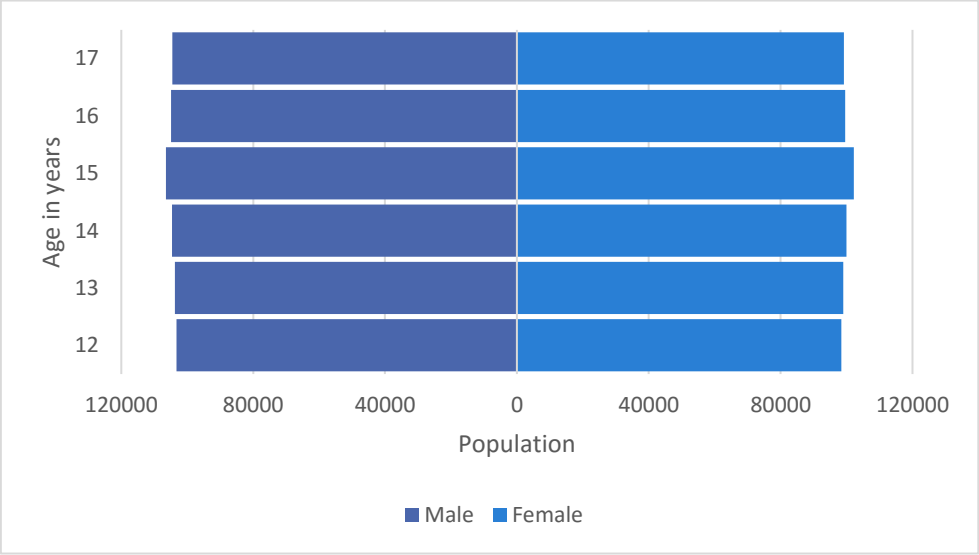


*Figure 3.4 Adolescents in The Netherlands*
*(Source: Centraal Bureau voor de Statistiek 2016c)*

Consequently, it is useful to briefly address the target population of this thesis, namely Dutch adolescents aged 12 to 17. The Netherlands houses 1.225.701 adolescents between 12 and 17, which is proportionally 7,3% of the population (Centraal Bureau voor de Statistiek 2015; Centraal Bureau voor de Statistiek 2016c). In figure 3.4 a graph is shown which represents the distribution of age and gender

in this specific group. There are slightly more boys than girls, namely an average of 51,2% male and 48,8% female. The age group of 15 year olds is the largest class. However, the differences between the ages and genders do not seem major.

## 3.3 Research design and data collection

In the next part of the chapter the various choices and methods for the practical analysis will be discussed. First, the decision for a specific research strategy and design will be indicated. The process of data collection will subsequently be explained.

### 3.3.1 Research design

A quantitative research strategy was chosen for this analysis alternatively to a qualitative approach, in order to effectively answer the research questions. This strategy seems particularly useful for this research since the aim of the study is to gain insights in the travel mode choice of Dutch adolescents. An advantage of adopting quantitative methods compared to a qualitative strategy is the possibility of generalizing the outcomes of the analysis to an entire population (Bryman 2012). This means that the results of this research may lead to general insights about adolescents in the Netherlands and their decision for a particular way of traveling to school, which fits the aim of this thesis.

A suitable way of executing this approach is by applying a cross-sectional research design. Practical ways of collecting data following this research design are observation schedules, structured interviewing, content analysis, diaries, analyzing of official statistics and the method most commonly associated with a cross-sectional research design, namely surveys. The survey is the method used for this particular analysis. A major benefit of utilizing a questionnaire is that it is an excellent way of approaching a large number of respondents and therefore generating results that may be generalized. By approaching a vast number of people, a variety of respondents can be reached which can help to provide a broad view of the population. An additional advantage of using a survey is the possibility reaching a variety of people who live geographically dispersed in a larger area (Bryman 2012). Since the target population of this thesis lives across the entire country this method is appropriate.

### 3.3.2 Data collection

Collecting data was not necessary for this analysis, since a data set that fits the purpose of this research was already available, namely the Dutch national travel survey (‘Onderzoek Verplaatsingen in Nederland 2012 – OviN 2012 versie 2.0’). This survey was carried out by the Centraal Bureau voor de Statistiek and Rijkswaterstaat in 2012. A consequence of working with an existing database is that it is not possible to ask specific questions that were not asked in the original questionnaire. Therefore, some characteristics that are associated with transport mode choice according to previous research were excluded from the analyses. However, the survey has resulted in a vast amount of data, which provides the possibility of generalizing results to the Netherlands. With its great amount of information for a relatively large area, the advantages seem to outweigh the negative aspect and therefore the Dutch national travel survey will be used for this thesis.

In the next part of this paragraph some information will be given about the execution of the original survey in order to explain how the data is obtained. The following information is provided by the Centraal Bureau voor de Statistiek (CBS) (2014). In the original research respondents were asked to report for one specific day where they went, what their purpose was, which transport mode they used and how long it took to get there. Additionally, some general personal and household characteristics were asked as well as some supplementary information such as if they were in possession of a driving license and if they owned vehicles, including cars and bicycles. This generated detailed information about daily transportation and travel behavior by Dutch inhabitants within the Netherlands.

The original observation period was from January 2010 to December 2012. By means of a letter, people were asked to fill out a questionnaire online. Every person was assigned a specific day and date in a particular week to fill out the survey, for the intention of the research was to obtain data of every day of the year. In the case of non-response, additional requests were sent to partake in the study, with again the same day of the week assigned to fill out the questionnaire. Moreover, first the participants were approached by means of Computer Assisted Web Interviewing (CAWI) and when they did not respond after several requests, they were reached by Computer Assisted Telephone Interviewing (CATI) if their phone number was known. When this occurred, people were no longer able to fill out the survey online in order to prevent multiple responses. In case of no known phone number a Computer Assisted Personal Interviewing (CAPI) tactic was used.

Participating in the study took an average time of 15 minutes if the questionnaire was filled out online or by telephone and approximately 20 minutes when the face-to-face method was employed. Not every respondent received all questions in the survey for there was a routing system in place which presented only the questions that were relevant for that particular person.

In addition to the basic inquiry some supplemental research was done. Extra participants were approached in every province where the number of response was lower than the average amount of response per province. This was the case for Groningen, Friesland, Drenthe, Overijssel, Flevoland, Utrecht, Zeeland and Limburg. The intention of this additional research was to obtain the same level of response in every region and achieve a representative sample distribution for the Netherlands. This means that the number of participants per province were theoretically in proportion to the population size per province.

The research units of the study were individuals rather than households. A sample was drawn from a sampling frame of the CBS which was based on the Gemeentelijke Basis Administratie (GBA). The target population of the original survey consists of all persons living in the Netherlands from age zero and older who are part of a private household and registered with the GBA. Inhabitants living in institutions, facilities and non-private homes were not included in the sample because it was assumed that the mobility of this group is severely restricted.

Additionally, not all mobility was included in the survey. For instance, mobility related to holidays was left out of the survey. Holidays are defined as a stay outside the own home with the aim of recreation consisting of at least four consecutive nights which are not spent with family or at the home of acquaintances. All the mobility during the holidays, including the transportation from home to the destination and back are excluded from the analysis. Furthermore, only mobility on Dutch territory is included in the data set. Mobility which occurs exclusively abroad is left out and transportation across borders is split into a Dutch part and a foreign part and only the Dutch part was added to the data set.

The sample contained approximately 0,3% of the total population. The response was 43.677 of which 43.307 were included in the database, which is a response rate of 52%. A number of responses was

not added to the data set for it was judged that they lacked quality. Reasons to reject particular completed questionnaires were that they were not genuinely answered or due to a high percentage of responding with 'I do not know' or 'I do not want to answer this question'.

### 3.4 Methods

In this paragraph the methods which are used to answer the research questions are explained, namely to what extent the choice between passive commuting, walking and cycling to school by Dutch adolescents is influenced by individual and household characteristics and other characteristics. By employing statistical methods, it is analyzed whether there are connections between the various characteristics and transport mode choice and what kind of relationships these are. All analyses are carried out using SPSS, version 23. First, descriptive statistics are utilized and subsequently advanced statistical methods. The descriptive statistics are combined with visual representations such as graphs which will provide a first impression of the data. This part of the analysis presents some general information regarding the variables, which provides a framework for the advanced statistical tests and helps to interpret the results.

In addition to the descriptive statistics, advanced statistics will be used. In order to answer the research questions, a multinomial logistic regression model is applied to the data. This model is appropriate for this particular research aim with this set of data for it is possible with a multinomial logistic regression model to have a categorical outcome variable (Field 2009). The aim of this study is to find which variables influence the choice to either use passive forms of transport, to walk or to cycle. The outcome variable is categorical and therefore a linear regression model cannot be used. A multinomial logistic regression model, while it is mostly comparable with a binary logistic regression model, differs in the sense that it is possible for the outcome variable to have more than two categories (Field 2009). Because there are three outcome categories, a multinomial logistic regression model is chosen.

Applied to this research this means that passive travel, walking and cycling act as dependent variables in this model. Passive transport is in this case the reference category. The independent variables are entered in multiple steps. First, the individual variables will be entered in the model, followed by the household variables, then the trip variable and finally are the environmental variables entered. By entering the variables in multiple steps, it is checked if the model containing all the variables is the best fit for the data, compared with the model when it includes only a part of the variables.

### 3.5 Data operationalization dependent and independent variables

In this part of the chapter will be discussed how the characteristics found in the literature review are operationalized into variables in order to perform the analyses. The variables are adopted out of the Dutch national travel survey database. The original dataset contains an extensive number of characteristics which are not all relevant for this thesis. In this paragraph only the useful variables are shown which are utilized in the analyses together with their scale of measurement and values. Some additional information is given when necessary. Several variables were adapted from their original form into variables more suitable for this particular thesis. In the appendix an overview is provided of the original variables in the database that were used, in what way they were recoded and the coding that is used in the analyses (table 7.1). In this paragraph, first is described what choices were made to isolate the target population from the remainder of the data. Subsequently, the dependent variables

followed by the independent variables are presented and where necessary supplementary information is given.

In order to separate the research units from the rest of the data, namely trips to school made by adolescents aged 12 to 17 in the Netherlands, several decisions were made. First, the persons who were age 12 to 17 were isolated in order to single out the adolescents. Next, the trip destination was restricted to education/taking a class as destination. Next, the days of the week were reduced to Monday, Tuesday, Wednesday, Thursday and Friday for it is assumed that secondary schools are only open on weekdays and therefore education related trips outside the normal weekdays are excluded. Lastly, the trip destination was restricted to education/taking a class as destination. By choosing to utilize the variable 'trip destination' instead of 'motive' the aim was to exclusively focus on trips from home to school and therefore not including the return from school. The reasons for making this particular choice were firstly to limit the number of trips per person in order to prevent a potential distortion in the analysis. Secondly, it is assumed that people do not necessary go home after school but might go to friends or exercise hobbies. By exclusively concentrating on the way to school it is attempted to keep the trips to a certain extent similar which may result in more meaningful analyses.

### 3.5.1 Operationalization variables

An overview of the relevant dependent and independent variables is given in table 3.1. The dependent or outcome variables in this thesis are passive transport, walking and cycling. The category passive transport includes transport by car, public transport such as the train, bus and metro and driving by moped or motorbike. This category is considered the reference category.

Age, gender and ethnicity are expected to provide information about a person's individual background. In addition, the number of parents, household income, household car ownership and household bicycle ownership are assumed to generate insights in the influence the youth's household has on transport mode choice. The term parents contains parents as well as caregivers.

The variables that are used to gain information about environmental characteristics are address density of the residential location, urbanicity of the municipality of residence, land use diversity, percentage of green, percentage of water, temperature, precipitation, wind speed and seasons. The variables which express address density can be used to interpret the degree of concentration of human activities such as living, working, going to school and shopping. Urbanicity is a variable which is based on the average address density of a municipality and measures the concentration of human activities for each municipality. The variable is divided into five categories which are highly urban, which means an average of 2500 or more addresses per square kilometer, very urban (with averagely 1500 to 2500 addresses per square kilometer), moderately urban (an average of 1000 to 1500 addresses per square kilometer), not very urban (per square kilometer averagely 500 to 1000 addresses) and not urban with an average of less than 500 addresses per square kilometer (Centraal Bureau voor de Statistiek 2016d).

The land use diversity is measured using the Shannon land use diversity index, which is a common approach to measure diversity. In the index the number of different land use types and the proportional area distribution among land use types are used to gain insight in the land use diversity. If the index is equal to zero, this implies that there is no land use diversity and when the index increases the land use diversity increases (Kuosmanen 2010). The percentage of green and the percentage of water are measured per residential PC4 zones. PC4 zones are areas in the Netherlands with addresses

*Table 3.1 Description, scale and values of the relevant variables*

| Variable | Description | Scale | Values |
|---|---|---|---|
| Transport mode | Transport mode used for the trip | Nominal | 0= Passive transport<br>1= Walking<br>2 = Cycling |
| ***Individual characteristics*** | | | |
| Age | Age of the respondent in years | Ratio | Current age |
| Gender | Gender of the respondent | Nominal (Dichotomous) | 0= Female<br>1= Male |
| Ethnicity | Ethnic group of the respondent | Nominal | 1= Native<br>2= Western<br>3= Non-western |
| ***Household characteristics*** | | | |
| Number of parents | Number of parents in household | Nominal (Dichotomous) | 0 = 1 parent<br>1= 2 parents |
| Household income | Net annual household income | Ordinal | 1= <€10000<br>2= €10000-20000<br>3= €20000-30000<br>4= €30000-40000<br>5= €40000-50000<br>6= >€50000 |
| Household car ownership | Number of cars owned in household | Ratio | Number of cars |
| Household bicycle ownership | Number of bicycles owned in household | Ratio | Number of bicycles |
| ***Environmental characteristics*** | | | |
| Address density for residential location | Residential address density in number of addresses per km² | Ratio | Address density |
| Urban density | Urban density of the municipality of residence | Ordinal | 1= Highly urban<br>2= Very urban<br>3= Moderately urban<br>4= Not very urban<br>5= Not urban |
| Land use diversity | Shannon land use diversity index in a buffer of 200 meters | Ratio | Index |
| Green percentage | Combined area percentage green (excluding agricultural land) in residential PC4 zone | Ratio | Percentage |
| Water percentage | Combined area percentage water in residential PC4 zone | Ratio | Percentage |
| Temperature | Daily maximum air temperature (°C) | Interval | Temperature in °C |
| Precipitation | Daily precipitation sum in millimeters | Ratio | Precipitation in millimeters |
| Wind speed | Daily average wind speed in meters per second | Ratio | Wind speed in meters per second |
| Season | Season in which the trip occurred | Nominal | 1= Winter<br>2= Spring<br>3= Summer<br>4= Autumn |
| ***Trip characteristics*** | | | |
| Distance | Trip distance in kilometers | Ratio | Distance in kilometers |

that have the same first four numbers of the postal code (First Element 2016). Furthermore, the seasons that are used are the meteorological seasons, which means that March, April and May are considered spring, June, July and August are summer, Autumn consists of September, October and November and Winter is December, January and February (Koninklijk Nederlands Meteorologisch Instituut 2016b).

The trip characteristics that were considered to be relevant for the research are distance and the time of day when the adolescents departed from home. Distance as well as duration were available in the dataset. However, it was chosen to exclude duration, for distance and duration are closely connected and therefore no independent variables and this could compromise the quality of the statistical analyses. In the literature review was found that distance as a characteristic was mentioned more than

Duration in previous research which is the reason for choosing this particular variable instead of duration. Finally, it is chosen to exclude the time of day from the analyses, due to the choice of only including the way to school in the model. The differences between travel in the morning and in the afternoon are therefore no longer present in the data, because the majority of youths travels in the morning to school. The advantage of having more representative data, was considered to outweigh the disadvantage of missing this variable in the analyses.

# 4. Results and discussion

In this chapter the results of the statistical analysis are explained. First, the general characteristics of the sample and the descriptive statistics are discussed. These statistics provide the first insights in the characteristics of the variables and their relative proportions of passive transport, walking and cycling. Subsequently, the multinomial logistic regression model is applied and the results of that analysis are described. The aim of performing this statistical test is to provide insights into which variables are important for the mode choice to school among adolescents. Findings from the previously discussed literature will be used to explain the results. As was established in the previous chapter, the data is assumed to be representative for the population and therefore the results can be generalized to all Dutch adolescents (CBS 2014).

## 4.1 Descriptive statistics

The sample that is used in this research consists of a total of 5161 trips. In table 4.1 an overview is given of the descriptive statistics. The most frequently used travel mode is cycling, which was used for 3989 trips (77,3%). Passive transport was chosen for 965 trips (18,7%) and walking was the least common transport mode, with 207 trips (4,0%). The younger age categories (especially 12, 13 and to a lesser extend 14) are more represented in the data than the other ages. The older the age, the less represented the group is within the data. Gender is divided evenly; 2581 (50%) of the sample is male, and 2581 (50%) is female. The adolescents are mostly native Dutch (85,1%) and of the non-native youths is almost twice as much of a non-western ethnicity (9,5%) compared to a western ethnicity (5,4%). The majority of the adolescents live in a household with two parents (87,1%) compared to 12,9% of the households with one parent. The greater part of the youths lives in a household with a net annual income of more than €.30.000 and only 1,5% has a net annual household income of less than €.10.000. The average number of cars in a household is 1,5 and the mean for household bicycle ownership is 5,1. The average address density is 1179,1 addresses per km², with a standard deviation of 1141,215. The most common outcome for urban density is not very urban with 26,2% and the least common urban density category is highly urban (10,2%). The other categories seem to be relatively similar. The average land use diversity has a score of 1,791 with a standard deviation of 0,481. 58,2% is the mean for the percentage of green in the residential PC4 area and 5,5% is the average percentage of water in residential PC4 areas. The mean maximum daily temperature that was measured was 12,4˚C. The lowest temperature was -6,4 ˚C and the highest that was measured was 34,7 ˚C. The mean daily precipitation sum was 2 mm, with a standard deviation of 4,045 mm, and the average daily wind speed was 4,1 meters per second and had a standard deviation of 1,853. Notable in the seasons is that there are less trips during summer (12,8%) compared to the other months (32,7% in autumn, 26,2% in winter and 28,3% in spring). This difference is probably related to the summer holiday, during which no trips to school take place. Finally, the average distance adolescents travel to school is 7,6 km. The shortest distance is 0,1 km and the longest distance is 159,2 km. The long maximum distance might be due to specialized schools, or vocational schools which are less common and therefore possibly a longer distance from the place of residence

*Table. 4.1 Summary of descriptive statistics*

| Variable | Min | Mean | Max | St. dev. | Categories | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Transport mode | --- | --- | --- | --- | Passive transport: 18,7% | Walking: 4,0% | Cycling: 77,3% | --- | --- | --- |
| ***Individual characteristics*** | | | | | | | | | | |
| Age | --- | --- | --- | --- | 12: 19,5% | 13: 19,5% | 14: 17,9% | 15: 16,0% | 16: 14,6% | 17: 12,6% |
| Gender | --- | --- | --- | --- | Male: 50% | Female: 50% | --- | --- | --- | --- |
| Ethnicity | --- | --- | --- | --- | Native: 85,1% | Western: 5,4% | Non-western: 9,5% | --- | --- | --- |
| ***Household characteristics*** | | | | | | | | | | |
| Number of parents | --- | --- | --- | --- | 1 parent: 12,9% | 2 parents: 87,1% | --- | --- | --- | --- |
| Household income | --- | --- | --- | --- | <€.10000: 1,5% | €.10000-20000: 3,9% | €.20000-30000: 13,3% | €.30000 -40000: 22,0% | €.40000-50000: 22,4% | >€.50000: 37,0% |
| Household car ownership | 0 | 1,5 | 10 | 0,783 | --- | --- | --- | --- | --- | --- |
| Household bicycle ownership | 0 | 5,1 | 10 | 1,820 | --- | --- | --- | --- | --- | --- |
| ***Environmental characteristics*** | | | | | | | | | | |
| Address density for residential location | 2,9 | 1179,1 | 11443,0 | 1141,215 | --- | --- | --- | --- | --- | --- |
| Urban density | --- | --- | --- | --- | Highly urban: 10,2% | Very urban: 23,4% | Moderately urban: 21,2% | Not very urban: 26,2% | Not urban: 19,0% | --- |
| Land use diversity | 0,000 | 1,791 | 2,792 | 0,481 | --- | --- | --- | --- | --- | --- |
| Green percentage | 3,0 | 58,2 | 97,5 | 21,467 | --- | --- | --- | --- | --- | --- |
| Water percentage | 0,0 | 5,5 | 58,8 | 6,844 | --- | --- | --- | --- | --- | --- |
| Temperature | -6,4 | 12,4 | 34,7 | 7,112 | --- | --- | --- | --- | --- | --- |
| Precipitation | 0,0 | 2,0 | 58,9 | 4,045 | --- | --- | --- | --- | --- | --- |
| Wind speed | 0,6 | 4,1 | 14,8 | 1,853 | --- | --- | --- | --- | --- | --- |
| Season | --- | --- | --- | --- | Winter: 262% | Spring: 28,3% | Summer: 12,8% | Autumn: 32,7% | --- | --- |
| ***Trip characteristics*** | | | | | | | | | | |
| Distance | 0,1 | 7,6 | 159,2 | 10,065 | --- | --- | --- | --- | --- | --- |
| *n=5161* | | | | | | | | | | |

### 4.1.1 Individual characteristics

When looking at the distribution of age per transport mode to school, there are clear differences in mode choices for the different ages. According to figure 4.1, there is a smaller number of school trips by bicycle for youths with higher ages, particularly among 16 and 17 year olds. In addition, when the age increases it becomes more common to choose passive forms of transport. This might be related to that schools are often further away when youths get older, which increases the probability of choosing passive transport (Mäki-Opas et al 2014) combined with that adolescents from the age of 16 are allowed to ride a light motorcycle or a scooter (Rijksoverheid 2015b). Another noticeable difference is that 12 year olds relatively walk more than older youths. This might be because some 12 year olds may still go to a primary school, which is generally closer. Closer distances are related to more walking (Van der Horst-Nachtegaal 2009).

There seem to be no major differences in travel mode choice to school between the genders, except for that girls choose cycling less often and passive transport more frequently compared to boys. This outcome was mentioned in the literature review, in which was described that boys were more likely to cycle compared to girls, while girls were more likely to use a form of passive transport (Leslie et al 2010).

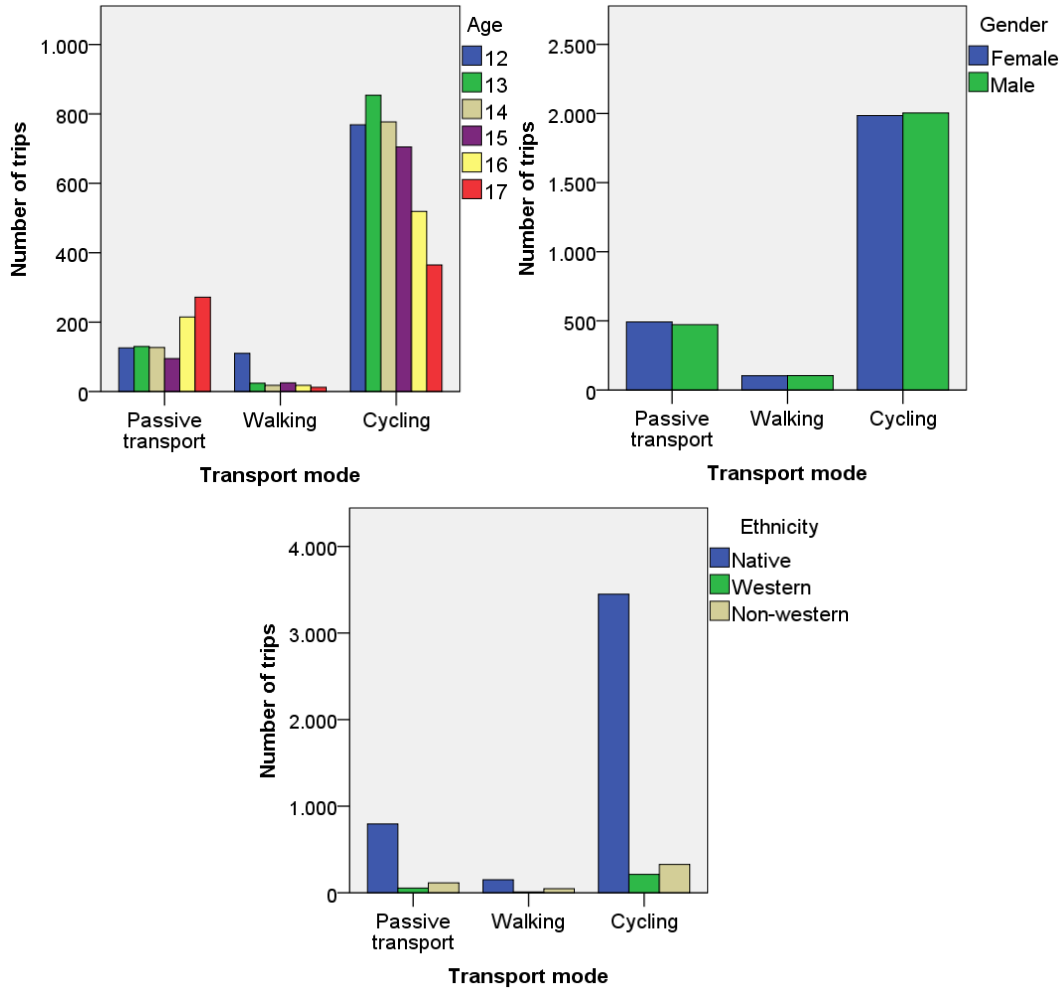


*Figure 4.1 Transport mode by age, gender and ethnicity*

Furthermore, there are differences in mode choice among the ethnic groups. Relatively few adolescents with a non-western ethnicity cycle compared to native Dutch youth. The proportional distinctions between the ethnic groups seem to be smaller within passive transport as well as walking. Based on previous research this result is also expected, because native Dutch youths are far more likely to cycle than adolescents with a non-western ethnicity (Van der Horst-Nachtegaal 2009; De Bruijn et al 2005). This might be because of cultural distinctions (Mäki-Opas et al 2014) and the related differences in bicycle ownership (Van der Horst-Nachtegaal 2009).

### 4.1.2 Household characteristics

For household composition, there seems to be no major contrast between one parent and two parent households regarding travel mode choices, except for a relative high amount of cycling among youths who live in a household with two parents (figure 4.2). This might be because of the availability of bicycles per household. Households with two working parents often own more bicycles than households with merely one working parent (Van der Horst-Nachtegaal 2009).

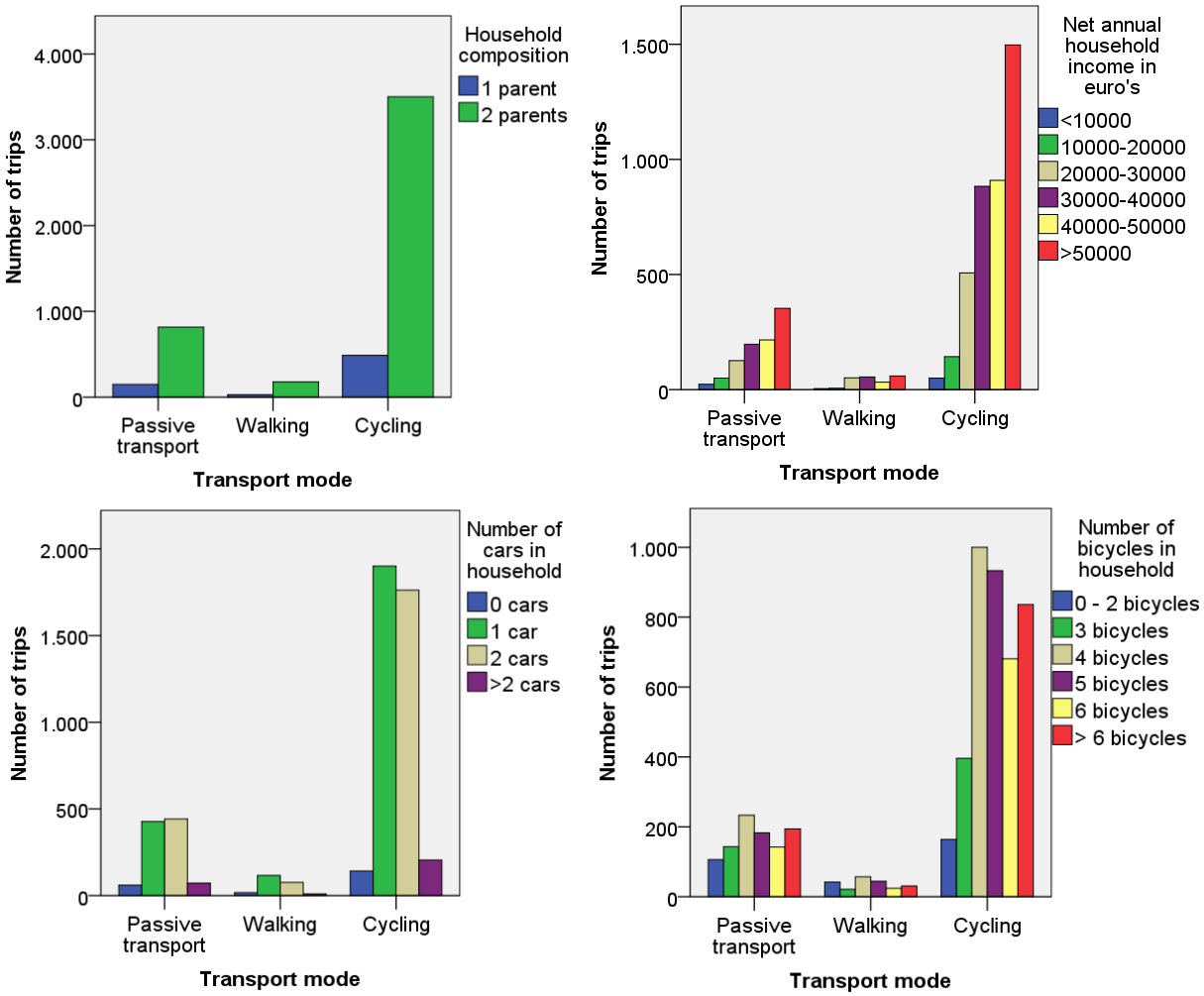


*Figure 4.2 Transport mode by household composition, net annual household income, number of cars in household and number of bicycles in household*

What is noticeable for net annual household income is that youth from households with a higher income tend to relatively cycle more and walk less. An explanation may be found as well in bicycle ownership. Households with lower incomes might own less bicycles than households with higher incomes (Van der Horst-Nachtegaal). Another possibility is that youth from households with a higher income might choose schools that are further away, because of the quality of the schools (Van Goeverden & De Boer 2013). This could increase the distances and therefore discourage walking. Cycling would be a more logical choice for longer distances (Van der Horst-Nachtegaal 2009).

There seems to be a distinction between the transport modes to school per number of cars in a household, for there is more cycling when there are one or two cars in a household compared to no or more than two cars. This might be related to the households' social economic status. When there is a higher social economic status, it would be likely that there are cars available in the households. As mentioned earlier, a higher social economic status could be connected with more cycling. This effect is particularly strong for households with one car and decreases when there are more cars. The decrease when there is more than one car in a household was expected, for the number of cars per household is thought to be negatively connected with active commuting to school, and this is particularly relevant when a household has more than one car available (Johansson et al 2011).

Additionally, there are distinctions between household bicycle ownership and the transport modes. Particularly, cycling is more often chosen when there are four or more bicycles in a household compared to relatively little walking. When there are zero to two bicycles available cycling is less common, and passive transport forms and walking to school are chosen more frequently.

### 4.1.3 Environmental characteristics

From figure 4.3 can be deduced that there is relatively little walking among youths living in a low density location and relatively much walking in regions with a higher density. These observations are supported by previous research, for walking seems to be less common in areas with a lower address density (Babey et al 2009; Davison et al 2008; Mitra 2013; Robertson-Wilson et al 2012). This might be because of the less infrastructure available for walking in these areas (Davison et al 2008) or that there might be less schools in low density areas which is expected to increase the travel distances to school and therefore discourage walking (Van Goeverden & De Boer 2013). In addition, when there is a higher urban density there seems to be more walking (Mitra 2013). A possible explanation could be the proximity of facilities within denser neighborhoods, which might make these areas more attractive for walking.

Additionally, there are differences in mode choice when looking at the urban density of the municipality. Cycling appears to be less common in either highly urban and not urban municipalities and relatively more passive transport is used in not very urban and not urban municipalities. Highly urban areas tend to have more traffic, which may decrease the feeling of safety, which could discourage cycling (De Bruijn et al 2005). The explanation for less cycling in non-urban municipalities might be the same as mentioned earlier. There might be less schools in low density areas which could increase the travel distances to school and therefore make active travel less appealing (Van Goeverden & De Boer 2013). Walking is chosen more often as a transport mode in highly urban and very urban

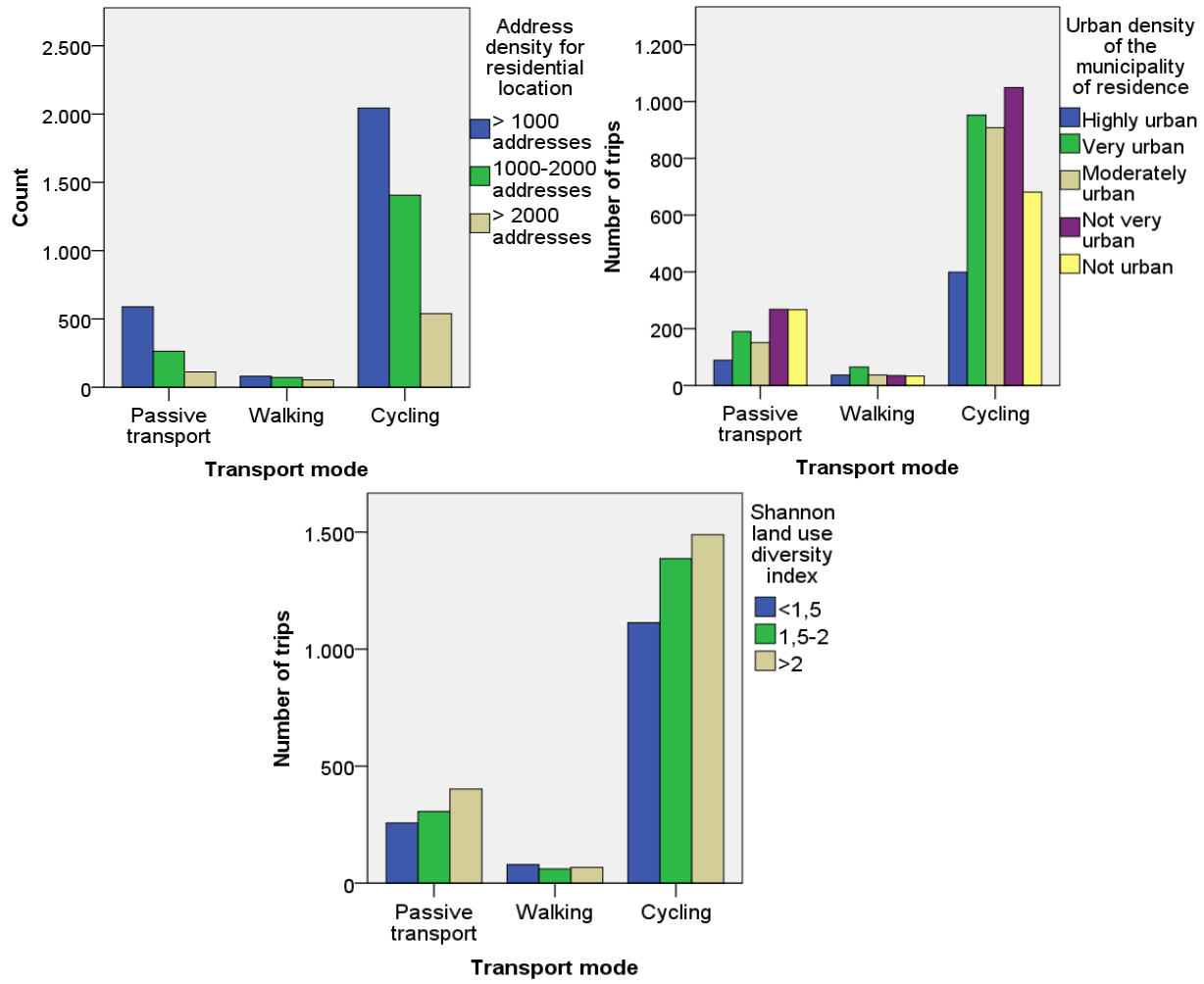


*Figure 4.3 Transport mode by address density for residential location, urban density of municipality of residence and land use diversity*

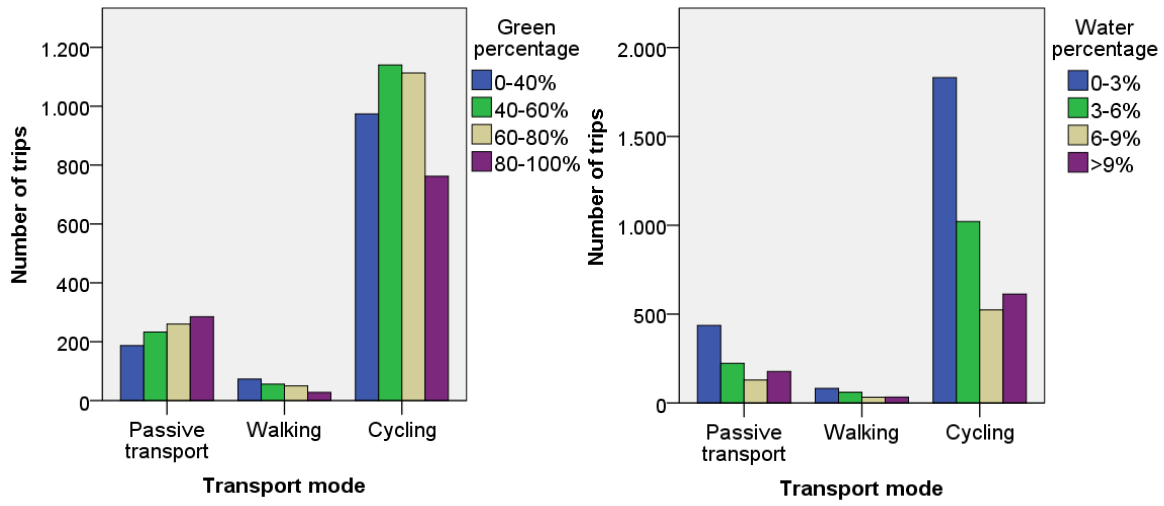


*Figure 4.4 Transport mode by green percentage and water percentage*

municipalities. A high density is related with more walking (Mitra 2013), which might be because of the proximity of facilities which makes the area more attractive for walking.
The results from land use diversity and transport mode are expected from the literature. There seems to be more walking and slightly more cycling in areas with a higher land use diversity. It is expected that a diverse land use decreases the distances between different destinations which could encourage active forms of transport (Madsen 2013; Wong et al 2011).

From figure 4.4 can be concluded that the chosen transport modes differ for different combined area percentages of green in residential PC4 zones. When there is a high amount of green there seems to be more passive transport and less walking. This might be because of the lower density of facilities when there is more green in an area and therefore longer distances. Longer distances might encourage use of passive forms of travel and discourage walking. It is also less common to cycle when there is 80-100% green in an area, which could as well be related to the longer distances which result from a high amount of green.

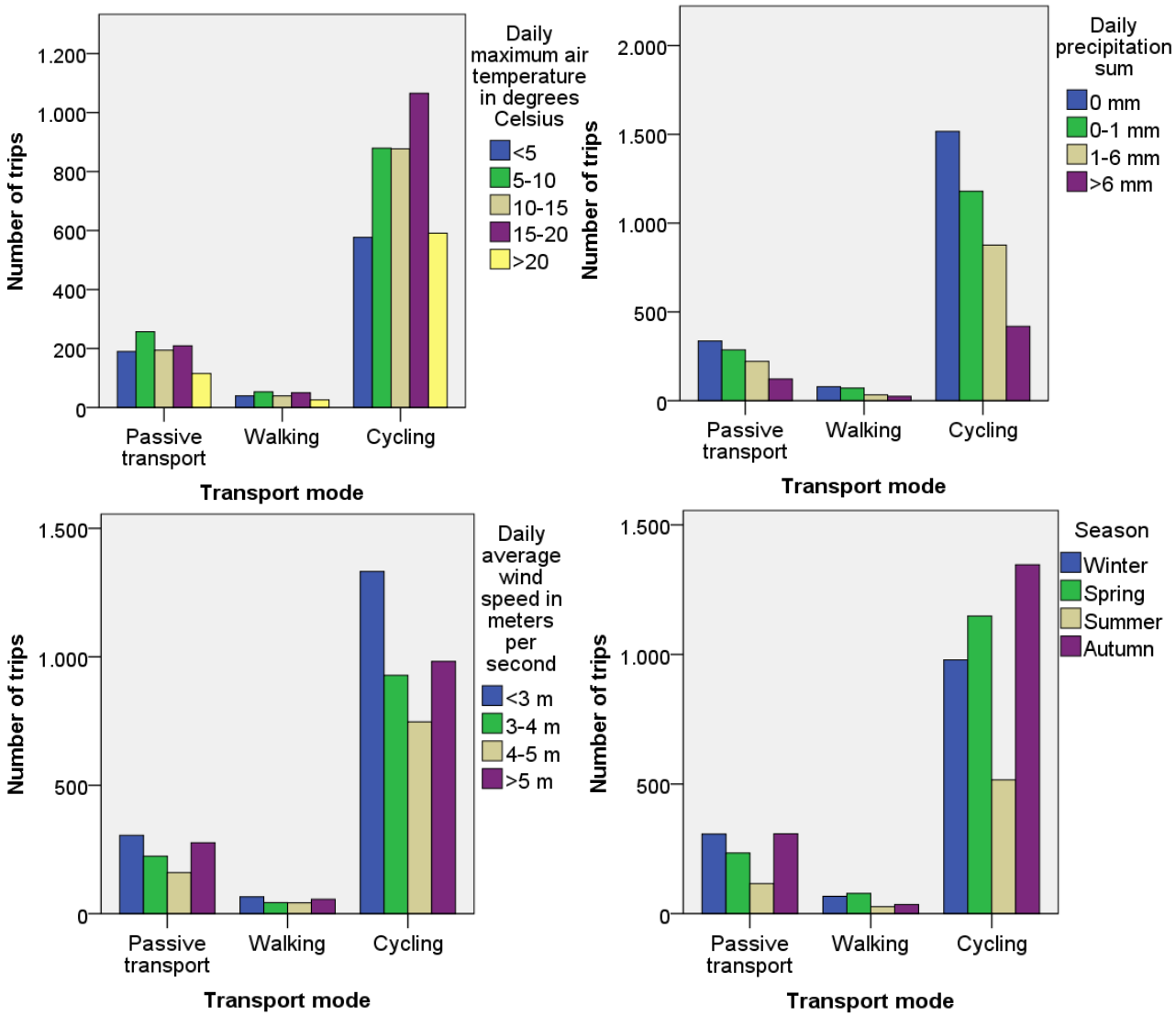


*figure 4.5 Transport mode by daily maximum air temperature, daily precipitation sum, daily average wind speed and season.*

The transport mode choices also vary per percentage of water in residential PC4 zones. When there is little water in the area (0-3%) there is a relatively high amount of cycling. This might be because the presence of water could act as a barrier for cycling (Ministerie van Verkeer en Waterstaat 2009).

From figure 4.5 can be assumed that during lower temperatures there is relatively more use of passive transport and when there are higher temperatures cycling is more often chosen. This is supported by previous studies for it was expected that people cycle less and often choose other transport forms during very low temperatures and cycle more in warm weather (Sabir 2011; Van Goeverden & De Boer 2013).

Additionally, when there is more precipitation cycling becomes less common. This is as well an expected result since precipitation is considered the most common barrier for active travel (Harrison et al 2015; Madsen 2013).

When there is a lower wind speed there seems to be more cycling. This is supported by literature, for cycling is thought to be more affected by strong wind than walking. This might be because cyclists are more exposed to strong wind than pedestrians (Fishman et al 2015).

According to figure 4.5 cycling also is less common during the winter, when there is more use of passive transport. Decreased temperatures may discourage cycling (Børrestad et al 2011; Madsen 2013) and lead to more use of passive transport.

### 4.1.4 Trip characteristics

Finally, there are major differences between the travel modes per distance (figure 4.6). Walking is almost never used for transport to school for distances greater than 5 km. Cycling decreases strongly when the distance increases and is almost never used for distances larger than 20 km. Passive transport seems to be the only form of transport for distances which are more than 20 km. These results were expected in the previously discussed literature for distance is the most consistently agreed on predictor of travel behavior (Børrestad et al 2011; Broberg & Sarjala 2015; Dessing et al 2014; Mitra 2013; Panter et al 2008; Pont et al 2009; Van Goeverden & De Boer 2013).

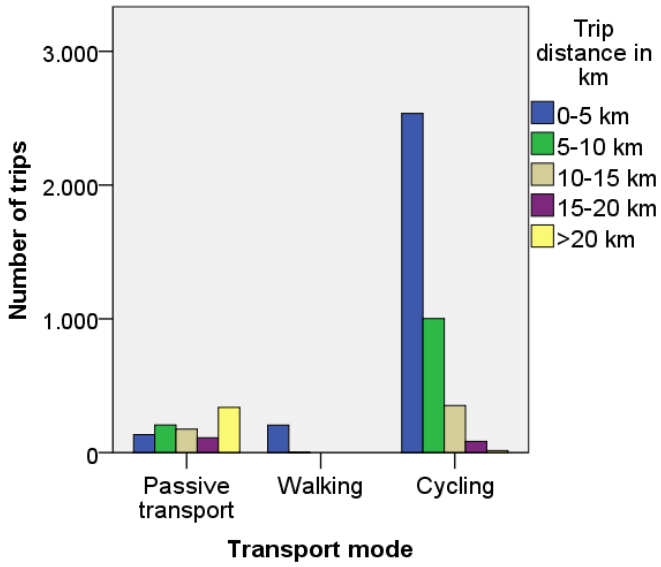


*Figure 4.6. Transport mode by trip distance*

## 4.2 Multinomial logistic regression analysis

From the previous paragraph can be deduced that there is likely to be a relationship between individual, household, environmental and trip characteristics and transport mode to school among adolescents. In order to further examine these connections a multinomial logistic regression model has been executed. In this model the transport mode acts as a dependent variable and individual, household, environmental and trip characteristics are used in the model as independent variables.

### 4.2.1 Fit of the model

After examining the fit of the model, it can be concluded that the model as a whole is significant at the 99% confidence level with a -2 Log Likelihood of 3640,528 and a chi-square of 2982,158. It can therefore be determined that there is a significant relationship between the independent and dependent variables. A measure for the quality of the model is the Nagelkerke R Square. The score for this model is 0,607 which indicates a reasonably strong connection between the predictors and transport mode. In addition, the model predicts 86,7% of the transport modes correctly, which is an increase compared to the correctly predicted transport modes for the model when the independent variables were not included.

Additionally, several assumptions were checked before executing the multinomial logistic regression. Outliers could form a potential problem, as a few cases could excessively influence the model due to having very different scores than the other variables. These influential cases can be found by analyzing the residuals, which are statistics that express the difference between the observed and predicted scores (Field 2009). After analyzing the studentized residuals, cook's distance, DFBeta and leverage statistics, the potential influential cases were inspected and finally 69 cases were removed from the database. These cases were excluded because the travel speed that was listed did not match with their transport mode. There were cases in which the speed was too slow as well as cases for which the speed was too fast.

The data was also checked for potential multicollinearity. Multicollinearity means that there is a strong correlation present between two or more predictors, which could affect the results of the analysis (Field 2009). Firstly, there are no correlations between the independent variables that are higher than 0,8 or 0,9. The highest correlation is between address density for residential location and green percentage (r=-0,67). When exploring possible multicollinearity further, there are no tolerance values less than 0,1 and there is in addition no VIF score higher than 10. It can therefore can be concluded that this assumption is met.

### 4.2.2 Results and discussion multinomial logistic regression analysis

After executing the multinomial logistic regression, it can be determined which variables significantly influence the mode choice of adolescents to school. All the individual characteristics, namely age, gender and ethnicity, significantly contribute to choosing a particular transport mode. Of the household characteristics, only the household car ownership and household bicycle ownership have a significant connection. Urban density, water percentage, temperature and precipitation are the

significant environmental characteristics. Furthermore, distance has a significant effect as well on the mode choice of adolescents.

*Table 4.2 Results multinomial logistic regression with passive transport as reference category*

| Variable | Values | Transport mode | | | | | |
|---|---|---|---|---|---|---|---|
| | | Walking | | | Cycling | | |
| | | Wald | Sig. | Exp(B) | Wald | Sig. | Exp(B) |
| Intercept | - | 57,020 | ,000*** | - | 70,241 | ,000*** | - |
| ***Individual characteristics*** | | | | | | | |
| Age | Age | 46,607 | ,000** | 0,641 | 44,993 | ,000** | ,812 |
| Gender (ref=Male) | Female | 3,280 | ,070 | 0,694 | 10,723 | ,001** | ,722 |
| Ethnicity (ref=Native) | Western | 1,293 | 0,256 | 0,589 | 2,066 | ,151 | ,741 |
| | Non-western | 1,325 | 0,250 | 1,424 | 21,854 | ,000** | ,465 |
| ***Household characteristics*** | | | | | | | |
| Number of parents (ref= 1 parent) | 2 parents | 1,953 | 0,162 | 1,616 | ,006 | ,938 | 1,012 |
| Household income (ref=<€10000) | €10000-€20000 | ,502 | ,479 | ,531 | ,186 | ,667 | 1,207 |
| | €20000-€30000 | ,219 | ,640 | 1,472 | 1,752 | ,186 | 1,686 |
| | €30000-€40000 | ,011 | ,916 | ,923 | 2,632 | ,105 | 1,872 |
| | €40000-€50000 | ,712 | ,399 | ,525 | 2,246 | ,134 | 1,788 |
| | >€50000 | ,096 | ,757 | ,793 | 2,325 | ,127 | 1,793 |
| Household car ownership | Number of cars | ,001 | ,979 | 1,004 | 5,024 | ,025* | ,861 |
| Household bicycle ownership | Number of bicycles | ,202 | ,653 | 1,031 | 52,476 | ,000** | 1,265 |
| ***Environmental characteristics*** | | | | | | | |
| Address density for residential location | Index | ,595 | ,440 | 1,000 | 3,987 | ,046* | 1,000 |
| Urban density (ref=Not urban) | Highly urban | ,032 | ,857 | 1,104 | 3,226 | ,072 | ,623 |
| | Very urban | 1,628 | ,202 | ,593 | 12,310 | ,000** | ,501 |
| | Moderately urban | 2,962 | ,085 | ,514 | ,547 | ,460 | ,872 |
| | Not very urban | 4,186 | ,041* | ,486 | ,689 | ,406 | ,883 |
| Land use diversity | Index | 2,968 | 0,085 | ,646 | 2,064 | ,151 | ,846 |
| Green percentage | % | ,841 | ,359 | 1,007 | 1,072 | ,300 | ,996 |
| Water percentage | % | ,684 | ,408 | ,986 | 14,067 | ,000** | ,975 |
| Temperature | °C | 2,270 | ,132 | 1,033 | 2,270 | ,132 | 1,033 |
| Precipitation | mm | 2,670 | ,102 | ,952 | 5,180 | ,023* | ,973 |
| Wind speed | m/s | ,062 | ,804 | ,985 | 2,548 | ,110 | ,957 |
| Season (ref=Winter) | Spring | ,542 | ,461 | 1,271 | ,936 | ,078 | 1,320 |
| | Summer | 2,071 | ,150 | ,497 | 2,667 | ,102 | ,675 |
| | Autumn | 2,716 | ,099 | ,567 | 3,098 | ,333 | 1,174 |
| ***Trip characteristics*** | | | | | | | |
| Distance | km | 219,343 | ,000** | 1,031 | 725,382 | ,000** | ,757 |
| **p<,05, **p<,01* | | | | | | | |

In table 4.2 an overview is provided of the results of the multinomial logistic regression. The Wald statistic indicates whether the independent variable makes a significant contribution to the outcome (Field 2009) and represents the relative importance of the independent variables for the logit (De Vocht 2008). Whether or not this contribution is considered significant can be found in the table in the

adjacent column, together with the confidence level. Exp(B), or the odds ratio, expresses the change in odds when there is a unit change in the predictor. A value of Exp(B) higher than 1 signifies that when the predictor value increases, the odds of the outcome occurring become higher. A value lower than one represents a decrease in odds that the outcome occurs when the predictor value increases (Field 2009). The results of the analysis are discussed separately for each variable category.

### *Individual characteristics*

Age has a significant influence on walking as well as on cycling. For walking, age is the second most important variable with a Wald score of 46,6 and for cycling it is the third most important variable with a Wald score of 45,0. When adolescents get older it becomes increasingly less likely that they walk or cycle to school. The probability of walking decreases with approximately 36% per year and for cycling the probability declines with 19%. These results were predicted by previous research and the descriptive statistics. The outcome might be related to that schools tend to be further away when youths get older and longer distances often lead to passive transport (Mäki-Opas et al 2014). For example, vocational schools are less common than secondary schools, which could increase the probability of a longer distance to school (Bringolf-Isler et al 2008). Additionally, when adolescents get older, they become more independent from their parents and therefore more likely to make their own transportation decisions (Mitra 2013). While their parents might have encouraged them to cycle or walk to school at a younger age, older youth might choose passive transport forms such as a light motorcycle (Van Goeverden & De Boer 2013). Adolescents are allowed to ride a light motorcycle or a scooter from age 16 (Rijksoverheid 2015b).

Gender also has a significant influence on the choice for a particular transport mode to school among adolescents. However, this variable is only significant for cycling and not for walking. It seems to be less likely for girls to cycle to school than for boys, with the probability of cycling being approximately 28% less for girls than for boys. This might be because of a traditional division between girls and boys. Parents tend to be more protective towards girls, which could lead to less travel freedom (McDonald 2012). There might also be a difference in perception of the environment, which could lead to different travel behavior (Panter et al 2008; Nelson & Wood 2010). For example, girls might feel less safe in parks or places with a high traffic volume (Nelson & Wood 2010), which could lead to choosing passive transport instead of cycling. While this relationship between gender and transport mode was discussed in the literature review (Leslie et al 2010), the results are different than expected, since it was speculated that gender differences might not be common in countries where cycling is more common (McDonald 2012), such as the Netherlands with its strong bicycle culture (Martens 2007). However, from the analysis it appears that gender does have a significant influence on the choice for cycling.

Ethnicity has as well only a significant impact on cycling. Ethnicity is the fourth most important characteristic for cycling with a Wald score of 21,9 for a non-western ethnicity compared to a native ethnicity. Adolescents with a western ethnicity compared to native Dutch youth have an about 26% lower probability to cycle to school and youth with a non-western ethnicity are approximately 54% less likely to bike to school. This outcome was expected from the descriptive statistics as well as from previous research. The reason for these differences could be found in the different cultural backgrounds. Because the bicycle is traditionally an important transport mode in the Netherlands (De Bruijn et al 2005), most native Dutch children learn to cycle at a young age. This is less common among youth with non-western background, since cycling is not a part of their original culture (Mäki-Opas et al 2014). When they do not learn it from their parents at a young age but when they are older, they are likely to have less experience with cycling. This could lead to a decreased probability of choosing

cycling as a transport mode (Ministerie van Verkeer en Waterstaat 2009). Another barrier for cycling for non-native Dutch adolescents is that there might be less or no bicycles available in their household (Van der Horst-Nachtegaal 2009).

### *Household characteristics*

The household characteristics which have a significant influence on travel mode choice to school are household car ownership and household bicycle ownership. However, these characteristics only have a significant influence on cycling. More cars per household decreases the probability of cycling by approximately 14%. This effect was expected from the literature review as well as from the descriptive statistics. Not having access to a car could be a direct motivation to commute actively to school (Panter et al 2008). Additionally, the availability of a car enables being driven to school and could therefore encourage passive travel (Mitra 2013; Van Goeverden & De Boer 2013).

Furthermore, household bicycle ownership is the second most important variable for choosing cycling with a Wald score of 52,5. For each bicycle per household more, the probability of cycling increases by around 27%. A logical explanation is that owning a bicycle enables cycling. In addition, for households in which cycling is common owning bicycles seems to be more likely than for households in which bicycles are not frequently used.

### *Environmental characteristics*

Urban density is the third most influential predictor for walking with a Wald score of 4,2 for not very urban compared to not urban. When the municipality of residence is highly urban, the probability of walking is approximately 10% compared to a non-urban municipality. When the municipality is not very urban, the probability of walking decreases with around 51%. This was expected from the literature review, since a higher density is often related with a number of facilities close together which leads to short distances and could encourage walking (Mitra 2013). The lower probability of walking in less urban environments can be explained by that youths in non-urban areas tend to live further away from their school. When there is a lower population density in an area, the school density is also expected to be lower (Van Goeverden & De Boer 2013). Longer distances increase the likelihood of passive transport (Davison et al 2008; Robertson-Wilson et al 2012). There might also be less infrastructure for walking in these areas, which could discourage walking (Davison et al 2008). Additionally, urban density also has a significant influence on cycling. For cycling the classification very urban seems to be the relatively most important category with a Wald score of 12,3. When the municipality is very urban, the likelihood of cycling decreases with 50% compared to a non-urban municipality. This effect was previously suspected in the descriptive statistics and in the literature review. It was expected from previous research that in larger, denser cities there was an increased use of public transport and walking instead of cycling (Ministerie van Verkeer en Waterstaat 2009; Van Goeverden & De Boer 2013). This might be because highly urbanized municipalities tend to have more traffic that moves at a higher speed. This may lead to traffic safety issues among cyclists, which discourages cycling (De Bruijn et al 2005). In addition, in more urbanized cities there is often good public transportation, which may encourage passive travel to school (Van Goeverden & De Boer 2013). When the urban density is less urban the probability of cycling versus passive transport still decreases, but less than for the denser municipalities, namely approximately 13% for moderately urban compared to not urban and around 12 percent for not very urban compared to not urban. Similar to walking this might be explained by the generally longer distances to school in these areas (Van Goeverden & De

Boer 2013) which increases the probability of choosing passive transport (Davison et al 2008; Robertson-Wilson et al 2012).

Another environmental characteristic with a significant influence on mode choice is water percentage. The percentage of water in an area has a significant influence on cycling. A higher percentage of water decreases the probability of cycling with approximately with 2,5% per percentage of water. This might because water could act as a barrier for cycling, for waterways can only be crossed in specific places when there are bridges available that are suitable for cycling (Ministerie van Verkeer en Waterstaat 2009). Another suggestion is that this could be related to safety issues for cyclists regarding the traffic on bridges. The space on bridges is limited with often no possibility of moving aside which could increase feelings of unsafety.

Additionally, temperature has a significant impact on cycling. When the temperature rises, the probability of cycling to school increases with 5% per degree °C. In previous research a connection between higher temperatures and more cycling was found as well, for it was expected that people cycle more in warm weather compared to colder weather circumstances when there is more use of other transport modes (Sabir 2011; Van Goeverden & De Boer 2013). This could be because cyclists are more sensitive to extreme weather conditions than people who walk or travel passively (Sabir 2011).

Moreover, precipitation has a negative significant influence on cycling. When the amount of precipitation increases, the likelihood of cycling to school decreases with 2,7% per millimeter. This was already suspected in the descriptive statistics and the literature review. Precipitation can form a barrier for cycling (Harrison et al 2015; Madsen 2013) and lead to choosing different transport modes such as public transport or the car. Possible explanations are that cycling during precipitation can be uncomfortable, more challenging as well as more dangerous (Sabir 2011). This affects cycling more than walking, because it is easier to find shelter against precipitation when walking, by for instance using an umbrella or finding shelter under the cover of a building (Fishman et al 2015).

### *Trip characteristics*

Distance is the most important variable for explaining transport mode choice to school among adolescents and is significant at the 99% confidence level. For walking the Wald score was 219,4 and for cycling the Wald score was 725,4. The probability of choosing walking decreases with approximately 3% per kilometer and for cycling it reduces by 24%. These results were predicted by the descriptive statistics and the previously discussed literature for distance is the most consistently agreed on predictor of travel behavior (Børrestad et al 2011; Broberg & Sarjala 2015; Dessing et al 2014; Mitra 2013; Panter et al 2008; Pont et al 2009; Van Goeverden & De Boer 2013). When the trip to school is shorter, the probability of walking or cycling increases (Børrestad et al 2011; Dessing et al 2014; Panter et al 2008) and when the distance gets longer, youth are less likely to choose a form of active transport compared to passive transport (Babey et al 2009; Broberg & Sarjala 2015; Mitra 2013; Van Goeverden & De Boer 2013).

# 5. Conclusions

Obesity and overweight are a major health threat among adolescents (Mendoza & Liu 2014) and the number of obese and overweight adolescents in the Netherlands is rising (Nationaal Kompas Volksgezondheid 2014). The underlying cause of overweight and obesity is an energy imbalance between the intake of calories and the calories that are expended (WHO 2015). A way of preventing and counteracting this is by increasing the amount of physical activity. An accessible and feasible way of increasing the daily amount of physical activity is by promoting active travel to school (D'Haese e.a. 2011; Trapp e.a. 2012). The aim of this research was to provide insights in the mode choice among Dutch adolescents between passive transport, walking and cycling to school. Obtaining knowledge about the commuting habits of adolescents could contribute to more specific and therefore more effective strategies and policies in order to counteract and prevent overweight and obesity among adolescents.

## 5.1 Answering research questions

In order to obtain insights into the school travel behavior of Dutch adolescents, the following research questions were formulated: 'To what extent is the choice between passive transport, walking and cycling to school by Dutch adolescents influenced by individual and household characteristics?' and 'to what extent is the choice between passive transport, walking and cycling to school by Dutch adolescents influenced by other characteristics?'. After analyzing the existing literature and executing the analyses these questions can now be answered.

Cycling was the most common transport mode among Dutch adolescents with 77,3% of the trips, 18,7% of the trips was made with a passive transport mode and walking was the least common transport mode with 4,0% of the trips. All the individual characteristics, namely gender, ethnicity and age, have a significant influence on cycling, however age is the only individual characteristic that also has a significant influence on the choice for walking. Age is the most important individual characteristic for explaining the travel mode choice. In addition, when considering all the variables, it is the second most important predictor for explaining walking and the third most important variable for cycling. When adolescents get older they are increasingly less likely to walk or cycle and more likely to choose a form of passive transport. In previous research it was found that narrow age groups should be distinguished when looking at their travel behavior, because they behave in different ways (Wong et al 2011). From this study this also seems to be true for Dutch adolescents. Within this age group, youths from 16 years and older seem to behave differently than younger adolescents, for they use more passive forms of transport and less active travel compared to the younger ages.

The results for gender were surprising, since it was expected that gender differences would not be common in countries with a strong bicycle culture (McDonald 2012) such as the Netherlands (Martens 2007). However, gender does have a significant influence on the choice for cycling. Girls are less likely to cycle to school than boys and are more likely to choose a passive transport forms compared to boys.

The outcome for ethnicity was expected from previous research (Van der Horst-Nachtegaal 2009; De Bruijn et al 2005). Non-native Dutch adolescents are less likely than native Dutch youths to cycle to school. Particularly few adolescents with a non-western ethnicity cycle compared to native Dutch youths.

The household characteristics that are significantly related to the choice for a particular transportation to school are household car ownership and household bicycle ownership. The influence is however only significant for cycling and not for walking. When there are more cars in a household, the probability of cycling decreases. This seems to be particularly relevant when there is more than one car. This effect was expected from previous literature (Johansson et al 2011).

Household bicycle ownership is the second most important variable for explaining the choice for cycling compared to passive transport. More bicycles in a household are related to an increase in cycling. Particularly when there are zero to two bicycles available, cycling is less common compared to passive transport and walking. Owning four of more bicycles per household increases the probability of cycling to school.

Other characteristics that influence the transport mode choice to school among Dutch adolescents are the environmental characteristics urban density of the municipality of residence, water percentage, temperature and precipitation. Furthermore, the trip characteristic distance is connected to mode choice. Urban density of the municipality of residence has in addition the choice for cycling also influence on walking. Urban density is for walking the third most influential variable. When the municipality is highly urban the likelihood of walking is highest, and when the municipality is less urban the probability of walking decreases, which was expected from the literature review (Mitra 2013). When the urban density is less than highly urban, the probability of walking decreases compared to a non-urban municipality. While for walking a higher urban density has an encouraging influence, this is not the case for cycling. In municipalities that are highly or very urban the probability of cycling decreases, which was also expected (De Bruijn et al 2005; Johansson et al 2011; Ministerie van Verkeer en Waterstaat 2009; Van Goeverden & De Boer 2013).

Another environmental characteristic that significantly influences travel mode choice to school is water percentage. When there is a higher percentage of water in the area, the probability of cycling decreases. However, there is presently not much research which touches on this subject. This might be an interesting topic for future research, for water is an important feature in the Dutch landscape and many Dutch adolescents encounter water during their commute to school.

Other natural environmental characteristics that are connected with the choice for a particular transportation mode are temperature and precipitation. These characteristics are also only significantly related to cycling and not to walking. An expected result was that when the temperature rises, the likelihood of cycling to school increases and when the temperature is lower there is more use of passive transport modes (Sabir 2011; Van Goeverden & De Boer 2013).

Precipitation has a negative influence on the probability of cycling to school. When the amount of precipitation increases, the likelihood of cycling of school decreases, which was expected as well (Harrison et al 2015; Madsen 2013).

The most important characteristic in relation to mode choice to school among adolescents is distance. This is the most important characteristic for explaining walking as well as cycling. The probability of walking and cycling decreases when the distance increases. This effect the most consistently agreed on predictor in previous research (Børrestad et al 2011; Broberg & Sarjala 2015; Dessing et al 2014; Mitra 2013; Panter et al 2008; Pont et al 2009; Van Goeverden & De Boer 2013). Among Dutch adolescents walking is almost never used for distances greater than 2 km for the commute to school and cycling is almost never chosen for distances greater than 22 km, in which case passive transport is used. These distances, particularly for cycling, are relatively long. This is probably because of the strong

Dutch bicycle culture which includes a widely available bicycle infrastructure, and the flat landscape in the Netherlands which is very suitable for cycling (Van der Horst-Nachtegaal 2009).

## 5.2 Strengths and limitations

An important strength was the fact that this research had a nationwide approach. Previous studies concentrating on Dutch adolescents were either focused on one city such as Amsterdam (Mäki-Opas et al 2014) or Rotterdam (Bere et al 2011; Prins et al 2009; Van der Horst Nachtegaal 2009) and the studies about Dutch adolescents that were conducted on a national level either focused mainly on ethnicity (Van Dommelen et al 2015), included cycling and not walking (De Bruijn et al 2005) or discussed Dutch adolescents as a subcategory (Van Goeverden & De Boer 2013). The nationwide approach of this study adds new insights to the current knowledge, because it can help understand transport mode choices among adolescents in diverse geographic locations, such as more rural regions and highly urban areas, alternatively to for example one city. Connected to this, is that due to the scale of this research, general statements about Dutch adolescents could be made. By utilizing a vast database general insights could be given about what characteristics were related to specific mode choices among Dutch adolescents. This adds valuable insights to the existing knowledge and can therefore be considered a strength. Another strong point of this research is the focus on adolescents. This group behaves differently than adults when looking at transportation because of their different activity patterns (Prins et al 2009) and different from younger children due to their increased independence and generally longer distances to school (Van Goeverden & De Boer 2013). As mentioned earlier, previous studies concentrating on Dutch adolescents could often not be generalized to the population. The fact that this study could provide general statements specifically about Dutch adolescents is an important strength. Another asset of this study is that it distinguishes between walking and cycling. These two transport modes were associated with distinct correlates in previous research (Dessing et al 2014) and are useful for different distances, for walking is only practical as a transport mode for shorter distances (Van Goeverden & De Boer 2013) while cycling can be used for longer distances (Trapp et al 2011). However, relatively few studies have made the distinction between walking and cycling (Bere et al 2011), which makes this is a strong point for this research.

In addition to the strengths this research has, there are also several limitations that should be noted. First, a typical downside of using a cross-sectional research design is that there is generally a weak internal validity. This means that the results from the analysis represent merely relationships between the variables of which no definitive causality may be assumed (Bryman 2012). Another limitation concerns the use of secondary data. A consequence of working with an existing database is that it was not possible to ask specific questions that were not asked in the original questionnaire or follow-up questions. Therefore, some characteristics that were associated with transport mode choice according to previous research, such as safety issues and perception of the environment, had to be excluded from the analyses. The information generated from the research was also general to a certain degree because there was no possibility to include personalized questions and therefore results (Bryman, 2012). Moreover, there was little information concerning the built environment along the route of the trip, which potentially could provide important information about what exactly has a relationship to particular mode choices.

A suggestion for future research is the usage of GPS-tracking or a walk-along combined with interviews among adolescents. These methods could potentially provide more in-depth information concerning motivations and personal characteristics. They might also help with understanding the characteristics

of the route to and from school itself and to what extend this influences the mode choice. Finally, a longitudinal study could be very useful for gaining more insights in the travel behavior of adolescents over time. Since age is an important characteristic for explaining mode choice and the amount of active travel generally decreases when youths get older it could be interesting to find out what elements are connected with this decline. Isolating these characteristics could potentially help with forming policies for counteracting the decrease of active travel over time.

### 5.3 Policy recommendations

By applying this knowledge about the commuting behavior of Dutch adolescents, several policy recommendations can be made in order to encourage choosing active forms of transport to school. First, distance was the most important characteristic for explaining the travel mode choice and could therefore potentially form a possibility for improvement. In order to stimulate active commuting to school the distances should not be too long between home and school. When the distances are longer, the likelihood of choosing active transport decreases. Therefore, schools should be widespread, so that as much youths as possible have a shorter travel distance to school. This implies that the merging of schools to serve a larger area should be avoided, for this could potentially increase distances for commuting to school and discourage walking or cycling.

Another possibility for encouraging active travel is by targeting the specific groups that are less inclined to use active travel. For instance, youths with a non-native Dutch background, particularly those with a non-western ethnicity, are less likely to cycle to school. Programs could be set up to, if necessary, teach them to cycle and/or to help them gain experience. Cycling experience could increase the skill level for riding the bicycle as well as confidence in traffic. This could lead to the perception of cycling being a safe and comfortable transportation option and therefore more attractive. Another problem this group faces is often a lack of bicycles in their household. This could be tackled by implementing a program which subsidizes bicycles or setting up a bicycle loan program. Subsidizing bicycles or a bicycle loan program could also be a solution for other adolescents (for example youths from households with a low socio-economic status) who have no or little bicycles available in their household.

Furthermore, another group that is choosing less for active transport are the older adolescents, particularly youths from 16 and 17. A part of this group chooses to ride a scooter or light motorcycle to school instead of active transport because they are allowed at this age. While this cannot be stopped, a slight improvement could be adding some active travel to their commute. By for example placing the parking spaces for scooters and motorcycles a distance behind the bicycle parking, this group has to walk at least a small part of their route. By making the scooter or light motorcycle less attractive by displacing the parking spaces, combined with education about the health benefits of active travel, the situation might be improved.

Additionally, regular attention should be given to making routes to school as safe and comfortable as possible. Particularly in highly urban municipalities, safe, comfortable bicycle routes that are separate from heavy traffic could encourage active transport. By communicating regularly with groups that are less inclined to use active travel such as youth with a non-western background and girls, situations that are perceived as unsafe can be isolated and addressed. Involving adolescents in this process could benefit the safety and therefore the attractiveness of school commutes and encourage them to travel actively.

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# 7. Appendixes

*Table. 7.1 Coding and recoding of the variables*

| **Characteristics** | **Original variable** | | | **New variable** | | |
|---|---|---|---|---|---|---|
| | Name variable | Values | Scale | Recoding | Values | Scale |
| Transport mode | KHvm | 1= Car as a driver<br>2= Car as a passenger<br>3= Train<br>4= Bus/tram/metro<br>5= Moped/mini-moped<br>6= Bicycle<br>7= Walking<br>8= Other | Nominal | 2, 3, 4, 5 → 0<br>7 → 1<br>6 → 2<br>1,8 → missing value | 0=Passive transport<br>1=Walking<br>2=Cycling | Nominal |
| ***Individual characteristics*** | | | | | | |
| Age | age | Age in years | Ratio | --- | Age in years | Ratio |
| Gender | male | 0= Female<br>1= Male | Nominal (dichotomous) | --- | 0= Female<br>1= Male | Nominal (dichotomous) |
| Ethnicity | ethnicity | 1= native<br>2= western<br>3= nonwestern<br>4= unknown | Nominal | 1 → 1<br>2 → 2<br>3 → 3<br>4 → missing value | 1= Native<br>2= Western<br>3= Non-western | Nominal |
| ***Household characteristics*** | | | | | | |
| Household composition | HHSam | 1=One-person household<br>2=Couple<br>3=Couple + child(ren)<br>4=Couple + child(ren) + other(s)<br>5=Couple + other(s)<br>6=1 parent household + child(ren)<br>7=1 parent household + child(ren) + other(s)<br>8=Other composition | Nominal | 6, 7 → 0<br>3, 4 → 1<br>1, 2, 5, 8 → missing value | 0= 1 parent<br>1= 2 parents | Nominal (dichotomous) |
| Household income | hhincome | 1= <€10000<br>2= €10000-20000 | Ordinal | --- | 1= <€10000<br>2= €10000-20000 | Ordinal |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | 3= €20000-30000<br>4= €30000-40000<br>5= €40000-50000<br>6= >€50000 | | | 3= €20000-30000<br>4= €30000-40000<br>5= €40000-50000<br>6= >€50000 | |
| Household car ownership | hh_ncars | Number of cars in household | Ratio | --- | Number of cars in household | Ratio |
| Household bicycle ownership | hh_nbicycles | Number of bicycles in household | Ratio | --- | Number of bicycles in household | Ratio |
| ***Environmental characteristics*** | | | | | | |
| Address density for residential location | res_dens | Address density for residential location (number of addresses per km²) | Ratio | --- | Address density for residential location (number of addresses per km²) | Ratio |
| Urban density | Sted | 1= Highly urban<br>2= Very urban<br>3= moderately urban<br>4= Not very urban<br>5= Not urban | Ordinal | --- | 1= Highly urban<br>2= Very urban<br>3= moderately urban<br>4= Not very urban<br>5= Not urban | Ordinal |
| Land use diversity | shan200 | Shannon land use diversity index of residential PC4 resampled from 25 to 200 m | Ratio | --- | Shannon land use diversity index | Ratio |
| Green percentage | pgreen | Combined area percentage green (excl. agricultural land) in residential PC4 | Ratio | --- | Combined area percentage green (excl. agricultural land) in residential PC4 | Ratio |
| Water percentage | pblue | Combined area percentage water in residential PC4 | Ratio | --- | Combined area percentage water in residential PC4 | Ratio |
| Temperature | TA_max | Daily maximum air temperature | Ratio | --- | Daily maximum air temperature in °C | Ratio |
| Precipitation | Psum | Daily precipitation sum | Ratio | --- | Daily precipitation sum in mm | Ratio |
| Wind speed | Ws_avg | Daily average wind speed in meters per second | Ratio | --- | Daily average wind speed in m/s | Ratio |
| Season | month | month | Nominal | 12, 1, 2 → 1<br>3, 4, 5 → 2<br>6, 7, 8 → 3<br>9, 10, 11 → 4 | 1= Winter<br>2= Spring<br>3= Summer<br>4= Autumn | Nominal |
| ***Trip characteristics*** | | | | | | |
| Distance | trip_distance_km | Trip distance in km | Ratio | --- | Trip distance in km | Ratio |

*Table 7.2 Overview variables used in the analyses and recoding used in the multinomial logistic regression analysis*

| **Characteristics** | **Variable** | | **Recoded variable** | | |
|---|---|---|---|---|---|
| | Variable name | Values | Variable name | Recoding | Values |
| Transport mode | Transport_mode | 0=Passive transport (reference category)<br>1=Walking<br>2=Cycling | | | |
| ***Individual characteristics*** | | | | | |
| Age | age | Age in years | --- | --- | --- |
| Gender | male | 0= Female<br>1= Male<br>(reference category) | --- | --- | --- |
| Ethnicity | Ethnic_group | 1= Native<br>2= Western<br>3= Non-western | Rec_ethnic_group | 3 → 1<br>2 → 2<br>1 → 3 | 1= Non-western<br>2=Western<br>3=Native<br>(reference category) |
| ***Household characteristics*** | | | | | |
| Household composition | Number_of_parents | 0= 1 parent<br>1= 2 parents | Rec_number_of_parents | 1 → 0<br>0 → 1 | 0= 2 parents<br>1= 1 parent<br>(reference category) |
| Household income | hhincome | 1= <€10000<br>2= €10000-20000<br>3= €20000-30000<br>4= €30000-40000<br>5= €40000-50000<br>6= >€50000 | Rec_hhincome | 6 → 1<br>5 → 2<br>4 → 3<br>3 → 4<br>2 → 5<br>5 → 6 | 1= >€50000<br>2= €40000-50000<br>3= €30000-40000<br>4= €20000-30000<br>5= €10000-20000<br>6= <€10000<br>(reference category) |
| Household car ownership | hh_ncars | Number of cars in household | --- | --- | --- |
| Household bicycle ownership | hh_nbicycles | Number of bicycles in household | --- | --- | --- |
| ***Environmental characteristics*** | | | | | |
| Address density for residential location | res_dens | Address density for residential location (number of addresses per km²) | --- | --- | --- |
| Urban density | Sted | 1= Highly urban<br>2= Very urban<br>3= moderately urban<br>4= Not very urban | --- | --- | --- |

| | | | | | |
|---|---|---|---|---|---|
| | | 5= Not urban<br>(reference category) | | | |
| Land use diversity | Shan200 | Shannon land use diversity index | --- | --- | --- |
| Green percentage | pgreen | Combined area percentage green (excl. agricultural land) in residential PC4 | --- | --- | --- |
| Water percentage | pblue | Combined area percentage water in residential PC4 | --- | --- | --- |
| Temperature | Ta_max | Daily maximum air temperature in °C | --- | --- | --- |
| Precipitation | Psum | Daily precipitation sum in mm | --- | --- | --- |
| Wind speed | Ws_avg | Daily average wind speed in m/s | --- | --- | --- |
| Season | Season | 1= Winter<br>2= Spring<br>3= Summer<br>4= Autumn | Rec_Season | 4 → 1<br>3 → 2<br>2 → 3<br>1 → 4 | 1= Autumn<br>2= Summer<br>3= Spring<br>4= Winter<br>(reference category) |
| ***Trip characteristics*** | | | | | |
| Distance | trip_distance_km | Trip distance in km | --- | --- | --- |