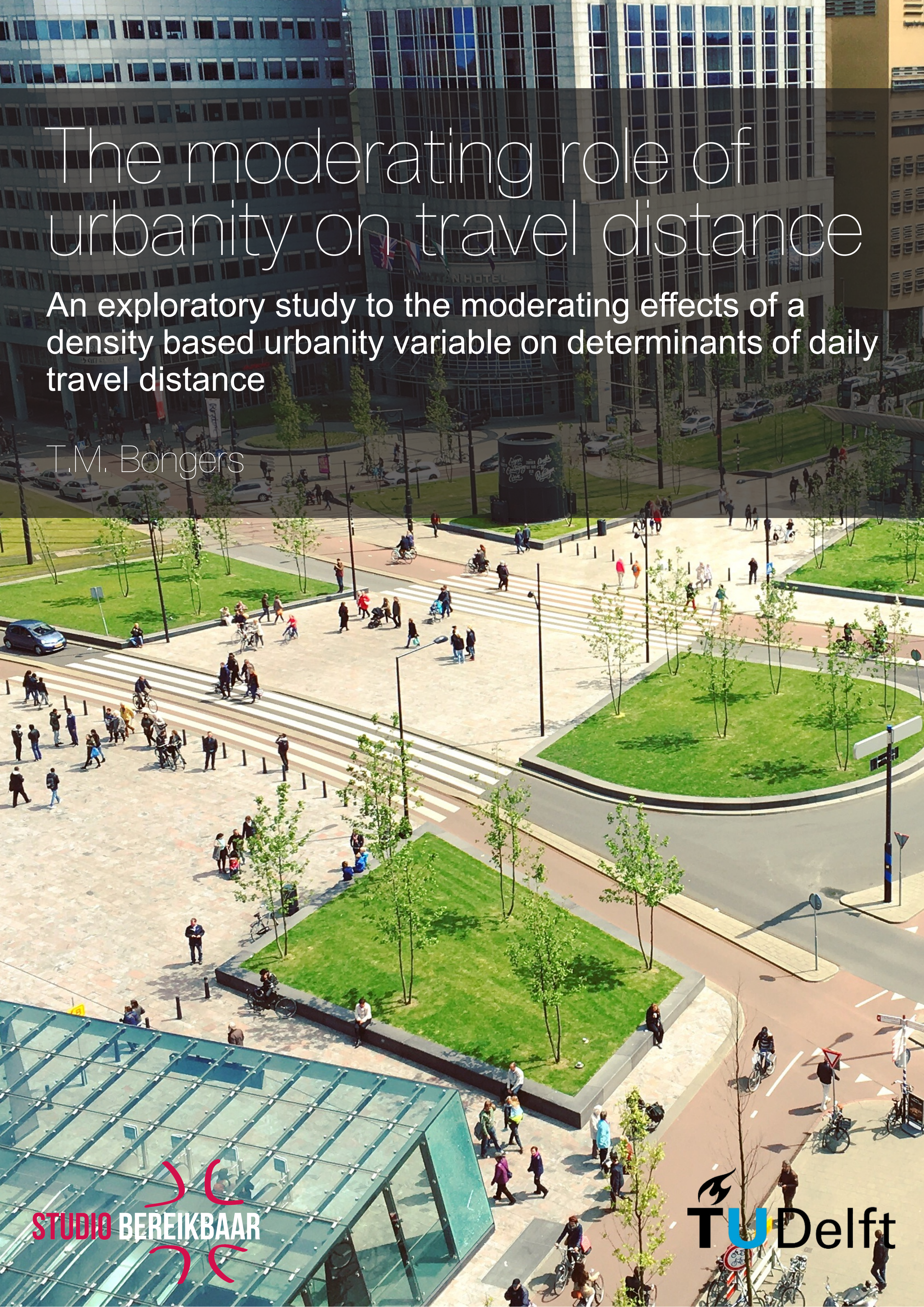
The moderating role of urbanity on travel distance

An exploratory study to the moderating effects of a density based urbanity variable on determinants of daily travel distance

T.M. Bongers



STUDIO BEREIKBAAR

TU Delft

The moderating role of urbanity on travel distance

AN EXPLORATORY STUDY TO THE MODERATING EFFECTS OF A DENSITY BASED URBANITY VARIABLE ON DETERMINANTS OF DAILY TRAVEL DISTANCE

by

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PREFACE

Dear reader,

Before you lies the result of roughly six months of hard work. This thesis does form the final step of completing my Master Transport, Infrastructure and Logistics and thereby also the six years I spent at the Delft University of Technology. While having written it all on my own, this thesis would not have become the way it is now without the help of various persons.

First, I want to thank Prof.dr. Bert van Wee for his expert feedback and the supportive guidance during all meetings. Secondly, I want to thank my second supervisor Dr. Kees Maat for his detailed feedback and his challenging but constructive questions. His feedback ensured that this thesis stayed understandable for readers less involved in the process, something that sometimes proved to be a challenge. Further, I especially want to thank my daily supervisor Dr.ir. Maarten Kroesen. I experienced our regular meetings as pleasant and very helpful, especially in the long periods I had to work from home. The meetings ensured that I continuously kept working and had regular access to his knowledge, advice and support.

Next to my academic supervisors, I also want to thank Ir. Manus Barten for offering me the opportunity to write my thesis at Studio Bereikbaar. Manus me enthusiastic for the topic of travel behaviour in varying (urban) settings. His practical angle of view challenged me to leave the purely scientific way of thinking and make it more relevant to practice. Besides Manus, I also thank my temporary colleagues at Studio Bereikbaar for the past few months. The working days at the office, the regular meetings and project Roosendaal all offered valuable practical insights and some welcome distraction from my thesis.

Furthermore, I want to express my gratitude to my roommates, friends and my parents for their support throughout the past half-year. Special mentions go to my parents for, consciously or unconsciously, inspiring me to do something in the field of mobility, and to Lucie for her continuous support and pushing me to getting the most out of this thesis.

T.M. Bongers
Delft, September 2021

Summary

Introduction

To accommodate the growth in population and mitigate the housing shortage, lots of (urban) development is necessary the upcoming decade(s). An ongoing discussion is where these houses have to be built. Besides that problem, sustainability is a major topic in urban development and mobility. Challenges related to the environment do not limit themselves to the reduction of greenhouse gasses, but also include improving the air quality and making cities climate resistant. In the field of spatial urban development, the strategy of densification has been considered as the most relevant approach for sustainable urban development. This compact development provides accessibility to activities by proximity rather than providing good means of transportation. It aims to reduce car driving, which results in less energy consumption and various other social and environmental benefits. The success of densification strategies is however dependent on the local circumstances. Dependent on the location, strategies that aim to reduce car use can result in a shift of the negative externalities to other areas. It is also possible that travel patterns of individuals change, and hence the positive effects are partly negated. Related to densification, it could be that time saved by the proximity of activities is used to travel more and/or longer distances to activities located further away. Since travel behaviour is a complex phenomenon which is influenced by transport infrastructure networks, land use patterns, sociodemographic traits and personal perceptions, it is necessary to understand the local circumstances and the way they interact with travel behaviour. That way, mobility strategies can be accurately formulated such that they achieve the desired effects.

The contribution of this study is added knowledge about the relation between travel behaviour and the built environment. While a wide variety of studies already explored the relationships between travel behaviour, the built environment and other determinants, still some gaps remain. Most existing studies focused on the homogeneous, direct effects of built environment and other determinants on travel behaviour. Less attention is paid to another type of effect, that of a moderation of the effects of other determinants by the built environment. Those moderating, or interaction, effects arise when an independent variable influences the effects another independent variable has on the dependent variable. In short, the effects of those determinants depend on a third variable, being the level of urbanisation in this study. If moderation effects are present but not identified, the overall effect of the built environment might be under- or overestimated. To learn more about the travel patterns of people in various levels of urbanisation, this study focuses on travel distance as travel behaviour indicators. Findings might indicate whether densification strategies have desired effects and how this depends on other determinants of travel behaviour.

Methodology

First, a literature review is conducted to identify sociodemographic traits, travel attitudes and built environment variables from which other studies proved that they affect travel behaviour. The identified determinants are operationalised with data from the Netherlands Mobility Panel (MPN). The MPN is a panel survey in which data about individuals, households and travel behaviour is collected. The used sample contains data of 3,077 (valid) respondents which combined made 27,898 unique trips in the three day study period. Opposed to sociodemographics, the travel attitudes cannot be measured directly. As they are latent variables, they have to be determined

based on scores respondents give on various statements on modes, mode-use and accessibility. By applying a principal factor analysis with varimax rotation, seven mode related attitudes, four more general travel related attitudes and one accessibility related attitude are identified. The built environment variable of interest is a combined job and population density based level of urbanisation with six levels, from rural to metropolitan.

To explore the possible moderation effects of the level of urbanisation on other determinants of travel distance, a moderated multiple regression (MMR) analysis is performed. The MMR is an expansion of a multiple linear regression model where interaction terms between determinants can be added to the model. Descriptive statistics of the MPN data show that there is a distinction visible between the two highest levels and the four lowest levels of urbanisation. Therefore, the MMR is performed twice. Once with an urban/non-urban classification and once with the six levels. Since the exploratory character of this study, interaction effects between the moderator and all other determinants are included such that possible interactions can be explored for a wide set of determinants.

Results

The MMR analyses show that the level of urbanisation moderates the effects of various sociodemographics and travel attitudes on the daily distance travelled in total and by specific modes. These results show that the effects of various sociodemographic traits and travel attitudes on daily travel distance are not homogeneous, but their direction and strength depends on the level of urbanisation of the residential location. All dependent variables are influenced by significant interaction effects, withe exception of *other modes*. Especially the effect on daily distance by train are dependent on the level of urbanisation. To better understand the moderation effect of the level of urbanisation, three specific effects are studied in more detail. By interpreting these specific results, some specific findings are found which prove the importance of acknowledging the possible presence of moderation effects.

The first specific finding is that the effect of car availability is different in varying levels of urbanisation. The more urbanised an area is, the higher the increase in distance travelled by car when having a car available at all times compared to not having one available. Especially in metropolitan areas, people who always have a car available travel long distances with that car. As car and train are competitors for trips on medium and long distances, a reverse effect can be observed for the distance travelled by train. When someone always has a car available, the walking distance decreases. That decrease is weaker in the lesser urbanised areas and turns into an increase for rural inhabitants. All these differences could be a result of the destination patterns and local options to travel by certain modes. Further, the effects of density are weaker for people who always have a car available than for people who do not always have a car available. That is indicated by the fact that the differences between the levels of urbanisation are larger for those without (always) access to a car compared to those who have a car available.

The second specific result that is highlighted shows that in urban areas people with higher education walk more than lower educated people, whereas that effect is not present in non-urban areas. In general, the influence of education is strong in urban areas and weak in non-urban areas. The difference in the effect of education could be a result of varying degrees of segregation between various sociodemographic groups in the levels of urbanisation. The result also shows that the built environment has a limited effect on people with a low education, but has an increasing influence on people as the level of education increases from low to medium, and from medium to high.

The third highlighted result is a moderation of the effect of attitude towards accessibility of the residential location on total, car and walking distance. This finding does support the theory of residential self-selection that argues that people are going to live on a location that allows them to travel the way they want to. In the more urbanised areas, people that value accessibility travel longer distances, but travel less by car. That supports densification strategies near public transport nodes, but also points out that people replace short trips to nearby activities with longer and/or more trips.

Conclusions and recommendations

The results show that the density-based built environment variable moderates the effects of various determinants on daily travel distance. These results show that the effects of various sociodemographic traits and travel attitudes on daily travel distance are not homogeneous, but their direction and strength depend on the density of the residential location. This indicates that the actual effects of density and a sociodemographic trait or travel attitude are larger, or smaller, than the sum of both individual effects. As missing the interaction effects results in under- or overestimations of the effects of those determinants on daily distance travelled, it is important to acknowledge that not all determinants have the same effect in each area. The spatial heterogeneity of the relationships between determinants of travel behaviour and travel behaviour implies that interventions should tailored to local conditions.

Conclusions can also be drawn from the specific results. The results from the interaction effects between car availability and the level of urbanisation indicate that when someone buys a car to always have one available, the logical increase in car kilometres and decrease in train and walking kilometres is stronger in more urbanised areas. When the goal is to reduce car kilometres, the relative gain is therefore higher when metropolitan inhabitants shed a car than inhabitants of other levels. These results also indicate that the full potential of high densities, namely less distance travelled by car and more distance travelled by train and walking, can only be reached if people do not always have a car available. For policy makers, this implies that densification strategies should be accompanied by strategies that focus on reducing car ownership. Special attention should go to reducing car ownership in metropolitan areas given that metropolitan inhabitants with a car make a lot of daily vehicle-kilometres.

Another conclusion can be drawn from the interaction effect between level of urbanisation and education on walking distance. With increasing level of education, the daily walking distance increases, but only for inhabitants of urban and metropolitan areas. Since the mean walking distances for lowly educated are comparable over the levels of urbanisation, there can be concluded that density only affects walking distance for medium and highly educated people. Further, education does not show to have effects on walking distance in non-urban areas. In cities, where density has influence, policies should therefore focus on promoting walking among lower educated people, since their walking levels are lower than their medium and higher educated counterparts. In non-urban areas, education does not seem to have a strong effect on walking distance. In those areas, car dependency is high, and presumable habitual car use for short trips is too. The main challenge in those areas is therefore to prevent that people make habitual use of the car and instead walk to activities.

Following from the moderation of the effect of accessibility attitude by the level of urbanisation, there can be concluded that densification works better for people that are committed to using the modes that suit a high density environment. Therefore, it is important to consider mobility strategies as separate part of densification strategies, but as something that is vital for the success of the strategy.

Discussion

Although interesting results are found, some methodological, conceptual and data related limitations of this study should be taken into consideration. First, the used method cannot prove which of two variables that interact is the moderator. Theories are necessary to assign one of them the role as moderator. Secondly, the use of cross-sectional data means that no causality can be proved because the time-precedence requirement of causality is not met. The third category of limitations is conceptual. Travel behaviour is a complex phenomenon with various categories of determinants which are also possibly influencing each other. It is possible that certain effects are over- or underestimated because some of the more complex relationships are not included. Therefore it is important to look at the presence and possible explanations for moderation effects rather than only looking at the coefficients.

Future researches could focus on these limitations. They could also focus on more specific research opportunities like studying the motivations of car ownership and use of metropolitan inhabitants such that efficient measures can be taken that allow the full potential of high density to be reached.

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List of Abbreviations

BTM Bus, tram and metro

CA Cronbach's alpha

CBS Centraal Bureau voor de Statistiek (Statistics Netherlands)

hh households

LoU Level of urbanisation

MMR Moderated multiple regression

MLR Multiple linear regression

MPN Netherlands Mobility Panel

KiM Netherlands Institute for Transport Policy Analysis

KMO Kaiser-Meyer-Olking

GDPR General data protection regulation

PAF Principal axis factoring

PT Public transport

RSS Residential self selection

SEM Structural equation modelling

TOD Transit Oriented Development

1

INTRODUCTION

The relationship between the built environment and travel behaviour has received a lot of attention in scientific community recent decades (Wang, Chai, & Li, 2011). In these studies, the effects of variables influencing travel behaviour are often considered to be homogeneous. However, there are indications that rather than having one single effect, determinants of travel behaviour can have varying effects dependent on the status of other variables (Clifton, 2017). When a variable influences the effects of another variable on travel behaviour, also called moderation, the results of mobility and spatial strategies can deviate from the expected results. In these cases, the travel behaviour of individuals is different based on variations in context, possibly resulting in over- or underestimations of the effects of transport and spatial strategies (Zhang & Zhang, 2020). This research studies the possible presence of moderating effects by the built environment on the effects sociodemographics and travel attitudes have on daily travel distance (see Chapters 2 and 3).

In this chapter background information about the problem on which this thesis is focused will be introduced. After the problems and corresponding complexity have been explained, research gaps that follow from the literature review in Chapter 2 will be explained. Those gaps will be translated into a research objective and operationalised with research questions. The chapter will end with a schematic overview of the research.

1.1. BACKGROUND

Worldwide cities are growing. Currently 50% of the people is living in urban areas, and that percentage is growing (UNDESA, 2018). This is also the case in the Netherlands, where especially the Randstad region around the four largest cities is growing fast (de Jong & Daalhuizen, 2014). For example, the number of inhabitants in The Hague is expected to grow with four thousand per year, which would require fifty thousand new houses by 2040 (De Zwarte Hond et al., 2017). A lot of urban development is needed to accommodate all these new residents. Besides this challenge, aiming for more sustainable travel behaviour is a major topic in urban mobility (Banister, 2008). Challenges related to the environment do not limit themselves to the reduction of greenhouse gasses, but also include improving the air quality and making cities climate resistant (GemeenteRotterdam, 2020). Hence, there is a need for using the public space in cities in a more efficient way to keep them accessible, liveable and attractive, as it is necessary for cities to be connected from within and to other cities in order to function (Kasraian, 2017). In the field of spatial urban development, the strategy of densification has been considered as the most relevant approach for sustainable urban development (Næss, Saglie, and Richardson, 2020; Haaland and van Den Bosch, 2015).

Urban densification can be achieved by building on 'green field' sites near the outskirts of cities where no buildings are present, by establishing houses on 'brown field' locations that used to have other purposes (industrial sites, harbour sites) or by replacing low-density buildings by high-rise buildings (Haaland & van Den Bosch, 2015). Compact urban development provides accessibility to activities by proximity rather than high mobility. Therefore, densification has benefits such as less car driving, lower energy consumption and other social aspects of sustainability (Næss et al., 2020). An adaptation of densification strategies is the one of Transit Oriented Development (TOD) in which densification is concentrated in the proximity of Public transport (PT) nodes. Increases in development density near PT nodes is assumed to increase PT access and by that increase PT ridership and healthy lifestyles and reduce vehicle miles, traffic pollution and energy consumption (Singh et al., 2017; Maat, Van Wee, and Stead, 2005). TOD can be applied in urban areas, but as space is often limited there, it can also be applied around PT nodes in lesser urbanised areas.

Despite housing them on strategical locations, an increase in the number of inhabitants does still result in an increase in total mobility. After all, having more inhabitants, visitors and employees results in more movements. Also, the saved time by the short distances to nearby activities and PT nodes induces the choice of activities located further away. The time saved by having activities and PT nodes in the near proximity is then used to make more and/or longer trips to more preferred destinations (Maat et al., 2005). Not only could densification and TOD lead to more and/or longer trips, they could also cause a shift of efficiency gains to other places or sectors (Næss et al., 2020). To make it even more complex, the success of TOD strategies is not systematic, uniform or predetermine, but depends on local circumstances and policies (Chapple and Loukaitou-Sideris (2019) via (Papagiannakis, Vitopoulou, & Yiannakou, 2021)). Therefore, to achieve the desired effects, tailor suited strategies with differentiation over areas, target groups and time are needed as every area has his own characteristics (Van Acker, Goodwin, & Witlox, 2016).

1.2. COMPLEXITY OF TRAVEL BEHAVIOUR

Making those tailor suited policies is not that easy. Daily travel behaviour is very complex, multi-faced and influenced on multiple scales like individual, household, local and societal (Elldér, 2015). Within these levels people's travel behaviour is influenced by transport infrastructure networks, land use patterns, sociodemographic traits and attitudes towards travel modes (Kasraian, 2017). In smart investment strategies all uncertainties, including possible changing attitudes and behaviour, should be taken into account (Hilbers et al., 2016). Also, campaigns to change behaviour work best when they are suited for specific target groups (Broer, 2013). For those reason, formulating mobility strategies requires a deep understanding of local mobility conditions, - patterns, - preferences, - mode choices and human behaviour (Tyrinopoulos & Antoniou, 2013).

Practice shows that travel behaviour indeed is not understood completely. Classic traffic models are not able to deal properly with complex urban (multi-modal) mobility and recent development like increasing importance of individual characteristics and attitudes (Bakker, 2020). So does the traffic model used in the metropolitan area Rotterdam The Hague predict an increase of car traffic in the cities, while the observed car usage has been constant or even declining the past years. This decline in car usage came at expense of increased cycling, which also cannot be observed properly in the models (de Graaf, Veurink, and Lodder, 2017; Puylaert, 2017). Part of this discrepancy of the models could be caused by the complexity of mobility related to attractiveness of cities. Cities offer lots of potential activities and persons to interact with within short distance (PBL, 2019). Here, travel choices do not occur in a vacuum but rather in a complex web of choices on how people live, work and recreate and the constraints under which they make those choices (Van Acker et al., 2016).

1.3. URBAN FORM SYNERGIES

It may be not completely understood, but it is known that (good) mobility offers various opportunities for cities. It allows people to access qualitative urban environments where people meet and where urban life, innovations and culture prosper (Malmö Stad, 2016). A city open for movement and people spending time on streets, together with walkability, human scale, varied and interesting urban environments leads to understanding, trust, social contacts and safety (Malmö Stad, 2016). Those contacts are essential for the prosperity of cities as the core of the economic success of cities is companies profiting from each others proximity (Derksen et al., 2014). Besides these so-called economic agglomeration effects, cities also offer agglomeration effects at the consumer side. Lots of amenities require mass and density. The same amenities make cities attractive places to live and be (Derksen et al., 2014). Attractive cities attract new inhabitants, especially ones that are highly educated. That is interesting with a view on mobility as cities with a large share of highly educated adapt better to changing economic circumstances, which could affect mobility too (Marlet & Ponds, 2011).

Sato and Zenou (2015) indeed found that in denser areas people interact more with others and have more random encounters than in sparsely populated areas. Here, the level of urbanisation clearly influences the number of interactions, which on its turn relates with travel behaviour of people. Following this connection, questions can be raised about other possible indirect effects level of urbanisation might have. Chen and Felkner (2020) answered a similar question related to sustainable transportation, as there was limited attention for interactions that might exist between individual variables influencing travel behaviour. They found that there are synergies between various urban form variables that indicate that certain effects from higher urban density can only be reached when other variables reach a certain level. That finding has significant implications for policy makers as the existence of synergies could reduce the effectiveness and efficiency of measures, or could even deliver undesired outcomes (Chen & Felkner, 2020).

To predict the (changing) travel patterns and steer them into desired directions, transport models can be used. The traditional four-step trip models however are not prepared to model the changes and developments that are discussed in earlier sections (Wegener, 2013). Not only are those models not able to accurately model new developments according to Wegener (2013), they also are not always consistent with actual observed developments anymore as the theories used for them have hardly changed the past 30 years (Clerx, de Romph, & Kochan, 2017). A reason for the lack of consistency with real-life observation could be that there is lack of knowledge about determinants for travel behaviour. Another reason that researchers have also discussed is the probability that "certain characteristics of the built environment work together —synergistically— to influence travel behaviour; in other words, the full effect is greater than the sum of the effects of the individual characteristics." (Van Wee & Handy, 2016, p.19). As mentioned, Chen and Felkner (2020) indeed found some synergies between built environment variables. However, they only studied the effects between density and three other variables, leaving open space for studying more and more complex interactions. Better understanding possible synergies between the built environment and other determinants would provide knowledge that can be used to more accurately predict the effects of various transport related strategies and policies.

1.4. RESEARCH GAPS IN EXISTING RESEARCH

Current research on the relationship between built environment and travel behaviour is extensive, but there are some gaps that could be addressed to gain additional knowledge about the relationship.

Firstly, just a few studies have considered moderating effects of built environment on travel behaviour (Sun and Yin, 2020; Ding et al., 2018). Those moderating, or interaction, effects arise when an independent variable influences the size of the effect of another independent variable on a dependent variable (Handy, van Wee, & Kroesen, 2014). In other words, they are the changers of relationships in a system (Little et al., 2007). Heres and Niemeier (2017) pointed out that due to the multidimensional nature of built environment variables they not only influence travel behaviour directly but also indirectly. Hence, interaction effects should be included in future studies to identify the significance and magnitude of the heterogeneous spatial effects on travel behaviour (Clifton, 2017; Cheng et al., 2021). That corresponds with a methodological challenge Handy et al. (2014) give. Having a focus on cycling behaviour, they point out that there are potentially important interaction effects that have not been systematically studied before. Especially as some authors argue that travel patterns are getting more and more disentangled from the built environment (Elldér, 2015), it is interesting to study possible moderation effects of the built environment. After all, if moderation effects are present but not identified, the overall effect of the built environment and/or the other determinants might be under- or overestimated. This study will focus on possible moderation effects between built environment variables and other determinants of travel behaviour in more depth. This will contribute to a more comprehensive understanding of the impacts of the built environment on travel behaviour (Wang et al., 2011). By doing so, there will be contributed to knowledge about which built environment characteristics affect travel decisions most effectively for different populations (Guan, Wang, & Jason Cao, 2020). The built environment variable with which moderation effects are studied is the level of urbanisation, a density-based variable that classifies an area based on the number of houses and jobs. That variable provides valuable knowledge for much needed spatial strategies which is missing in most existing studies. After all, the connected challenges of urbanisation and sustainability require a cohesive and integrated approach on a national scale (Ministerie van BZK, 2020). How the choice for this variable was made is discussed in more detail in Chapter 3.

Secondly, the studies that have included moderating effects of built environment variables mainly control for rather than include sociodemographics as determinants for travel behaviour in the possible interaction (Haybatollahi et al., 2015, among others). Guan et al. (2020) did find that sociodemographic attributes could strengthen or weaken certain relationships. In a study from Kim and Mokhtarian (2018) certain sociodemographics indeed showed to result in different behaviour when moderated by attitudes. Most previous studies did not examine possible indirect effects of demographics on the sensitivity to built environment variables (Bhat & Guo, 2007). This study will explicitly include sociodemographic variables and travel attitudes as possible determinants that interact with the built environment. As there might be heterogeneity in the explanatory power of sociodemographics, not including them could result in under- or overestimating the effects of the built environment on travel behaviour. The same applies for travel attitudinal variables which are often excluded, mainly due to lack of data in travel surveys (Bhat & Guo, 2007). This thesis will use data from the Netherlands Mobility Panel, which contains data based on which travel attitudes can be identified. As travel attitudes lessen the impact of the residential self-selection problem (Bhat & Guo, 2007) (see Chapter 2), those will be included in the analysis.

Thirdly, this study will consider the effects of determinants on various travel behaviour indicators and travel motives. The majority of studies that have included moderating effects of the built environment mainly have a specific focus on a single travel behaviour variable. An example relates to a focus on commuting as only travel motive (Sun & Yin, 2020). Other studies for example have a narrow focus on just vehicle ownership (Kim and Mokhtarian, 2018; Yin and Sun, 2018;Bhat and Guo, 2007), cycling duration (Gao et al., 2018) or walking behaviour of elderly (Cheng et al., 2021). Focusing on a single mode has the limitation that it does not capture the interdependency between travels by different modes (Guan et al., 2020). As travel patterns are changing and getting more varied (Næss et al., 2018), looking at determinants for travel behaviour for more travel motives should get more attention as the focus on the impacts on narrow dimensions of travel does not provide the overall effect on travel (Bhat and Guo, 2007; Zhang and Zhang, 2020). This study will therefore not focus on a single travel motive and will include various modes to capture mode interdependency.

Fourthly, there is a gap related to the specific knowledge of the effects of the built environment in the Netherlands. In research related to determinants of travel behaviour there is questioned whether results from varying spatial areas can be used in other areas (Lindelöw et al., 2017). This question mainly concerns the potential generalisability of results from American studies to European cities. While some studies show that the results are generalisable, there are some problems with transforming studies and findings to another spatial context. These problems relate to differences in the use of certain modalities, compactness of urban structures and neighbourhood design. Those differences are not only present when comparing America with Europe, within Europe differences can be observed too. As example, cycling is way more popular in the Netherlands than it is in other European countries (Gao et al., 2018). Therefore, it is interesting to study the Dutch context, as the relationships between location patterns and travel behaviour can differ between regions and countries (Elldér, 2015). Results from such studies can help with formulating various strategies that have to be applied to reduce the housing shortage and/or reduce the environmental impact of travel in the Netherlands. This study will use data from the Netherlands and therefore aims to contribute to local knowledge needed to accurately formulate spatial and transport related strategies.

1.5. RESEARCH OBJECTIVE

The first section of this chapter showed that densification is considered to be a relevant approach for sustainable urban development. It is considered to reduce travel distances due to the proximity of lots of activities. However, there is argued that the saved time is used to travel more often and/or longer distances, and that the effects depend on the local conditions. This thesis will focus on the daily travelled distance as travel behaviour indicator to identify the effects of density on travel distances.

The objective of this thesis is to explore whether there are moderation effects of the built environment on determinants of travel distance. Knowledge about possible interaction effects of the level of urbanisation on travel behaviour could help governments with designing travel policies better suited for different regions and different target groups. The focus is therefore specifically on identifying possible interaction effects rather than finding or proving determinants for travel behaviour. Recognising such heterogeneity provides more behavioural insights about people's response to changes in the built environment, which likely provides more accurate forecasts of spatial policy intervention outcomes (Guo, Bhat, & Copperman, 2007).

The research will start by specifying a conceptual model of the relationships between built environment, sociodemographics, attitudes and travel behaviour by looking for determinants proven to be significant in existing studies. The identified determinants will be tested on the Netherlands Mobility Panel data with a moderated multiple regression analysis where the built environment will moderate the effect of other determinants on daily travel distance.

1.6. RESEARCH QUESTIONS

As the project context showed, it is interesting to study the effects of travel behaviour determinants on travel behaviour in varying spatial settings. As there are indications that different effects arise in different local settings, questions about the role of built environment arise. Currently limited knowledge is available about interactions between the built environment and other determinants of travel behaviour. To obtain more insights in the presence of possible synergies between determinants of travel behaviour, the following main research question is formulated:

> “What is the role of the built environment as moderator of the effects of explanatory variables on daily travel distance?"

Since the main research question is still relatively broad, it is divided in various sub-questions which all focus on a single specific part. The first sub question is focused on finding built environment variables that are known to affect travel behaviour and therefore might be interesting to test as moderator on the effects of other determinants.

> 1. "Which built environment variables could influence the effects of other travel behaviour determinants on travel distance indicators?"

The answer on this question will be found by a literature review. This is done by searching for search strings like 'travel behaviour AND (built environment OR urban form)', 'urban AND non-urban AND travel behaviour', 'differences AND trip distance AND built environment' and related terms on scientific search engines Scopus and Google Scholar. The interesting papers that show up are scanned for there relevance based on their abstracts and conclusions. If interesting, they also form the starting point for snowballing, where interesting references used in the first paper are read and so on.

The second sub question tries to find a set of sociodemographic characteristics and travel related attitudes that are known to influence travel behaviour. These will be used to test whether the built environment moderates effects of determinants on travel behaviour.

> 2. “Which sociodemographic characteristics and travel related attitudes that influence travel behaviour are reported in literature on travel behaviour?”

Again, a literature review is used to find answers on this question. Search strings that are used include 'travel behaviour AND determinants', 'sociodemographics AND travel behaviour', 'travel attitudes AND travel behaviour', 'trip distance AND socio-economics' and similar search strings using synonyms and related terms. Again, scientific search engines Scopus and Google Scholar will be used, and snowballing is applied to find other interesting studies. As will become apparent in Chapter 3, a factor analysis will be needed to identify the attitudes.

The third sub question has a focus on identifying the actual differences in travel behaviour between the various levels of urbanisation in the Netherlands. Having these insights eases the interpretation of the results and might already indicate the importance of the built environment on travel behaviour.

3. “What are differences in daily travel distance between areas with varying built environments in the Netherlands?”

This question will be answered by giving descriptive statistics related to the travel distance and modal split. The descriptive statistics will be analysed and compared with the output of other travel studies to give an idea about the representativeness of the used data.

After possible explanatory variables that follow from the literature have been identified, they will be tested on the available data to determine whether they can explain travel behaviour in areas with different built environments. This will be done with a Moderated multiple regression (MMR) analysis, which will be introduced in Chapter 3.

4. "Which effects of explanatory variables on daily travel distance does the built environment moderate?"

1.7. SOCIETAL RELEVANCE

This research has relevance for both science and for society. Current day, different regions are experiencing different problems related to accessibility, sustainability and quality of life (van de Coevering et al., 2016). Various strategies and policies are applied to promote a sustainable transport system to solve part of these problems. Having knowledge about what factors influence mobility could support decision makers in implementing strategies and policies (Chowdhury & Scott, 2020). After all, “the built environment constitutes one of the foundations of sustainable mobility“ (Elldér, 2015, p.53). As the built environment greatly impacts daily travel distances, the importance of including location and built environment aspects within urban and regional planning is clear (Elldér, 2015). In the Netherlands knowledge about the built environment – travel behaviour relation is becoming increasingly important as there is a huge shortage of houses. Various predictions say that up until 2040 one million houses have to be build (Alkemade, Strootman, & Zandbelt, 2018). An ongoing discussion is where those houses should be built. As the location affects travel behaviour, along with other determinants, it is important to have insights in the way built environment and travel behaviour interact. Obtaining knowledge about possible varying effects of determinants on travel behaviour in varying built environments could thereby help to develop strategies and policies that achieve their desired effects.

1.8. EXPECTED OUTPUT

The main part of the thesis will be a research paper. First, the problem will be conceptualised by performing a literature review of existing studies. That conceptual model will be operationalised with MPN data and a factor analysis. The factor analysis is applied to identify the latent attitudes of respondents, and creates a list of travel related attitudes based on a large set of statements. Thereafter the operationalised variables can be used in the moderated multiple regression analysis to identify moderation effects of the built environment on the effects of determinants of travel behaviour. This will provide additional knowledge about differences in the effects of determinants in varying built environments. The research paper will be concluded with recommendations for policy makers and scientists that follow from the results.

1.9. RESEARCH OVERVIEW

Figure 1.1 gives a visual summary of the proposed research. The research is divided in five parts. In the visual representation of the structure of this thesis the main objective of each part is given. Part 1, the current part, introduces the problem and the structure of the research.

The second part forms the theoretical 'Literature review' part. In this part, existing literature about the subject is analysed to identify built environment variables, sociodemographic characteristics and travel related attitudes that influence travel behaviour. Further, the literature about the subject is summarised in a conceptual model representing the relationships that are studied in this study and the ones that are present but not explicitly taken into account.

The third part is the model preparation part. In this part, the data from the Netherlands Mobility Panel will be discussed. There, an overview is given of the information the 3,077 respondents provided and other data derived or calculated by the researchers of the MPN study. To include the latent travel attitudes, it is necessary to perform a factor analysis on certain statements included in the questionnaire. When the determinants are operationalised, descriptive statistics of them will be given. Next, the MMR method which will be used to explore possible interaction effects is introduced. The method will be explained briefly and limitations and how to deal with them will be given. The third part ends with the specification and operationalisation of the in Chapter 2 introduced determinants of travel behaviour.

The fourth part is the modelling part. First, some descriptive statistics of the travel behaviour of the respondents in the used data will be presented. Thereafter, the moderated multiple regression analysis will be performed after which the model results will be presented and interpreted. That will be done by first discussing the general results of the analysis, after which a few specific results will be highlighted.

The fifth part is the part where the research is finalised. In Chapter 5 conclusions are drawn about the general and result specific findings from the statistical analysis. After that, some main limitations of the study, data and methods will be discussed. Following this discussion, recommendations for future research will be given.

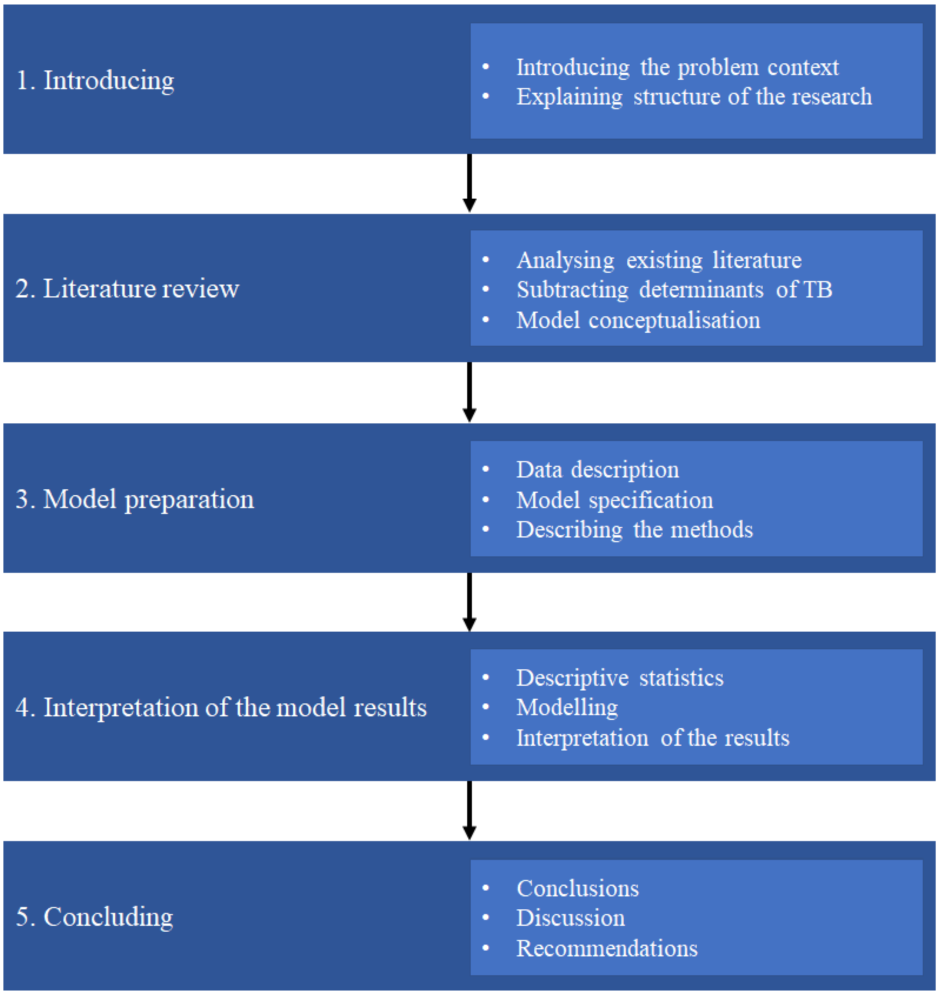

Figure 1.1: Visual representation of the thesis structure

2

Literature review

Chapter 1 introduced the problems on which this study in centred. In this chapter existing literature about the relationship between built environment, travel behaviour and other determinants of travel behaviour is reviewed. First, the context of the travel behaviour - built environment relationship will be introduced briefly. After that, the relationships of travel behaviour with three categories of determinants will be explained for each category separately. The findings will be conceptualised at the end of the chapter.

2.1. Context of land use - transport relationship

It is necessary to study the relationships between land-use, transport infrastructure and travel behaviour in order to understand the development of cities (Kasraian, 2017). Most studies about mobility and urban form investigate spatial differences in mobility for a specific year by applying cross-sectional designs (van de Coevering et al., 2016; Stead and Marshall, 2001; Boarnet, 2011). It is apparent that there are differences between various areas, caused by among others density, presence of activities, socio-economic variables and the availability of transport modes (Stead & Marshall, 2001). However, differences between areas with different urban forms are growing (Scheiner, 2010; Jonkeren, Wust, and de Haas, 2019). Questions can be raised about the reasons why these differences grow, which factors influence the growth and what the role of human behaviour is in this phenomenon (Næss et al., 2018).

2.1.1. The Wegener cycle of the transport-land use relationship

These questions can be seen in the greater context of the relationships between transport and land-use. One of the classic theories about the relationship between transport and land-use and vice versa is one by Wegener and Fürst (2004). This theory summarises the set of relationships between transport and land-use in a cycle. As can be seen in Figure 2.1, the cycle has a detailed form and can be summarised in four core components.

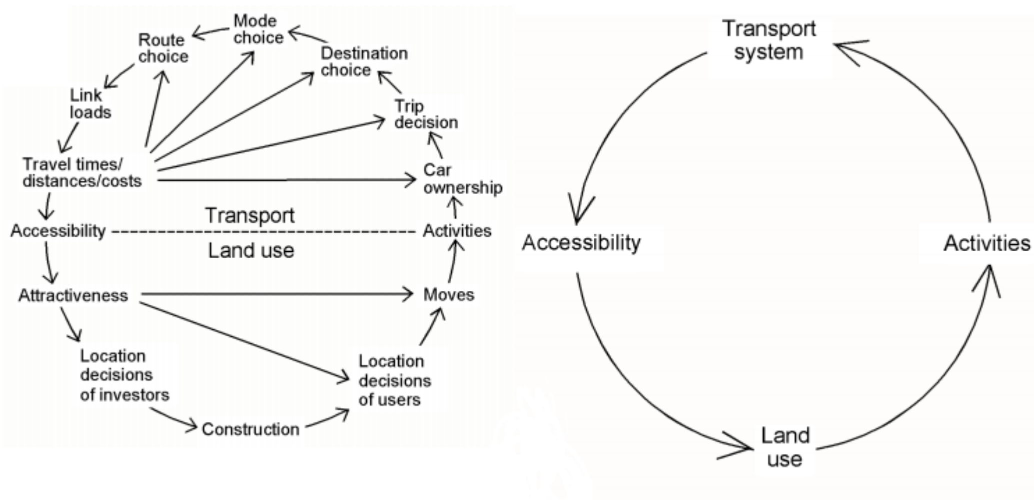

Figure 2.1: Wegener transport - land-use cycle. Adjusted from Wegener and Fürst (2004)

The right cycle contains four elements which form a loop. Starting at the top, the transport system influences accessibility. The distribution of infrastructure creates opportunities for spatial interactions which can be expressed as accessibility (Wegener & Fürst, 2004). On its turn, accessibility has a relation with land use as it influences decisions about locations. The better accessible a location is, the more attractive it is for land use developments. The distribution of land uses as houses, shops or jobs determines the activities that people can undertake, such as living, shopping and working. People require means of transportation to overcome the distances between the activity and their residential location. In that way, activities influence the transport system as they determine the demand. As can be seen in the left cycle, there are some extra relations between sub elements. To indicate that the aspects in real-life are determined by more factors than just the ones included in the cycle, Bertolini (2012) added some external factors and a direct link between accessibility and activities, as can be seen in Figure 2.2. Bertolini (2012) therefore argues that the cycle should be seen as an open rather than a closed cycle. Another critic of Bertolini is that there is difference in the time the various elements need to change. Patterns of activities can change relative fast, while transport systems and land use take longer to develop. For that reason, he added a link between accessibility and activities. Despite his critics, Bertolini acknowledges that the Wegener transport – land use cycle is an useful framework for exploring relationships between built environment and travel behaviour. The theoretical framework is used in this research as it explicitly presents the structuring role of transport behaviour following from land use. The Bertolini adaptation is used too, as it presents the influence of external factors on travel behaviour.

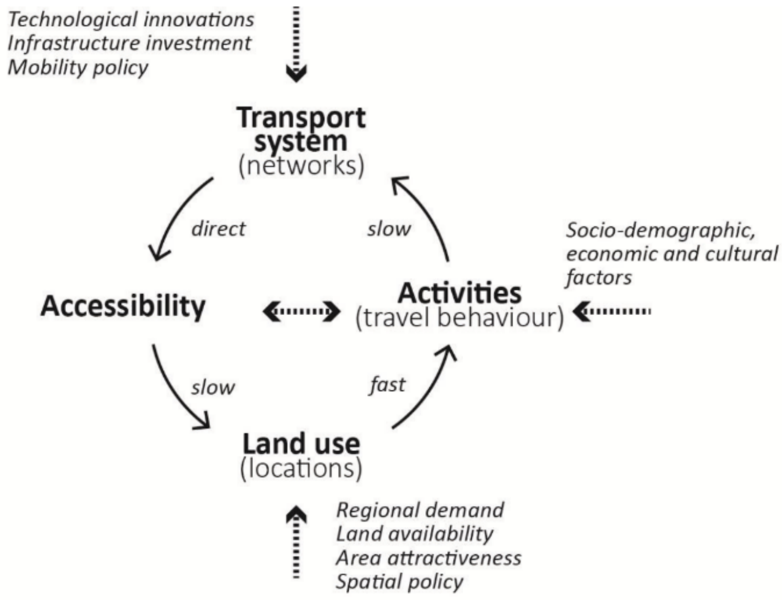

Figure 2.2: Transport - land-use feedback cycle, and beyond (Bertolini, 2012)

2.1.2. SPATIAL HETEROGENEITY IN TRAVEL BEHAVIOUR

In one of the many studies on travel behaviour, Tribby and Tharp (2019) studied differences in cycling behaviour between urban and rural areas in the USA. They found that, controlling for various covariates, the prevalence of cycling did not differ that much between urban and rural areas. However, the variables for classifying persons as a bicyclist or non-bicyclist did vary between urban and rural areas. According to the authors that suggests that the factors that are important for rural bicyclists differ from those from urban bicyclists. Hence, there might be heterogeneity between the explanatory powers of determinants for cycling, and travel behaviour in general, in different urban levels.

The idea of Tribby and Tharp (2019) about possible heterogeneity of determinants for travel behaviour in different regions is also stated by Clifton (2017), who says that the significance, magnitude and signs of the relationship between built environment and travel behaviour might differ for different economic, demographic and other social groups. As example of this possible heterogeneity, Bhat and Guo (2007) argue that it might be that high income households (hh) own several cars and use them more than low income households, creating a situation where high income households are less sensitive to built environment attributes in car ownership and use compared to low income household. The same was stated by Sun and Yin (2020) who say that residing in large cities could reduce the effect of income on car ownership. With a focus on walking behaviour of elderly, Cheng et al. (2021) also found spatial heterogeneity in the relationships between the built environment and travel behaviour. Heres and Niemeier (2017) pointed out that built environment variables might interact with other factors to create moderating effects on travel, as underlying structure for the heterogeneity.

This idea of interactions between built environment and travel behaviour has not been widely studied yet (Sun and Yin, 2020; Clifton, 2017; Zhang and Zhang, 2020). That is also noted by Handy et al. (2014) who indicate that in current research one of the methodological challenges that remains to be studied in depth relates to the possible presence of interaction effects. Interaction, or moderation, effects arise when an independent variable affects the effect of another independent variable on a dependent variable. Due to interaction effects, individual decision variables may have different effects on behavioural outcomes, travel in this case, based on variations in context (Zhang & Zhang, 2020). Hence, the built environment interacts with individual factors, jointly producing travel behaviour (Zhang & Zhang, 2020). Therefore interaction effects are relevant to consider, as it might be that due to the interaction effects policies might not work in certain contexts. A hypothetical example could for example be that for some reason free PT tickets do lead to an increase in PT use for women, but to a decline in PT use for men. Providing free PT tickets to men then would have an effect opposite to the proposed effect. Knowing that beforehand would allow to change the policy and only provide free PT tickets to women. While being an extreme example, it does indicate that including interaction effects could indicate possible heterogeneity in the influence of various variables on travel behaviour.

2.1.3. RELATION WITH THE FOCUS OF THIS THESIS

The urban development strategies of densification and TOD are applied at locations near lots of activities and PT. In other words, houses are built at accessible locations, which does follow the by Wegener and Fürst (2004) proposed link from accessibility to land use. Subsequently, the land use affects the travel behaviour of people. To obtain more knowledge about how travel behaviour is affected, the focus of this thesis is on the link from 'land use' to 'activities'. Following the adaptation of Bertolini (2012), the external factors affecting land use and travel behaviour are included within the scope of this thesis. In his cycle, Bertolini (2012) names sociodemographics, economic and cultural factors as possible external factors influencing travel behaviour. Literature suggests that on top of those, attitudes, preferences and social norms, hereafter attitudes in short, also influence peoples travel decisions (Heinen, 2011). Hence, three categories of factors that influence travel behaviour can be distinguished. Literature about the relationship of those three categories with travel behaviour will be discussed separately in the following sections.

Various studies indicate that there is spatial heterogeneity in the effects of various determinants on travel behaviour. The presence of interaction effects between the built environment and the determinants underlying this heterogeneity has received little attention. For all categories of determinants, interactions that have been found will be discussed to get an idea about the variables that should be included in this study.

2.2. TRAVEL BEHAVIOUR AND THE BUILT ENVIRONMENT

Following the Wegener cycle, land use is known to influence travel behaviour. In literature, land use is often referred to as built environment (Kasraian, Maat, & van Wee, 2016). By a definition from Kaklauskas and Gudauskas (2016), the built environment refers to the human-made surroundings that provide the setting for human activity in which people live, work and recreate on a day-to-day basis.

The relationship between built environment and travel behaviour is a subject that received a lot of attention in scientific literature. According to Ewing and Cervero (2010) there are more than two hundred built-environment/travel studies which have examined a wide set of estimated effects, controlled for various influences and used various statistical methods. This chapter will discuss the findings from some of those studies.

2.2.1. THE ROLE OF THE BUILT ENVIRONMENT

In travel research the influences of built environment on travel behaviour have often be named with words beginning with a D . The terminology started with three main D's *Density*, *Diversity* and

Design (Cervero & Kockelman, 1997). Later, the D's were elaborated by the addition of *Destination accessibility* and *Distance to transit* (Ewing & Cervero, 2010). That results in the following five categories of variables influencing travel behaviour:

- Density
- Diversity
- Design
- Destination accessibility
- Distance to transit

Ewing and Cervero (2010) give an explanation of the five D's, which is summarised here. *Density* concerns a variable of interest per unit of area, often being population, dwelling units and jobs. Here, population and jobs are sometimes combined into an overall activity density. *Diversity* generally concerns the number of different land uses in an area. Most of the times diversity is included as an entropy measure. *Design* focuses more on the characteristics of the street network of an area, being for example number of intersections or average block size. The fourth D, *Destination accessibility* relates to the distance to various activities, hence it is often measured as number of activities reachable within a certain time or distance, or as distance to the nearest activity location of a certain activity type. The fifth D, *Distance to transit* can be seen as a specification of the *Destination accessibility* with transit being the activity of focus.

Although being popular in literature (the original paper is cited almost four thousand times), some scholars have criticised the classification. While the D's are catchy, they can cause confusion as they are not unambiguously (Handy, 2018). For example, *Design* indicates the street network connectivity or block size, whereas the word implies that it relates to the aesthetic qualities of the street environment (Handy, 2018). Further, the various D's are not independent from each other, but rather interdependent, resulting in possibly overestimating their effects. Besides that general criticism, another point of critique is that the authors of the studies that first proposed the several D's are all American. That especially becomes apparent in *Design*. It makes sense to look at the number of intersections and average block size in American cities, where cities lack historically grown city centres and are laid out in neat grids. That is more difficult and probably less interesting in European (and in this case Dutch) cities with historically grown cities where blocks are very different in terms of shape, size and orientation.

Despite the critics, this thesis does use the classification of built environment variables using the five D's, as it is an easy way to distinguish different built environment variables from each other. However, it is not the aim to include all of them in the analysis, as they are not all equally interesting in the Dutch context, do not all fall within the scope of this project and they are likely to be interdependent.

2.2.2. BUILT ENVIRONMENT AND INTERACTIONS

While not being an often studied topic, interaction effects have been studied a few times in the relation of built environment with travel behaviour. Those studies for example have a focus on interaction effects of built environment variables on the relationship between travel attitudes and travel behaviour to examine the variations in sensitivity among respondents to built environment variables (Guan et al., 2020; Bhat and Guo, 2007).

Built environment variables can interact with other urban form variables. While often used interchangeable, in this context urban from mainly relates to a more aggregated built environment variable, like municipality size in a study from Gao et al. (2018). Those can interact with more disaggregated built environment variables, possibly clarifying inconsistent associations between environment and travel behaviour (Gao et al., 2018). Gao et al. (2018) looked at the role of natural and built environment variables in cycling duration in the Netherlands. They aimed to study how these variables contribute to differences in cycling duration in Dutch municipalities, and also explored interaction effects between environment variables and municipality size on cycling. Related to the built environment they found several significant interaction effects with municipality size, where municipality size was a categorical variable based on number of inhabitants. The first significant interaction effect they found was one with address density and street density. The positive associations of those variables on cycling duration were smaller or even negative in small urban areas compared to larger cities. A second significant interaction effect with municipality size came from the number of bus stops. Small urban and rural areas have a more positive association between number of bus stops and cycling duration than medium-sized and large cities have. The third significant interaction effect is one between distance to train station and municipality size. In large cities, the negative association between distance to train station and cycling duration was stronger compared to less urbanised areas. The last variable with an interaction effect with municipality size was percentage of green, being a natural environment variable but which can be connected to the built environment. In the four largest cities the inverse relation of more green to cycling duration was most present. Land-use diversity, which was proved to be significant in relationship with a local access variable by Zhang and Zhang (2020), did not have a significant interaction with municipality size related to cycling duration. That built environment matters when looking at the effects on travel behaviour at multiple levels, like neighbourhood and city level, is supported by Sun and Yin (2020). They have found that city-level built environment elements can strengthen or weaken the effect of neighbourhood-level built environment elements on commute duration.

2.3. TRAVEL BEHAVIOUR AND TRAVEL ATTITUDES

Besides built environment factors, Bertolini (2012) included external factors that influence travel behaviour in his adaptation of the Wegener cycle. These external factors mainly relate to personal factors, from which two categories can be distinguished: sociodemographic and attitudinal factors (Hunecke et al., 2007). This section focuses on the relationship between attitudinal factors and travel behaviour, with inclusion of possible interactions with the built environment in that relationship.

2.3.1. THE ROLE OF ATTITUDES

According to Van Acker et al. (2016) travel behaviour is not only determined by price, speed and comfort, but also shaped by underlying opinions and orientations, including beliefs, interests and attitudes. As there are various studies that show that travel patterns are changing and getting less connected to the built environment, it is relevant to know whether other factors are getting more important. Variables that could get more important are underlying opinions and orientations, including beliefs, interests and attitudes, as those also shape travel behaviour (Van Acker et al., 2016). There are various definitions of attitudes being used in research on their role on travel behaviour. This thesis will use the following definition by Eagly and Chaiken (1993, p.1): "Attitude is a psychological tendency that is expressed by evaluating a particular entity with some degree of favour or disfavour". That definition connects to the way respondents of the data source used in the analysis were asked about their attitudes (see Section 3.2.2) and corresponds to the hypothesis underlying the use of factor analyses to cluster various statements (see Appendix D).

In the transport domain, attitudes are generally regarded as more or less stable personal dispositions, which makes them effective for explaining past and future travel behaviour (Kroesen & Chorus, 2018). This is based on the notion that people act rationally, which assumes that behaviour follows from attitudes. However, various studies showed that behaviour is not only a result from attitudes, but also influences attitudes itself (Kroesen, Handy, and Chorus, 2017; van de Coevering, Maat, and van Wee, 2018). As cross-sectional data will be used, this thesis will follow the line of reasoning that states that attitudes are more or less stable personal dispositions. That way, they can be used to explain travel behaviour on which data is collected in the same year as the attitudes are collected. Possible consequences of considering attitudes as stable dispositions will be discussed in the final chapter.

The influence of attitudes along with the influence of other variables was tested in various studies (Handy, Xing, & Buehler, 2010). According to findings from among others Prillwitz and Barr (2011) Kitamura, Mokhtarian, and Laidet (1997), and de Abreu e Silva (2014), attitudes are to a certain extent important determinants for daily mobility. Categories of attitudes that were identified in these studies relate to mode specific, residential location, parking, pricing, environmental and social attitudes (de Abreu e Silva, 2014; Prillwitz and Barr, 2011; Lindelöw et al., 2017). That attitudes add value to models is also stated by Van Wee, Holwerda, and Van Baren (2002) who found that adding attitudinal variables to a model with sociodemographics and built environment variables increases the explanatory power of the model on travel behaviour. By doing so, some of the trends and interconnectedness between social and spatial aspects might be partially explained (Harms, Bertolini, & te Brömmelstroet, 2014). For that reason, Van Wee et al. (2002) argue that a "broad selection of preferences, attitudes and life styles should be the subject of study" (p.316). They also recommend research into the relevance of attitudes for the impact of land use on travel behaviour.

2.3.2. TRAVEL ATTITUDES AND RESIDENTIAL SELF SELECTION

The recommendation by Van Wee et al. (2002) proved to be relevant, as besides having a direct effect on travel behaviour, studies have also proposed indirect effects of attitudes on travel behaviour through built environment variables (Van Wee, De Vos, & Maat, 2019). In this process, called Residential self selection (RSS), people self select themselves in neighbourhoods that allow the use of preferred travel modes based on their abilities, attitudes, preferences and needs (van de Coevering et al., 2018). In Wegener cycle, this relationship closes the cycle as seen from land use as starting point. The danger of RSS is that when present, the influence of built environment on travel behaviour is likely to be overestimated (Mokhtarian & Cao, 2008). In those cases, findings related to differences in travel behaviour might be more a matter of residential choice than travel choice (Mokhtarian & Cao, 2008). Mokhtarian and Cao (2008) gave an overview of a few methodological approaches to account for the self-selection problem. One of them is to explicitly account for the influences of attitudes by including them as explanatory variables with direct influence on travel behaviour. The goal of this approach is not to identify causal relationships, but to assess the relative importance of the relationship between attitudes and travel behaviour (Kitamura et al., 1997). If built environment variables are still significant, the careful conclusion can be that they exert some influence on their own, separate from the influence of self selection (Mokhtarian & Cao, 2008). As attitudes and preferences indeed can lead to residential self-selection, it is important to include them in order to disentangle the influences of the built environment and possible self selection, and still gain a reliable estimate of the effects on travel behaviour (Hong, Shen, and Zhang, 2014; Ding et al., 2018).

2.3.3. TRAVEL ATTITUDES AND THE REVERSE CAUSALITY HYPOTHESIS

Besides studies showing that the relationship between built environment and travel behaviour is affected by travel attitudes, other studies have focused on the reverse causality hypothesis. That hypothesis states that not only the choice for built environment is influenced by attitudes, but that built environment has indirect effects on travel behaviour via attitudes too. This hypothesis follows the line of reasoning that attitudes can change due to influences from the built environment. There are various possible reasons for changing attitudes through built environment. This can either be a result of a direct influence of the built environment on attitudes, or indirectly via the effect of the built environment on travel behaviour (Van Wee et al., 2019). People can alter their perceptions towards modes and thereby their attitudes towards that mode in response to new experiences and exposures. For example, when suffering from traffic congestion in urban areas, people might get a more negative attitude towards driving a car and consider the use of other modes of travel (Næss, 2009). Being exposed to travel by train after moving to a neighbourhood close to a station could increase pro-rail attitudes (Van Wee, 2009). Hence, travel attitudes are more likely to be interdependent with the built environment and travel behaviour rather than being a stable predisposition for travel behaviour (Scheiner, 2018).

2.3.4. TRAVEL ATTITUDES AND INTERACTIONS

As the residential self selection and reverse causality theories show, there are some direct and indirect effects via travel behaviour between the built environment and travel attitudes that show the importance of including them directly. Cao (2015) tested whether there are also interaction effects between built environment variables (on neighbourhood level) and travel attitudes. He found that the interaction term between neighbourhood type and the pro-transit attitude was significant in his study on USA based data. Following that findings, Cao (2015, p.189) concluded that "the influences of the attitude on travel behaviour are conditional on the type of residential neighbourhoods. That is, neighbourhood environments and attitudes interact.". In a study comparing various neighbourhoods in Malmö, Sweden, Lindelöw et al. (2017) found that the preference for neighbourhood walkability significantly affected walking frequency in two of the three considered neighbourhoods and preference for commuting distance and preference for walking was significant in the other one. As the study looked at various neighbourhoods, the findings mainly relate to the Design of the neighbourhoods. Another study that found heterogeneity in the effects of travel attitudes on travel behaviour is one by Guan et al. (2020). From that study follows that travel attitudes have a larger impact on car travel in urban areas, compared with suburban areas, and the effect of attitudes on transit trips is stronger in transit-oriented areas than it is in non-transit-oriented studies (Guan et al., 2020).

2.4. TRAVEL BEHAVIOUR AND SOCIODEMOGRAPHICS

Bertolini (2012) also included sociodemographics as factors that affect travel behaviour. That makes sense, because quite some studies have shown that socioeconomic and demographic characteristics are at least as important as built environment variables and the influence of them changes in different ways over time (van de Coevering, Maat, and van Wee, 2021; Feng et al., 2017). This section will briefly discuss the effects of sociodemographics on travel behaviour and interactions with the built environment in that relationship.

2.4.1. THE ROLE OF SOCIODEMOGRAPHICS

In general, quite some studies looked at the effects of various sociodemographic characteristics on travel behaviour. Sociodemographic characteristics that are included in lots of studies on travel behaviour include age, gender, income, ethnicity, occupation, education, household size, household composition, number of children, driver license ownership and (household) car ownership (in varying combinations in among others Bird et al., 2018; Ma, Mitchell, and Heppenstall, 2014; Bird et al., 2018 and Stead and Marshall, 2001).

One of the sociodemographic characeristics that received a lot of attention is gender. Most studies found that males commute further and more often than females (Susilo and Maat, 2007; Ng and Acker, 2018). However, some of the studies did find insignificant or opposing effects when looking at gender for different ages or cities (Ng & Acker, 2018). Understanding how gender affects mobility and how it does so differently in different contexts requires contextualised studies. It is essential to see the individual as embedded in neighbourhood, region and larger society (Hanson, 2010). Saelens, Sallis, and Frank (2003) argue that it is likely that people with varying characteristics could be affected by land use in different ways. One of the studies that did look into this is one by Salon et al. (2019). They observed that prior studies did have inconsistency in the indicated associations between travel behaviour and built environment characteristics. On one hand that could be a result of variety in used methods and data. On the other hand, it could be that there is heterogeneity in the underlying relationships. For that reason, Salon et al. (2019) studied the relationships between built environment and travel behaviour, cycling behaviour in specific, separately for different population groups. Their findings indeed indicated a substantial heterogeneity in the relationship between built environment and travel behaviour between genders, adults and children and children of varying ages. Further, there seemed to be variables that have opposed effects on certain groups. According to Salon et al. (2019), there were just a few studies that looked at possibly heterogeneity in the relationship between cycling and built environment, from which the majority looked at heterogeneity between various demographic groups. Heterogeneity in the response to built environment changes has been studied less.

A study that did look into spatial heterogeneity of the effects of sociodemographics is one by Harms et al. (2014). They studied the differences in bicycle usage between urban scales, ages, genders and more in the Netherlands as they identified that "there is limited generalisable knowledge about the underlying patterns and trends in this country" (p.240). Related to the spatial differences, they found that cycling volumes in urban areas increased over the period 1994 – 2012. This growth is partially caused by the increasing number of people living in urban areas. Further, urban areas have a relative high share of teenagers and young adults, which cycle more than older people. On the other hand, cities also have higher shares of people with migrant backgrounds, which cycle less often than people who are born in the Netherlands. Therefore, it is likely that there is heterogeneity between the effects sociodemographic characteristics have on travel behaviour.

2.4.2. SOCIODEMOGRAPHICS AND INTERACTIONS

Most studies to the effects of the built environment include sociodemographics, but control for rather than directly including them. Given their importance, it is important to explicitly include them in models (Badoe & Miller, 2000). Further, as it is especially the interaction between socioeconomic factors and urban form which is central to understanding people's travel decision making, including interaction effects is valuable in explaining travel behaviour (Badoe & Miller, 2000). Therefore, Badoe and Miller (2000) argue that it is not a question of which determinants are more important in explaining behaviour, it is a question of understanding how behavioural responses to changes in built environment will vary by personal characteristics. Hence, looking at possible heterogeneity in the relationships between sociodemographics and travel behaviour as result of a moderation by the built environment is expected to provide valuable insights in the way travel behaviour is influenced. An example of an interaction effect of the built environment on an effect of a sociodemographic trait on travel behaviour is given by Yin and Sun (2018). Their study showed that built environment is a moderator between household income and car dependency, and therefore concluded that heterogeneous effects of sociodemographics should not be ignored.

In a study to the effects of built environment on motorised and non-motorised trip frequency in the San Francisco Bay Area, Guo et al. (2007) found significant interaction effects of population density with sociodemographic factors they included. Examples of significant interactions in their study are population density with couple only households and maintenance businesses with young adults, both on number of maintenance trips made by car. Based on those findings, they concluded that the overall effect of population density depends on the sociodemographic composition of the population that lives in an area (Guo et al., 2007). Bhat and Guo (2007) looked at interactions on the relationship of demographics on car ownership decisions. In their study, they found that income is a key variable in affecting the sensitivity to built environment variables when looking at vehicle ownership. Further, employment density and street block density interact with unobserved household-specific factors influencing vehicle ownership. These variations in sensitivity to built environment attributes can lead to inconsistent results regarding the effects the variables have on travel behaviour, which can lead to inappropriate policy decisions (Bhat & Guo, 2007). In a different study, Van Acker and Witlox (2010) did look at the effects of car ownership on travel behaviour instead of looking for interactions affecting car ownership as dependent variable. They found that "lower car ownership and use is associated with living in high-density and mixed-use neighbourhoods which have poor car accessibility and are located close to the CBD ... or a railway station" (Van Acker & Witlox, 2010, p.73). A similar effect was found by Silva, Golob, and Goulias (2006) whose study showed that land use patterns affect car ownership and use, but that the effect is different for the location someone resides and work in.

2.5. CONCEPTUAL MODEL

The function of the conceptual model is to give a representation of the fundamental principles and relationships underlying this research. This study focuses on the link between land use and travel behaviour in the Wegener cycle of land use - transport, with inclusion of the external effects on travel behaviour as stated by the adaptation from Bertolini (2012). Here, three categories of independent variables with a relationship with travel behaviour can be identified: built environment variables, sociodemographic characteristics and travel attitudes. A substantial amount of literature shows that those categories of variables have a direct relationship with various aspects of travel behaviour. Besides those direct links with travel behaviour, built environment and travel attitudes likely also have a two-directional link as discussed in the sections about residential self selection (Section 2.3.2) and reverse causality (Section 2.3.3). Further, there is a feedback link from travel behaviour to travel attitudes as a result of the indirect influence built environment can have on attitudes by letting them experience the use of a mode (Van Wee et al., 2019). All of those different links have been studied before extensively, with studies using different methods, travel behaviour indicators, control variables and sources of data. However, less research has focused on possible interaction effects that could influence the relationship between the various independent variables and travel behaviour.

While various studies included interaction effects, there remain some gaps regarding interaction effects of the built environment. The first is that built environment is often included as binary variable with just urban and suburban or urban and non-urban as levels (Guan et al., 2020). Secondly, sociodemographic variables are often just controlled for rather than directly included in the interaction, which could lead to missing interaction effects (Guan et al., 2020). Thirdly, mainly due limitations in data availability, a large part of studies did not have the opportunity to include travel attitudes (Bhat & Guo, 2007).

To fill this gap in existing research, this thesis will add a built environment variable as moderator variable for the effects sociodemographic traits and travel attitudes have on travel behaviour. Besides having a direct link to travel behaviour itself, the moderator variable affects the relationships between the independent and dependent variables. These links can be read as follows: the built environment influences the effect a sociodemographis characteristic (or attitude) has on travel behaviour. The different categories of variables and links between those categories can be seen in Figure 2.3. The feedback link from travel behaviour to travel attitudes and the two-way relationship between travel attitudes and built environment do not fall within the scope of this study. Therefore, while being included in the conceptual model for a complete overview of the relationships between the various categories of determinants and the dependent variable, these links will not be included in the analysis. Only the solid links in Figure 2.5 will be operationalised in next chapter and analysed afterwards.

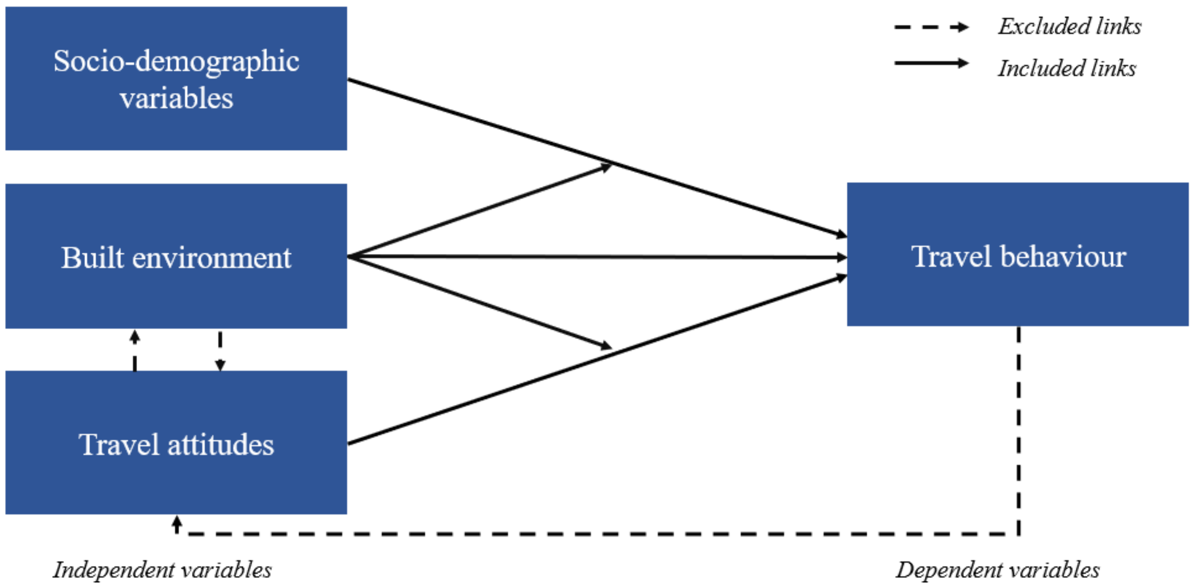

Figure 2.3: Conceptual model of variables influencing travel behaviour moderated by the built environment

For all three categories of independent variables, the variables that are reported in scientific literature have been discussed. Table 2.1 summarises all determinants that are discussed in this chapter. The built environment variables follow from the five D's framework. The sociodemographics are based on traits that the majority of other travel behaviour studies included or controlled for. The attitudes do not only relate to travel behaviour on its own, but also include attitudes about the wider beliefs of individuals that might influence travel related choices. The next chapter will describe the data and discusses which of the variables will be included in the main analysis.

Table 2.1: Overview of determinants influencing travel behaviour following from literature

Category of determinants	Determinants
Built environment	Density
	Diversity
	Design
	Destination accessibility
	Distance to transit
Sociodemographics	Age
	Gender
	Household size
	Household composition
	Number of children
	Educational level
	Income
	Ethnicity
	Daily occupation
	Driver license ownership
	Car ownership
Travel attitudes	Mode attitudes
	Parking attitudes
	Pricing attitudes
	Environmental attitude
	Attitude towards residential location
	Social norms

3

METHODOLOGY

This chapter will discuss the data, model specification and method that will be used to identify possible interaction effects of the built environment with other explanatory variables. Following the conceptual model with which previous chapter was ended, this chapter will introduce the determinants that are included in the analysis. These determinants will be based on the available data from the Netherlands Mobility Panel. By doing so, the conceptual model will be operationalised such that it can be used in the analysis. After that, the Moderated Multiple Regression (MMR) method that is used to study the moderation effects of the built environment is introduced and explained.

3.1. THE NETHERLANDS MOBILITY PANEL

The Netherlands Mobility Panel (MPN) (Dutch: Mobiliteits panel Nederland) is a panel survey on individual and household travel with as main objective to establish short-run and long-run dynamics in the travel behaviour of individuals and households (Hoogendoorn-Lanser, Schaap, & OldeKalter, 2015). The MPN was started by the Netherlands Institute for Transport Policy Analysis (KiM) (Dutch: Kennisinstituut voor mobiliteitsbeleid) in 2013 in cooperation with the University of Twente and Goudappel Coffeng. Every year the KiM collects data in order to map the travel behaviour of Dutch inhabitants. The MPN provides knowledge about the relationship between personal characteristics and travel behaviour of individuals and how these change over time (Jorritsma et al., 2016). The by the MPN collected data enables various research questions with as goal to gain a better understanding of factors explaining changes in travel behaviour (Hoogendoorn-Lanser et al., 2015).

Data from the MPN is not openly accessible, although access can be freely requested. After a request, this study got granted access by the KiM. The next sections will elaborate choices about the used data and discuss determinants of interest that can be used in this study based on the available data.

3.1.1. DATA CHARACTERISTICS

Every year the MPN questionnaire is distributed to approximately 2,500 full households and the individuals in them. Along with this questionnaire, respondents are asked to keep track of their travel behaviour for a period of three consecutive days in a travel diary (Hoogendoorn-Lanser et al., 2015). The MPN uses a place-based diary, which is a combination of the traditional trip-based diary and the activity-based diary. The idea behind combining the trip- and activity-based diaries is that respondents are better in remembering their activities and visited locations than all of the trips they made (Stopher, 1992). In the diary, data are collected about their displacements, travel motives, mode choice, travel company, delays and parking costs. Further, respondents provide information about their personal and household characteristics in the questionnaire. As the same group of respondents is asked to fill in a travel diary every year, the MPN has the possibility to study observed individual mobility changes over time. Besides data provided by respondents, data about spatial transport-related characteristics and socio-economic characteristics of neighbourhoods are added by researchers afterwards (Hoogendoorn-Lanser et al., 2015). Further, every year a second questionnaire is provided to the respondents in order to obtain additional knowledge about specific subjects. Every even year respondents answer questions about various attitudes towards travel related aspects. Every odd year the questions focus on the influence of ICT on mobility. The MPN started in July 2013 and has collected data from every year since then. The most recent available data set at the start of this study originates from 2017. During the execution of this study, the data set from the 2018 wave was published. More recent data sets still have to be processed.

While the MPN collects longitudinal data, it can also be applied in cross-sectional studies. The main advantage of MPN data over other possible sources of data is the biennial inclusion of questions related to preferences towards various modes, the environment, the economy and accessibility of residential locations (Hoogendoorn-Lanser et al., 2015). As Chapter 2 indicated, travel attitudes are important to include as they affect travel behaviour, possibly influence or are influenced by the built environment and account for the residential self-selection problem. Another advantage of MPN data over other sources of data, like the Dutch National Travel Survey ODiN, is that the MPN collects data for a period of three days. That increases the probability of capturing infrequent trips and at the same time reduces the impact of those trips.

As the most recent data set at the start of this study originates from 2017, the most recent wave does not contain the additional questions about attitudes of the respondents. For that reason, this thesis will use data collected in 2016. The 2016 questionnaire has been filled in by 9,293 individuals. As not all of these individuals completed the questionnaires and travel diary, the data had to be cleaned such that only valid respondents are included. Before it could be cleaned, the various separate data sets had to be merged. Appendix B discusses step-by-step how the data are combined, cleaned, filtered and processed to make it ready for the main analysis. After all steps of data cleaning, 3,077 respondents remain in the sample.

Besides the personal and household data, the travel diary data have to be cleaned too. Again, this is discussed in more detail in Appendix B. In the end, the 3,077 remaining respondents made 27,898 valid trips. This number does include 'trips' that are not actually a trip because the respondent did not leave their house on one or more days. These are included in the analysis as the choice to not make a trip on a certain day does also provide information about the travel behaviour of individuals.

3.1.2. SAMPLE REPRESENTATIVENESS

As mentioned before, with 3,077 respondents the MPN sample is relatively small. To check whether the sample is a good representation of the Dutch population, the distribution of variables in the sample is compared with the distribution of those variables in the entire Dutch population.

The largest flaw of the data is the lack of respondents with a non-western origin. In the sample just 1.1% of the respondents has a non-western origin, whereas that is 12.3% in the Dutch population. Another limitation of the sample is the under-representation of lowly educated people. The differences between the sample and the population might affect the outcomes of the study. In the discussion possible effects of the differences will be related to the results. A full comparison between the sample and population can be found in Appendix C.

3.1.3. DATA PROVISION

Two years after the data from a specific study year have been collected, the anonymised version becomes available for analysis by third parties. Data that could be traced back to individuals are removed such that the data comply to the European General data protection regulation (GDPR). Further, the KiM offers the possibility to link additional data to the respondents in the data set by request. That way, some variables can be added without violating the GDPR. The classification of urbanisation that is used in this study (see Appendix E) is obtained in this way.

3.1.4. DATA LIMITATIONS AND STRENGTHS

While the MPN provides interesting data, it is limited by its number of respondents. Whereas the MPN has just 9,293 respondents from which the majority did not complete the full questionnaire and/or diary, the major yearly Dutch travel survey ODiN has about 40,000 respondents (CBS, 2018). This large difference is partially reduced when looking at the number of trips because the MPN collects travel data for three days rather than one. However, the difference is still considerable. On the other hand, the MPN contains a set of travel related attitudes, which is a great advantage over other data sources.

To see how the results from the MPN relate to those from the OViN (the predecessor of ODiN), Hoogendoorn-Lanser et al. (2015) compared various travel behaviour indicators. Regarding overall mobility they found that the average number of trips per person per day is higher in MPN than in OViN. That does make sense as a place-based diary as used in the MPN generally results in more reported trips than activity- or trip-based diaries as used in OViN (Behrens & Masaoe, 2009). This higher number of trips mainly results from a higher reporting of short distance trips and slow modes (Hoogendoorn-Lanser et al., 2015). As OViN is known to have an under representation of short trips (CROW, n.d.), this is a positive difference. Other differences relate to a higher number of non-home-based trips and more unique locations visited in the MPN compared with OViN (Hoogendoorn-Lanser et al., 2015).

3.2. DATA COLLECTION

As briefly discussed in the previous section, the MPN collects a variety of data on households and individuals. This section will elaborate the data the MPN collects following the categories of interest as specified in the conceptual model in Section 2.5. This section will only focus on introducing the variables of interest. The section following this section will elaborate on the measurements of the variables and the analyses necessary to operationalise the in this section introduced variables.

3.2.1. DATA COLLECTION OF BUILT ENVIRONMENT VARIABLES

In the household questionnaire, one of the members of the household is asked to fill in questions about the residential location and parking possibilities of the household. These data are supplemented with additional data by the researchers of the KiM. Related to the built environment, various variables are present in the data. First, the geographical area where the household lives is known on four different levels, namely level of urbanisation, province, COROP-area and postal code on a two digit level (PC2). Here, the level of urbanisation is based on the average density of inhabitants per square kilometre in the residential municipality of respondents. Based on the living location of a respondent, researchers from the KiM derived some lower-level built environment variables which relate to the presence of amenities in the neighbourhood. Respondents also provide information about parking possibilities near their residential location.

The level of urbanisation in the MPN data is based on a standard definition from Statistical Netherlands, which classifies the Netherlands in five levels of urbanisation that do have roughly the same population size. When studying mobility, this definition can raise some questions as it does classify some very different areas in the same level of urbanisation. Therefore, this study uses another definition of the level of urbanisation. That definition is based on housing and job density in 500x500 meter squares, and classifies the urbanisation of postal code areas on a 4 digit level rather than municipalities. Data for this classification are obtained via Studio Bereikbaar, which constructed the classification based on data from Statistics Netherlands (District and neighbourhood key figures and 500 meter square statistics) and LISA concerning 2018. That year does not correspond with year of origin of the rest of the data that are used in this study. However, there is assumed that the level of urbanisation does not change fast and the classification of urbanisation in 2018 is almost identical to the classification in 2016. More information about the differences between the two different classifications of urbanisation can be found in Appendix E.

3.2.2. DATA COLLECTION OF TRAVEL ATTITUDES

The additional questionnaire that participants of the MPN have to answer in even years collects information about the perceptions and attitudes of people. Respondents received a list of various statements on which they had to indicate their level of agreement or disagreement on a five level Likert scale, from strongly disagree to strongly agree. To identify what respondents think of travelling by car, the following seven 'use' statements were presented. In order to identify the opinions from respondents about other modes too, the same seven statements were also asked about the use of train; Bus, tram and metro (BTM) and bicycle.

- I find travelling by car to be comfortable.
- I find travelling by car to be relaxing.
- Travelling by car saves me time.
- Travelling by car is safe.
- I find travelling by car to be flexible.
- Travelling by car is pleasurable.
- Travelling by car gives me prestige.

A flaw of the additional questionnaire is that it does not address attitudes towards walking. As walking is the main mode in 15.7% of the trips made in 2019 (CBS, n.d.), a walking attitude could provide additional knowledge about the choices people make. If there is a suspicion that this shortcoming influences the results, the effects will be discussed in the discussion.

In addition to the mode specific 'use' statements, respondents were asked about 21 additional statements with a specific focus on cars. Rather than the seven 'use' statements, these statements cover a broad aspect of more general opinions about cars. The statements cover subjects like environment, car as status object, costs, dependency of car and influences and opinions of friends. Again, respondents had to answer these questions on a five level Likert scale ranging from strongly disagree to strongly agree. As some statements relate to the use or possession of a car, those were not asked to respondents younger than 17. This results in the removal of all respondents younger than 17 years old (see Appendix B).

Besides statements about modes, respondents also filled in their agreement to statements regarding the factors that influenced the choice for their current residential location. The statements on factors that influenced the current residential location choice all have travel related aspects. Two of the five statements concern the presence of a train or BTM station within walking (or cycling) distance. The other three statements relate to the influence of the distance to shops, workplaces and highway entry or exit ramps on their residential choice. Just as the mode related statements, these statements are answered on a five level Likert scale.

3.2.3. DATA COLLECTION OF SOCIODEMOGRAPHICS

One person in each household has to fill in a household questionnaire. In this household questionnaire, questions related to the sociodemographic characteristics of the household are asked. Examples are the annual gross household income, composition of the household and the number of certain transport vehicles owned by the household. Whereas the household questionnaire is only filled in by one member of the household, every member is asked to fill in the questionnaire about personal characteristics. In that questionnaire, respondents were asked about a wide variety of social, demographic and economical characteristics. Examples of aspects the demographic questions focus on are age, gender and ethnicity. Besides questions regarding demographic characteristics, respondents were also asked about their socio-economic characteristics. These questions concern the current employment status, monthly salary, employment hours, employment location, educational level, vehicle ownership, drivers license ownership, travel costs subsidies, public transport subscriptions and access to and use of internet facilities.

3.2.4. DATA COLLECTION OF TRAVEL BEHAVIOUR

Travel behaviour data are collected in two ways, via stated and observed behaviour. The first way is collecting information about frequency of mode use by asking respondents directly in the individual questionnaire. In these questions, respondents can choose from seven answers indicating their estimated mode use frequency. These questions are asked for car, train, BTM, bicycle, moped/scooter, walking, private flying and work-related flying.

The second way travel behaviour data are collected, is through reported data in the travel diary. Rather than stated behaviour, travel diaries provide information about the actual travel choices people made. In the travel diary, respondents fill in all activities and trips they undertake in a three day period. For all displacements in these three days, respondents fill in the origin, destination, goal, distance, parking costs, delay, mode and number of travel companions. Based on these answers, information about the daily number of trips, number of trips per displacement, number of round trips, travel motive and travel duration is derived by KiM researchers. Various travel behaviour indicators like mode choice, average trip distance, average trip duration and trip frequency can be derived directly or indirectly. Since respondents also provide the modes they used, all travel behaviour indicators can be specified for specific modes.

3.2.5. DATA COLLECTION OF OTHER VARIABLES

Besides the aforementioned data, the MPN also collects data which are irrelevant for this research. These data mainly concern the occurrence of certain events and whether those events changed travel behaviour of respondents. As this study will only look at a single year, the effects of certain events happening does not fall within the scope of the study. For a more complete overview of information gathered in the MPN, the reader is referred to Hoogendoorn-Lanser et al. (2015).

3.3. DATA OPERATIONALISATION

Now the variables of interest that are included in the MPN have been introduced, they have to be operationalised such that they can be included in the analysis. For most variables this is pretty straightforward, but some variables require additional analyses to prepare them for the main analysis.

3.3.1. OVERVIEW OF INCLUDED VARIABLES

Table 3.1 presents the operationalised form of all variables that will be included in the analysis. This section will discuss the operationalisation of all of them per main category of determinants.

When comparing this table with Table 2.1 with which Chapter 2 was ended, some similarities and differences can be observed. With density (level of urbanisation) only one of the built environment variables is included. The others are not included, which is mainly a result of the chosen spatial scale of this study. The sociodemographic characteristics of household size and number of children are not included separately since the household composition already tells something about the presence of children (yes or no) and the number of persons (one or more). The other sociodemographic traits are all included in the MPN data, and hence will be included in the analysis. Car ownership is operationalised as car availability because that does tell something about the actual ability to use a car rather than just having one (and potentially having to share it with household members). That follows a line of reasoning that argues that availability is more important than private ownership (Van Acker, Mokhtarian, & Witlox, 2014). When comparing the included variables with the attitudes following from the literature summarised in Table 2.1, mode attitudes (i.e. car attitude), pricing attitudes (cost-sensitive), environmental attitudes (environmental sceptic), attitudes towards residential location (accessibility of residential location) and social norms (i.e. status sensitive) are operationalised. Parking attitudes have not been identified based on the MPN data, and hence will not be included in the analysis. The travel behaviour indicator of interest will be the average daily distance travelled in total and by each mode specific.

Table 3.1: Overview of the operationalised variables included in the analysis

Category	**Variable**
Built environment	Level of urbanisation
Sociodemographics	Age
	Ethnicity
	Annual gross household income
	Gender
	Level of education
	Household composition
	Drivers license ownership
	Daily occupation
	Car availability
Attitudes	Car attitude
	Cycling attitude
	Train attitude
	BTM attitude
	Prestige attitude
	PT efficiency attitude
	PT safety attitude
	General car attitude (car loving)
	Cost of driving attitude
	Environmental scepticism
	Status sensitive
	Accessibility attitude
Travel behaviour	Average daily distance travelled in total and by mode

3.3.2. OPERATIONALISATION OF THE TRAVEL ATTITUDES

Overlap can be expected within respondents' answers on the statements that are included in the additional questionnaire of the MPN. Mode enthusiast will likely answer positively on all statements, whereas people that do not use or like the mode will answer more conservative. Hence, it might be that the seven statements about a single mode together form a general mode attitude. To identify whether the variables can be used directly, or should be combined in some overarching variables, an explanatory factor analysis is conducted. With factor analysis the dimensional structure underlying the mode specific preference statements can be extracted (Haybatollahi et al., 2015). To extract the dimensional structure underlying the mode attitudes, a principal factor analysis is performed. This form of factor analysis, also called principal axis factoring, searches for the minimum number of factors that account for the common variance (Van Acker, Derudder, & Witlox, 2013). A step-by-step description about how this analysis was conducted can be found n Appendix D.

MODE USE STATEMENTS

The seven statements about the use of modes all capture various attributes of a mode attitude. As explained in the introduction of this section, it might be expected that people either tend to agree or disagree on the most statements for a specific mode. This is confirmed by a correlation analysis that shows correlations between six out of the seven statements on car and bicycle use, and seven out of seven for BTM and train use. That indicates that variations in the statements might reflect variations in a smaller number of unobserved more generic attitude variables (Van Acker et al., 2013). To identify which variables measure different aspects of the same underlying factor a factor analysis is performed. While some hypotheses can be formulated regarding the latent variables, less expected structures could arise. For that reason, rather than performing a separate factor analysis for each mode, all 24 mode use statements are all included in one factor analysis.

The factor analysis shows that seven factors can be identified. The seven factors along with the variables and their loading can be found in Table 3.2. The loading represents how the variables load on the factor, where higher scores indicate a better fit to the factor. In addition to the loading, the Cronbach's alpha (CA) of a factor is given. The CA provides a measure of reliability of the factor, where a value of 0.8 or higher is considered good and reflects high internal consistency (George and Mallery (2013), cited in Gliem and Gliem (2003)). Only the *PT safety attitude* has a CA below 0.8, but its value of 0.749 indicates a still acceptable internal consistency.

The first statements that share variance and hence can present one latent variable are the first six statements on car use. Therefore, this will be known as the *car attitude*. The second factor follows the same structure as the car attitude, but in this case with cycling as mode. Here, again the first six statements are included and the seventh statement about prestige is excluded. This latent structure will be named *cycling attitude*. The third factor does score good on three of the seven train statements. Although this factor covers just three out of the seven statements on train use it will be named *train attitude*. The same is the case for use statements related to BTM use. There, three variables share variance, resulting in a *BTM attitude*. The fifth factor scores good on the four statements of gaining prestige when using the modes. These variables did not score high on the mode specific attitudes, so there can be concluded that prestige forms a standalone attitude, which will be named *prestige attitude*. The sixth factor covers the time saving and flexibility statements of travelling by train and BTM. As both relate to the efficiency of PT, this attitude is named *PT efficiency attitude*. The last factor also covers statements of two modes in the form of safety of train and BTM use. Therefore, this statement is named *PT safety attitude*.

Table 3.2: Results of the factor analysis of the mode use statements

Factor	Statements		Loading	CA
Car attitude	Travelling by car is ...	Comfortable	.770	.845
		Relaxing	.728	
		Time saving	.599	
		Safe	.632	
		Flexible	.633	
		Pleasurable	.816	
Cycling attitude	Cycling is ...	Comfortable	.771	.848
		Relaxing	.839	
		Time saving	.522	
		Safe	.548	
		Flexible	.656	
		Pleasurable	.853	
Train attitude	Travelling by train is ...	Comfortable	.695	.891
		Relaxing	.718	
		Pleasurable	.736	
BTM attitude	Travelling by BTM is ...	Comfortable	.775	.912
		Relaxing	.786	
		Pleasurable	.804	
Prestige of using modes	Travelling by ... increases status	Car	.553	.803
		Train	.878	
		BTM	.793	
		Bicycle	.712	
PT efficiency attitude	Travelling by train is ...	Time saving	.654	.856
		Flexible	.674	
	Travelling by BTM is ...	Time saving	.648	
		Flexible	.645	
PT safety attitude	Travelling by ... is safe	Train	.713	.752
		BTM	.658	

CAR STATEMENTS

Besides the statements on the use of the four modes, respondents also answered 21 statements with a focus on various aspects like environment, economy, dependency and status object related to the car. Just as for the mode use statements, a factor analysis is performed to reduce the number of variables.

The results in Table 3.3 show that the seventeen included variables explain the variance of five different factors. Four of the five factors have a CA value of internal consistency between 0.7 and 0.8. While not as good as the factors identified in the mode use factor analysis, these values are still acceptable (George and Mallary (2003), cited in Gliem and Gliem (2003)). The Car scepticism factor has a CA value of 0.560, which is below an acceptable level. Hence, this factor will not be included in further analyses.

The first factor is based on high scores of statements that relate to the use of and advantages of the car. It has statements like dependency on a car and the pleasure obtained by driving a car. As all statements capture a positive attitude towards cars, this factor is called *general car attitude (car loving)* such that it can be separated from the *car attitude* which focuses on the actual use of the car. The second factor that can be identified is based on statements related to the costs of driving a car. As the statements are formulated in such way that higher costs relate to less driving, this factor captures the *cost of driving attitude* of respondents. This cost of driving attitude captures the attitude of respondents towards their opinion on the costs of driving, where people that are sceptic gave high scores and people that think cars are not expensive gave low scores. The third factor is based on three statements that all relate to the environment. Interestingly, one of those statements is pro environment, whereas the other two are negative towards worrying about the environment. This becomes clear when looking at the factor loading. The two negative statements have a positive loading, whereas the positive statement has a negative loading. Based on the factor loading, this factor relates to the *Environmental scepticism* of respondents. The second last factor is also the weakest one. The factor consists out of two statements related to scepticism of using a car, hence it is called *car scepticism*. This factor does only have a CA of 0.560, indicating low internal reliability. The fifth and last identified factor is based on just two statements. While not being ideal, its CA value is acceptable, so no changes are necessary. The two statements both cover the way a car contributes to how a person is seen by society. Therefore, this factor is called *Status sensitive*.

Table 3.3: Results of the factor analysis of the general car statements

Factor	**Statements**	**Factor loading**	**CA**
General car attitude (car loving)	Driving a car offers many advantages compared to the use of other transport modes	.634	0.737
	The car gives me the freedom to go wherever I want	.574	
	I cannot manage without a car	.560	
	If I have to go somewhere, I nearly always go by car	.519	
	Driving a car is fun	.463	
Cost of driving attitude	Due to costs, it is difficult for me to own a car	.825	0.781
	My current financial situation is a reason to postpone the purchase of a (new) car	.694	
	Due to high costs, I drive less with the car than I actually want to	.657	
	Due to costs, I opt to travel by public transport and bicycle instead of by car	.452	
Environmental scepticism	It is pointless to worry about the environment, because there is nothing you can do about it on your own	.758	0.719
	It does not make sense to not drive a car in order to benefit the environment, because other people continue to drive their cars	.736	
	The environment will benefit if people drive cars less frequently	-.469	
Car scepticism	I only use a car if it is really necessary	.583	0.561
	With the environment in mind, in the past year I have consciously tried to drive a car less	.626	
	In order for accessibility to be improved, it is necessary to sharply reduce car use	.432	
	My friends believe that you must only use the car when necessary	.402	
Status sensitive	A car says a lot about someone's personal taste / sense of style	.738	0.711
	A car says a lot about a person's status in society	.721	

ACCESSIBILITY STATEMENTS

A third set of statements relates to the importance of various accessibility related aspects on the choice of the current residential location. Again, it could be that there are people who think accessibility is important when choosing a residential location and people who do not take it into

account. It can be expected that if that is the case, individuals belonging to the first groups answer agreeing on all the statements and individuals belonging to the second group tend to answer more disagreeing. To identify whether there indeed is or are some latent variables underlying the five statements, an exploratory factor analysis is performed. As respondents had the option to answer 'not-applicable', some data preparation was needed to make the data ready for the analysis (see Appendix B).
The factor analysis shows that one factor that resembles all five statements. As all statements relate to an aspect of accessibility of a residential location, this factor is called *Accessibility attitude*. The factor loadings of the statements on the factor and the CA value are shown in Table 3.4.

Table 3.4: Results of the factor analysis of the accessibility statements

Factor	**Statements**		**Loadings**	**CA**
Accessibility attitude	A short ... was an important factor for the choice to reside at my current address	walking distance to a BTM station	.812	0.825
		walking/cycling distance to a train station	.775	
		walking /cycling distance to shops	.752	
		cycling distance to my workplace	.599	
		distance to a highway entrance or exit ramp	.565	

OVERVIEW OF THE OPERATIONALISED TRAVEL ATTITUDES

To end this section, an overview of the identified attitudes that will be included in the main analysis is given in Table 3.5. This table also contains some descriptive statistics of the attitudes in the sample. The car attitude has the highest mean attitude, which is not surprising given the popularity of the car in society. The bicycle attitude is the attitude with the second highest mean. That is also not surprising given the popularity of cycling in the Netherlands. When only looking at the modes, the BTM attitude is pretty low. That could be caused by the fact that these modes are not available in every area. The prestige attitude is the attitude with the lowest mean, indicating that on average Dutch people do not agree upon the fact that using modes results in prestige. Another attitude with a low mean is the environmental sceptic attitude. That indicates that a larger part of the respondents in the sample is worried about the environment rather than being sceptic about environmental worries.

Table 3.5: Overview of the operationalised attitudes

Variable	**Min.**	**Max.**	**Mean**	**SD**
Car attitude	1.17	5.00	4.14	0.58
Bicycle attitude	1.00	5.00	3.83	0.68
Train attitude	1.00	5.00	3.29	0.95
BTM attitude	1.00	5.00	2.70	0.89
Prestige attitude	1.00	5.00	2.26	0.76
PT efficiency attitude	1.00	5.00	2.42	0.80
PT safety attitude	1.00	5.00	3.72	0.76
General car attitude (Car loving)	1.00	5.00	3.77	0.76
Cost of driving attitude	1.00	5.00	2.42	0.96
Environmental scepticism	1.00	5.00	2.33	0.84
Status sensitive	1.00	5.00	2.71	0.94
Accessibility attitude	1.00	5.00	2.46	1.05

3.3.3. OPERATIONALISATION OF THE SOCIODEMOGRAPHICS

There are various relevant sociodemographics in the MPN data which are worth including in the analysis. This section briefly describes the specific measures and how they are measured in the data. This is summarised in Table 3.6. Some measurements are not directly present in the data but have been adjusted for various reasons, which will be explained briefly. Besides the variable and its measurements, Table 3.6 also presents some descriptive statistics about the presence of each measurement in the sample.

As already mentioned, a few adjustments have been made to the original data. The age variable in the MPN data exists out of nine categories. To reduce the number of dummies that have to be created to be able to conduct the main analysis (see 3.4.4), those categories are combined in three larger levels. The same is done with the level of education. The original MPN data contain eight different levels of education. To make the education variable easier to interpret and to compare it with international education standards, the different answers respondents could give are regrouped in three overarching levels. That also has the benefit that there no longer are levels with very few respondents. Changes were also made to the daily occupation of respondents. The term daily occupation is used rather than employment situation, as it relates more to what someone does rather than whether someone is working a certain number of hours a week. That variable was regrouped into three different categories with a main reason to create cohorts of sufficient sizes. To do so, the various levels that indicated unemployment with different reasons are combined in one single category. The car ownership variable is operationalised as car availability. That variable does not indicate whether someone owns a car (or multiple), but whether someone can always use that car or not. The benefit of that is that it could indicate agreements between household members regarding the use of cars that cannot become apparent when just looking at the number of cars. Examples are agreements that allow one to always have a car available despite having just one car or indications that despite having two cars one cannot always use a car since they have to be shared with three persons.

At last, the number of different levels in household composition was reduced as a few cohorts were really small. Therefore, three main categories were established which correspond with a definition used by Statistics Netherlands to enable a comparison of the sample with the population. As the household composition already does contain some information about the presence of children and the number of people in a household, these two will not be operationalised separately. In Appendix B the adjustments are discussed in more detail.

Table 3.6: Overview of the operationalised sociodemographics

Variable	Measurement	Sample distribution	
		Frequency	Percentage
Age	17-30 (Young adult)	710	23.1%
	30-60 (Adult)	1799	58.5%
	60+ (Elderly)	568	18.5%
Ethnicity	Native Dutch ethnic origin	2839	92.3%
	Non-Dutch ethnic origin	216	7.0%
	Unknown ethnic origin	22	0.7%
Gender	Male	1397	45.4%
	Female	1680	54.6%
Household income	Below national benchmark	520	16.9%
	National benchmark	565	18.4%
	Above national benchmark	1580	51.3%
	Unknown income	412	13.4%
Level of education	Low	54	17.7%
	Medium	1269	41.3%
	High	1264	41.1%
Drivers license	Person does have a drivers license	2831	92.0%
	Person does not have a drivers license	246	8.0%
Daily occupation	Working	1987	64.6%
	Student / attending school	282	9.2%
	Unemployed (various reasons)	808	26.3%
Household composition	Single person household	619	20.1%
	Multi-person household	846	27.5%
	Multi-person household with children	1612	52.4%
Car availability	Person always has a car available	1993	47.4%
	Person does not (always) have a car available	1084	52.6%

3.3.4. OPERATIONALISATION OF THE BUILT ENVIRONMENT VARIABLES

The focus of this thesis is on varying effects of determinants for travel behaviour in different levels of urbanisation. Hence, the built environment indicator has to relate to level of urbanisation. In general, level of urbanisation is measured as number of inhabitants or households per area. When looking at the five D's framework, this relates to *density*. The MPN data contain a variable that indicates the urban degree of the home municipality of a respondent based on population density. This is the standard classification by Statistics Netherlands, and divides the Netherlands in five levels with roughly the same population. However, some questions can be raised about the use of this classification for transport related studies. First, because the levels have roughly the same size, some very different areas are classified within the same level. Secondly, the relative large spatial scale of municipalities results in the loss of differences within those municipalities. Therefore, an alternative level of urbanisation variable developed by Studio Bereikbaar is used. Their classification has six levels, with unequal sizes ranging from less than one thousand to more than 12.5 thousand inhabitants and jobs per square kilometre. The definition uses a 3 kilometre radius of a location with a linear decreasing weight after 1.5 kilometre. That radius is larger than the 1 kilometre radius which is used for the Statistics Netherlands classification. The six levels, along with their boundary values and the sample distribution can be found in Table 3.7. A more elaborate comparison and discussion of the two level of urbanisation variables can be found in Appendix E.

Table 3.7: Overview of the operationalised level of urbanisation variable

Level of urbanisation	Level [inhabitants + jobs per km2]	Sample distribution	
		Frequency	Percentage
Metropolitan	>12,500	96	3.1%
Urban	6,000 - 12,500	386	12.5%
Suburban	4,000 - 6,000	449	14.6%
Low suburban	2,000 - 4,000	932	30.3%
Village	1,000 - 2,000	602	19.6%
Rural	<1,000	612	19.9%

First, an analysis with a two level classification is conducted. Table 3.8 does show the classification used for this analysis. As can be seen, the urban and metropolitan levels are merged to an urban category, and the other four levels are combined in a non-urban category. Subsequently, the significant moderation effects are studied in more detail with the six level classification.

Table 3.8: Overview of the operationalised urbanity variable

Level of urbanisation	Level [inhabitants + jobs per km2]	Sample distribution	
		Frequency	Percentage
Urban	>6,000	482	15.6%
Non-urban	<= 6,000	2295	84.4%

The built environment may have different effects on travel behaviour dependent on the spatial scale it is measured (Guan et al., 2020; Bhat and Guo, 2007). As Handy (2018) already mentioned, the five D's are likely to be interdependent. The main built environment variable of interest is one that covers large spatial scales. The other D's are mainly related to lower scale aspects of the built environment. Therefore, only the level of urbanisation will be included in the analysis to prevent possible interdependency between built environment variables. That also eases the interpretation of the results, as a possible moderating effect of one built environment variable on the effect of another built environment variable on travel behaviour would be difficult to interpret.

3.3.5. OPERATIONALISATION OF TRAVEL BEHAVIOUR VARIABLES

As discussed in the travel behaviour data collection section, the travel diary data open possibilities for the analysis of various travel behaviour indicators. Because of practical reasons a selection of travel behaviour variables has to be made. This can be a selection based on travel motives, modes or indicators. As mentioned in Chapter 2, having a focus on commuting as only travel motive, which is the case in a considerable part of existing studies on travel behaviour, does not do justice to understanding how urban form influences travel behaviour (Krizek, 2003). Focusing on a single mode has the limitation that it does not capture possible interdependency between various modes (Guan et al., 2020). Therefore, one travel behaviour indicator will be considered. By focusing on one indicator, distinctions between travel modes can be made and all travel motives can be included to obtain a full understanding of the influence of urban form on travel behaviour.

The travel behaviour indicator of interest is travel distance. With travel distances, information about the displacement patterns from people can become apparent. When making a distinction between modes, the modal share based on vehicle kilometres can be observed for each mode. That last one is interesting as modal split is of major interest for policy makers, because reducing the number of car kilometres is one of the means to improve the accessibility, safety, air quality and livability of city centres (Ewing & Cervero, 2010). But not only distance travelled by car is of interest, distances covered by other modes are too. Just as car, PT and active modes have implications on mobility, social justice, livability and health (Ewing & Cervero, 2010). The attention is not only a result of the desire to improve the current situation. Lots of new houses have to be built to accommodate a growing demand caused by growing populations and increased individualisation. Currently measures have to be taken to make sure that future travel behaviour is steered in the desired direction. The potential to moderate travel demand by changing the built environment is therefore of great interest for urban planners (Ewing & Cervero, 2010). To accommodate the growing housing demand in cities, densification is globally applied as method to overcome the problem of scarce space. While densification allows optimal use of mobility resources, it also puts additional pressure on existing transport networks (Noronha Pinto de Oliveira e Sousa & Caffarena Celani, 2018). Not only is travel behaviour in cities affected by densification strategies, compact-city policies could have second order effects that lead to further suburbanisation of households (Schwanen, Dijst, & Dieleman, 2004). Therefore, it is important to study travelled distances for various modes in various levels of urbanisation and increase understanding about the role of built environment on those distances.

The travel distance is operationalised as average daily distance travelled in total and per mode, and is measured in kilometres. In the rest of this thesis, various terms are used interchangeably to indicate the average daily distance travelled by a specific mode or in total. Terms like daily distance by car, average distance travelled by car and (daily) car kilometres all refer to the same travel behaviour indicator. The calculation of the average daily distance in total or by a specific mode is schematically shown in Figure 3.1. Per day, the distances of each trip are aggregated, by specific mode and in total. As the MPN collects travel data from three days, the process is repeated for three days. To obtain the average daily distance travelled in total and by each mode, the average of the three days is calculated. To clarify this, the average daily distance by car will be calculated with the hypothetical data in Figure 3.1. On day 1, the respondents travels 30 kilometres to work, and later on the day again 30 kilometres to home. Hence, on day 1 the daily distance by car is 60 kilometres. On day 2, this is repeated, so the daily distance travelled by car is again 60 kilometres. On day 3, the respondent does not have to work and decides to go to an amusement park by train. On this day, the car is not used, so the daily distance by car is 0 kilometres. To calculate the average daily distance travelled by car the mean of the three daily distances by car is taken. Adding 60, 60 and 0 makes 120, which returns an average of 40 kilometres per day. By calculating the average daily distance, the influence of outliers is reduced and a more accurate representation of the actual travel behaviour of respondents can be obtained.

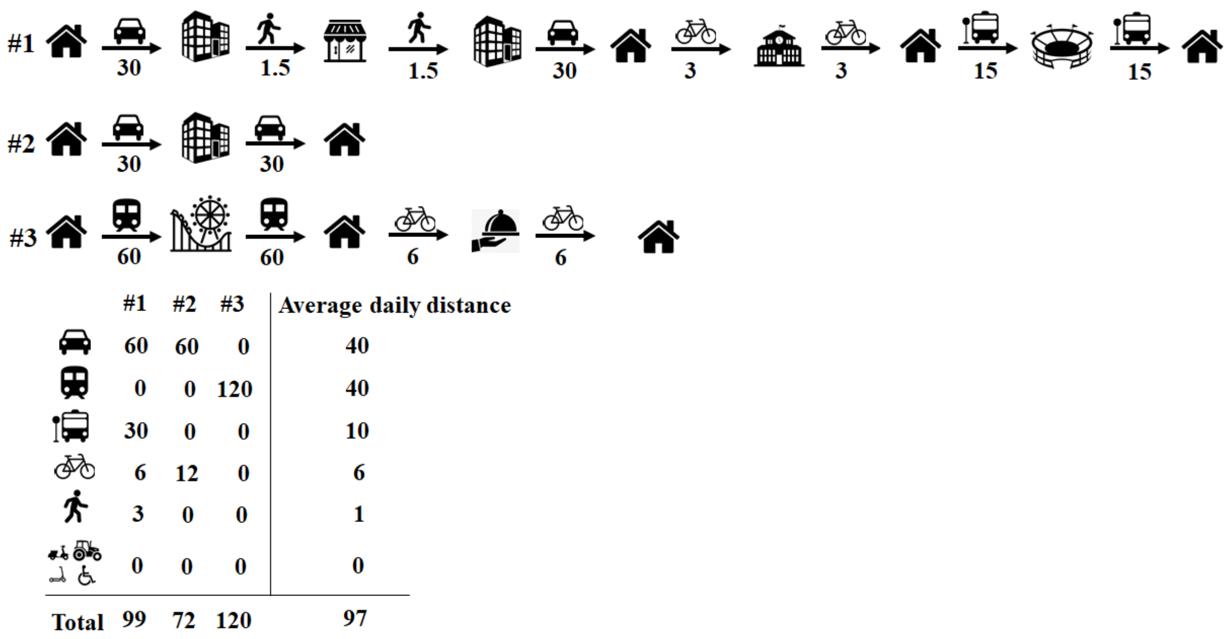

Figure 3.1: Example of the calculation of the average daily distance per mode

The distances in the MPN travel diary are directly measured, meaning that they are reported by respondents. Between the respondents, there is variety in the way how accurate the travelled distances are reported. Some respondents round the trip lengths to an integer value, some round to half decimal places and others report the distance accurate to one decimal place. Witlox (2007) researched the reliability of self-reporting travel distances. He concluded that rounding travel distances is not likely to result in over- or underestimation, and therefore will not influence the reliability of the self-reported data. Therefore, no corrections are needed to control for the varying reporting methods.

3.4. MODERATED MULTIPLE REGRESSION ANALYSIS

To test the effects of a wide variety of independent variables, a Multiple linear regression (MLR) analysis can be performed. With a MLR regression analysis a dependent variable can be predicted by multiple independent, or explanatory, variables. The parameters of the independent variables are estimated by ordinary-least squares which minimises the sum of the squares in the difference between the observed and predicted values of the dependent variable configured as a straight line. To test heterogeneity of determinants of average daily travelled distance in various levels of urbanisation, the relation between the independent and the dependent variables will be moderated by a built environment variable. Hence, the regular multiple regression analysis turns into a Moderated Multiple Regression (MMR). When a moderation effect (also named interaction) is present, the effect of a certain independent variable on the dependent variable is affected by the moderation variable (Aguinis & Gottfredson, 2010). When this is the case, the interpretation of the effect of the individual independent variables might be incomplete or misleading (Coulton & Chow, 1993).

3.4.1. MODELLING APPROACH

The MMR is an expansion of the basic MLR. MLR can be expressed with the following simple additive model (equation 3.1). The additive model assumes that effects of a change in an independent variable on the dependent variable does not depend on the level of other independent variables. Therefore, the effect can be described without stating the (fixed) level of other independent variables (Seltman, 2015).

$$Y = \beta_0 + \beta_1 X + \beta_2 Z + e \tag{3.1}$$

where:

Y	= Dependent variable
β_0	= Constant (also known as intercept)
$\beta_1 \& \beta_2$	= Estimated coefficient for the scores of the dependent variables
X & Z	= Observed score for the independent variables
e	= Estimated residual

To capture interaction effects, an interaction term is added to the additive model (equation 3.2).

$$Y = \beta_0 + \beta_1 X + \beta_2 Z + \beta_3 XZ + e \tag{3.2}$$

where:

β_3	= Estimated coefficient for the interaction term
XZ	= Interaction term

Moderation effects are symmetrical because $X \cdot Z = Z \cdot X$. Therefore, it is necessary to label one of the variables as moderator based on conceptual considerations (Aguinis & Gottfredson, 2010). When the moderation effect is statistically insignificant, the moderation model is turned back into the regular additive model. When the effect is significant, the moderator and relevant independent variables should be included in the model, even when their main effect is insignificant (Seltman, 2015). When the moderation is significant, two different effects can arise: synergy and antagonism. In the first, the signs of the coefficients of the moderation and the direct effect are the same. This indicates a strengthening effect where the whole is more than the sum of the single parts (Seltman, 2015). When the signs have opposite directions, the term antagonism is used to indicate that the total effect is less effective than the sum of the individual effects.

3.4.2. MMR limitations

MMR allows to test moderation effects. That is valuable as moderation effects can provide information about conditions under which independent variables have better or worse explanatory power (Aguinis & Gottfredson, 2010). MMR does have some limitations too. The most important is that MMR typically has low statistical power (Aguinis & Gottfredson, 2010). One aspect that limits the statistical power is the sample size of moderator variable. When having a categorical moderator, the statistical power of the model is enhanced when the subgroup proportions are equally divided (Aguinis & Gottfredson, 2010). That however, is not the case as more people are not divided equally over the various levels of urbanisation. To increase statistical power, it is important that the dependent variable is reliable and if possible variables are included as continuous rather than categorical.

Further, multicollinearity between variables can arise (Iacobucci et al., 2016). When multicollinearity arises, two (or more) independent variables are related with each other and the dependent variable (Akinwande, Dikko, Samson, et al., 2015). As result, the estimates might be unstable and incorrect, leading to possibly false inferences about relationships between the independent and dependent variables (Midi, Sarkar, & Rana, 2010). Looking at correlations between variables can provide insights in possible multicollinearity between variables.

A last problem is one that arises when an independent variable has no or no meaningful value for zero. This, for example, is the case in the attitudinal variables which are measured with scores from 1 till 5. The zero-point is relevant in MMR, because the interpretation of the coefficients depends on a meaningful zero-point and the intercept corresponds to the value of the dependent variable when all independent variables have a value of zero (Dalal & Zickar, 2012).

3.4.3. MEAN-CENTRING

The problem of not having a meaningful zero-point can be solved with mean-centring. Mean-centring is the process of subtracting the variable's mean from all observations such that the mean becomes zero. Without affecting the coefficients and p-values, mean-centring provides a more parsimonious interpretation of the coefficients. Instead of a possibly non-existent or a meaningless point zero, the coefficient represents the conditional slope of the predictor at the mean of another variable (Iacobucci et al. (2016) and McClelland et al. (2017)). Some authors argue that mean-centring is also useful to reduce the multicollinearity, although there can be questioned whether that indeed is the case. McClelland et al. (2017) showed that the unstandardised regression coefficients and standard errors did not change for the interaction term after applying mean-centring, something that is also shown by Echambadi and Hess (2007). Therefore, mean-centring is only used to make interpretation easier, and hence will only be applied to variables without a meaningful zero-point.

In model form, mean-centring looks as follows (eq. 3.3):

$$Y = \beta_0 + \beta_1(X - E(X)) + \beta_2(Z - E(Z)) + \beta_3(X - E(X))(Z - E(Z)) + e \tag{3.3}$$

where:

E(X/Z) = Mean of the variables

Mean-centring does not improve the overall model fit, which stays constant (Iacobucci et al., 2016). Hence, mean-centring is useful when the purpose of a study is to test significance and contributions of a set of individual independent variables on dependent variables, rather than having the sole purpose of looking at the overall model fit (Iacobucci et al., 2016). That does match the purpose of this study.

3.4.4. DUMMY CODING

The majority of the variables discussed above is categorical. These are variables for which the units of observation differ in terms of kind or type. However, the use of regression analysis requires that all variables in the model are continuous (Alkharusi, 2012). By applying a coding method, the categorical variables can be included in the regression analysis. One of the most used coding methods is dummy coding. With dummy coding, a categorical variable with *k* categories is represented by *k-1* dummy variables that have numerical values of zero and one. A one is assigned when a respondent belongs to the group the dummy variable represents, a zero if otherwise.

When the dummies are included in the regression analysis, the coefficients indicate the difference between the category the dummy variable represents and the reference level, which is the level that is not represented by a dummy variable.

Dummy coding is applied to all categorical independent variables included in the analysis, with exception of the level of education variable. For the first MMR, the level of urbanisation variable is dummy coded too. As mentioned, the variable will cover the difference between urban and non-urban areas. Hence, there is one dummy variable that indicates whether a respondent lives in an urban area or not. Level of education is not dummy coded as it is an ordinal categorical variable. Treating ordinal variables as continuous has the advantage that interpretation is simpler. This does require the assumption that the categories are equally spaced. The same is done for the level of urbanisation variable. For both variables a coding scheme starting at zero is chosen to meet the aforementioned requirement of having a meaningful point zero.

4
RESULTS

This chapter presents the results of the modelling part of this research. First, some descriptive statistics of the average daily distances travelled will be given. In the second part of this chapter the results of the moderated multiple regression analysis are presented, interpreted and related to other studies, theories and the used data.

4.1. DESCRIPTIVE STATISTICS OF THE TRAVEL DISTANCE

In Chapter 3 some descriptive statistics are given for the various determinants of travel behaviour that are included in this study. This section will give descriptive statistics of the trip distance to give some insights into the travel behaviour indicator before performing the main analysis.

On average, the respondents travelled 38.9 kilometres per day during the days captured in the travel diary. This corresponds with data from Statistics Netherlands from 2019, which indicate that on average men travelled 41 and women travelled 31 kilometres per day (CBS, n.d.). On average, that is around 36 kilometres a day for men and women combined. In general, people under the age of 18 travel fewer kilometres per day. That explains why the MPN average is slightly higher than the average found by Statistics Netherlands, since people younger than 17 years are not included in the sample. In Figure 4.1 the average daily distance travelled per person per day is presented by the levels of urbanisation and the various modes. As can be seen, the average daily distance travelled by car, as driver and as passenger combined, increases with decreasing urbanisation. When looking at the average daily distance travelled by train and BTM, a distinction between the lesser urbanised areas and the urban and metropolitan levels can be made. In areas with high urbanisation, the daily distance travelled by train and BTM is higher than in less urbanised areas.

Another observation is that the average distances travelled by cycling and walking are low. This corresponds with the short distances on which active modes are the main mode. Because only main modes are considered, access and egress distances are included in the distance travelled by the main mode. As walking, cycling and BTM are often used in combination with the train as main mode, the distance travelled by train is likely overestimated, while the distances travelled by foot, cycling and BTM are underestimated.

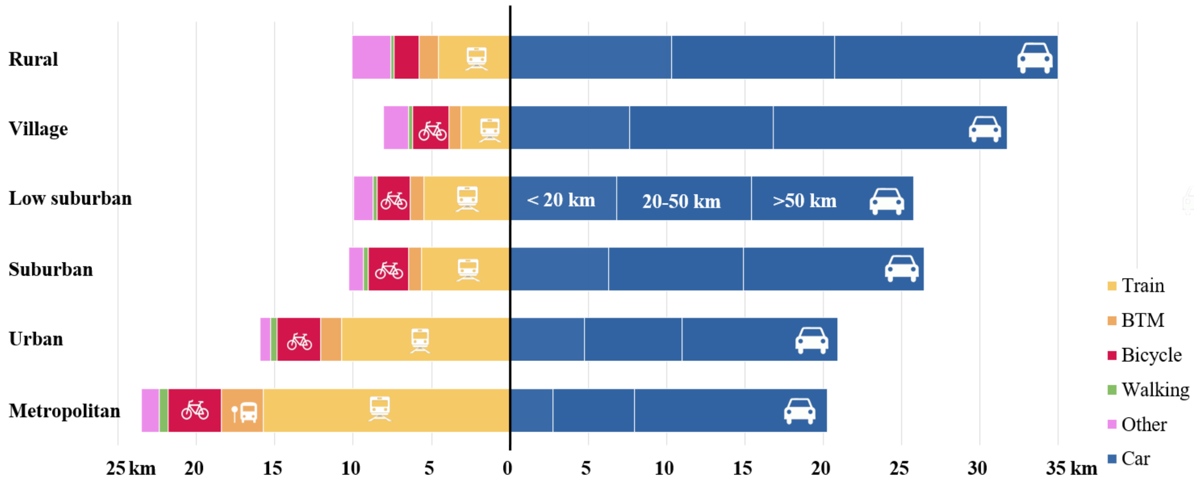

Figure 4.1: Average travel distance, per mode, per person, per day (data from MPN 2016)

Besides obtaining insights in the average travelled distance, the data on travelled distance can also be used to calculate the modal share. With the average travelled distance, the modal split can be calculated for each mode by dividing the average distance travelled with that mode by the total average distance travelled per person per day. The results of this definition of the modal split can be found in Figure 4.2. There can be observed that car and train are responsible for around 85% of the average daily distance travelled. That makes sense, as they are both able to cover long distances in relative short time. To also give an overview of the modal split based on choices for a mode rather than the distance travelled with them, the modal split based on frequency is also given in Figure 4.2. Logically, the shares of car and train decrease and those of cycling and walking increase. Based on the frequency based modal split, there can be concluded that as urbanisation diminishes, the share of car increases in terms of use frequency too. That does mainly come at the expense of the shares of train, cycling and walking. That latter mode is responsible for a quite considerable share of the trips by metropolitan inhabitants.

To check the reliability of the travel behaviour from the respondents included in the sample, a comparison is made with observed travel behaviour in the OViN study. The only large difference is related to the distance travelled by train. That share is higher in the MPN sample than it is in the OViN sample, probably caused by the fact that only main modes are considered. That the output is comparable with the output from the OViN indicates that despite some shortcomings, the sample still is relative good. The detailed comparison of the travel behaviour of the MPN sample with the OViN data can be found in Appendix C.

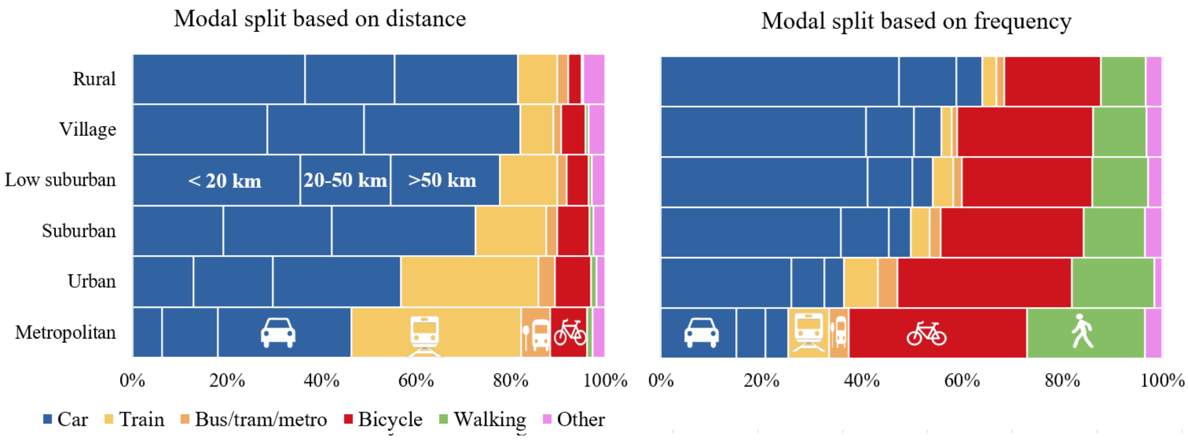

Figure 4.2: Modal split based on trip distance and trip frequency (data from MPN 2016)

Above descriptive statistics show that there are differences in travel behaviour between various levels of urbanisation. Especially between metropolitan and urban areas and the lesser urbanised areas differences in travel behaviour can be observed. Further analysis is required to identify whether there are also differences in the influence of determinants on this travel behaviour in various levels of urbanisation. The results of this MMR analysis will be discussed in the next section.

As the descriptive statistics show, the six levels can be split into two groups based on approximately similar travel behaviour when looking at the average distance travelled. In metropolitan and urban areas, respondents travel shorter distances with car, and use the train and BTM more often compared to the four other levels of urbanisation. As there is a clear distinction between the levels of urbanisation, first an urban/non-urban analysis is performed. This enables to research differences between urban and non-urban areas before going in more detail. This way, both differences between urban and non-urban areas as differences between specific areas can be identified. Based on the descriptive statistics, a distinction between urban (metropolitan and urban) and non-urban (suburban, low suburban, village and rural) areas is used. From here on, the distinction between urban and non-urban areas will be called urbanity. The term level of urbanisation will indicate that the variable being used has six levels.

4.2. GENERAL RESULTS OF THE MMR ANALYSES

In this section the results of the MMR analysis will be discussed. First, a summary of the full results will be given for the MMR analysis with urbanity as moderator. The same will be done for the MMR analysis with level of urbanisation as moderator. After that, some specific results will be presented, interpreted and related to other studies, theories and the used data to get an idea about the role of the built environment as moderator.

4.2.1. GENERAL RESULTS OF THE MMR WITH URBANITY AS MODERATOR

In Table 4.1 the results of the MMR analysis with urbanity as moderator are presented. To increase the readability of the table, all non-significant ($p > 0.05$) relationships are removed, with exception of the insignificant main effects of variables that have significant interaction effects with urbanity. The varying degrees of significance are marked with asterisks to make clear which coefficients are significant. Interaction effects that do not have a significant relationship with any of the dependent variables are removed from the table. The same is done with independent variables that do not have a significant relationship with at least one dependent variable, with exception of variables that do not have a significant direct relationship but have a significant interaction effect. Despite being excluded from the table, the variables are still included in the model, as removing them would change the coefficients of other variables. The full results table, with the insignificant variables included, can be found in Appendix F.

Table 4.1: General results of the MMR with urbanity as moderator

	Total	**Car**	**Train**	**BTM**	**Bicycle**	**Walking**	**Other**
Intercept	18.456*	10.040**	2.655	2.952	1.612*	0.403*	0.796
Urbanity (ref = non-urban)			-3.781	-2.986	1.101	-0.068	2.645
Gender (ref = female)	9.457*	5.596*			0.341**		2.141*
Dutch ethnicity (ref = non-Dutch)				-0.897**			
Unknown ethnicty (ref = non-Dutch)			-3.224	2.667**			
Job (ref = unemployed)	9.152*	5.771*	1.824			-0.103*	1.430**
Student (ref = unemployed)	15.136*		13.247*	1.445*		-0.171**	
Level of education	3.857*	3.005*	1.382**			-0.021	-0.749**
Adult (ref = young adult)				-0.997*			
Elderly (ref = young adult)	-10.999*	-6.463*	-4.608*	-1.024**			
Car available (ref = no car)	3.962**	8.250*	-2.456**	-0.684*	-0.934*	0.025	
Multi person hh (ref = single person hh)					-0.518**		
Multi person hh with children (ref = single person hh)	-5.460**		-3.341*	-0.128			
Benchmark income (ref = below benchmark)			2.267			-0.014	
Above benchmark income (ref = below benchmark)	6.823*	5.964*		0.737**			-2.020*
Unknown income (ref = below benchmark)					0.102		
Bicycle attitude					0.999*		
BTM attitude	-4.100*	-2.765**	-1.960*	0.421**			
PT efficiency attitude			0.989		-0.264**		
PT safety attitude	4.460*	2.449**	2.472*				
General car attitude (car loving)		5.989*	-2.161*		-1.313*	-0.052**	
Cost of driving attitude		-2.043**					
Accessibility attitude						0.023	
Urban × Unknown ethnicity			30.473*				
Urban × Benchmark income			-6.840**			0.365*	
Urban × Unknown income					-1.144**		
Urban × Education						0.143**	
Urban × Job			6.172**				
Urban × Multi-person hh with children				-1.869**			
Urban × Car available			-6.379**			-0.266*	
Urban × BTM attitude			-4.814*				
Urban × PT efficiency attitude			3.901**		-0.976*		
Urban × Accessibility attitude						0.073**	
Adjusted R-squared value	0.095	0.129	0.123	0.037	0.119	0.049	0.004

* $P \leq 0.01$
** $P \leq 0.05$

Because urbanity is dummy coded, the unstandardised coefficients show the differences in mean daily distance (in total/by a specific mode) compared to the reference category, which is non-urban for the urbanity variable. The same applies for all other dummy coded variables. Hence, for a categorical variable with three levels, a significant effect indicates a significant difference between the mean daily distance of that level with the mean daily distance of the reference level. Take for example the significant effect of car availability on daily distance travelled by train, which is also moderated by the urbanity. To understand the way the coefficients work, the MMR formula as discussed in Chapter 3 has to be recalled. To show the effect of car availability, only terms containing car availability are shown in equation 4.1. As the differences in the effect of car availability are of interest, the constant does not matter as it is the same for all 'scenarios'. Therefore, it is not included in the example and the scores are explicitly not the actual (predicted) means but the differences compared to the reference level of non-urban inhabitants with not always having a car available. The coefficients are not dependent on the scores of other determinants, hence the scores of other determinants do not matter when looking at the effect of car availability. The coefficients are however calculated in a model with all other determinants included. Therefore the effect of car availability that will be presented below is only applicable for a model with exactly the set of determinants as included in this MMR. The example below is based on the MMR model with urbanity as moderator and daily train kilometres as dependent variable. It does work the same way for other independent and dependent variables.

$$Y = ... + \beta_1 car\ availability + \beta_2 urbanity + \beta_3 car\ availability * urbanity + ... \quad (4.1)$$

$$Y = ... - 2.456 * car\ availability - 3.781 * urbanity - 6.379 * car\ availability * urbanity + ... \quad (4.2)$$

The coefficients in Formula 4.2 follow from Table 4.1. Next, the values for car availability and urbanity can be filled in, leading to the values in Table 4.2. In general, people who have a car available travel 2.456 kilometres less by train than people who do not (always) have a car available, indicated by the negative coefficient of the main effect of car availability. The same is applicable when comparing urban with non-urban areas. In general, people in urban areas travel 3.781 kilometres less by train than people living in non-urban areas. While that seems strange, it should be seen in the wider context of the included moderation effects. Urbanity is included in many interaction effects, which apparently results in an insignificant counter intuitive coefficient for the main effect. When adding the numbers of the direct effects of living in an urban area and having a car available, a reduction of 6.237 train kilometres would be expected. However, an interaction effect arises. Apparently, always having car available in urban areas does lead to an additional reduction of 6.379 kilometres of the daily distance covered by train, resulting in a total decrease of 12.616. Hence, urbanity strengthens the negative effect of car availability on distance travelled by train. As the interaction on its own does not provide information about which variable possibly influences the other (the moderation), this needs to be supported by a theory or hypothesis when discussing the results. In this case such theory could for example relate to differences in the competitiveness of train and car in different areas.

Table 4.2: Example of the interpretation of the coefficients with the effect of car availability on train distance

	Non-urban [0]	Urban [1]
Not (always) a car available [0]	0.000	-3.781
Always a car available [1]	-2.456	-12.616

The last row of Table 4.1 contains the adjusted R-squared values for the full models of all dependent variables. The R-squared value indicates the proportion of the variance of a dependent variable that is explained by the independent variables. The R-squared value ranges from zero, explaining nothing, to one, explaining the full variance. To prevent that every time an independent variable is added the model fit increases, even if that is just a result of chance, the adjusted R-squared value is presented. This value does account for the number of independent variables included in the regression model. With an adjusted R-squared value of 0.129 the car distance model has the highest proportion of explained variance. Even with a wide set of variables from which is known from literature that they have some influence on travel behaviour, the share of explained variance is pretty low. This is not uncommon in (cross-sectional) travel behaviour studies (Scheiner & Holz-Rau, 2007). It suggests that there is a considerable amount of knowledge missing about predicting travel behaviour (Krizek, 2003).

For BTM, walking and other modes, the adjusted R-squared values are very low. Apparently, some important variables are missing to predict these dependent variables accurately. It is not surprising that the set of independent variables explains less variance on these dependent variables. Other is a wide category with lots of varying modes, which makes it difficult to predict something for the group as a whole. To a lesser extent, that also applies to BTM. Especially as tram and metro are available in just a limited number of cities, whereas busses are available in the entire country.For walking, the absence of a walking attitude could be one of the reasons for the low variance that can be explained by the model. Also, walking is likely to be more affected by local built environment variables than it is by higher level spatial scales. The relative low adjusted R-squared values are not necessarily a bad thing, since the purpose of this study is not to fully explain the daily distance travelled, but to explore possible moderation effects of level of urbanisation. However, it could be that some important determinants for those dependent variables are not included, potentially resulting in the missing of additional interaction effects too.

4.2.2. RESULTS OF THE 6-LEVEL MMR ANALYSIS

To not only identify possible differences between urbanised and non-urbanised areas, but also identify differences on a more detailed spatial scale, the MMR analysis is also performed with the level of urbanisation included as continuous variable. Here the assumption is made that there is a linear relationship between the different levels, where rural is zero and metropolitan is five. The intercepts as shown in Table 4.3 therefore indicate the mean value of the distance travelled by a mode (or in total) in rural areas given that all other variables have a value of zero. In Appendix F the four detailed models are discussed, this section will only focus on the overall model. In Table 4.3 the results of the MMR are given for all dependent variables. Only significant variables are presented and variables without any significant relationships are removed from the table, with exception of variables that do not have a significant main effect, but have a significant interaction effect. The full table, including the for readability removed insignificant variables, can be found in Appendix F.

Table 4.3: General results of the MMR with level of urbanisation as moderator

	Total	Car	Train	BTM	Bicycle	Walking	Other
Intercept	15.942	5.135	5.086	5.455*	2.535**	0.403**	-2.672
Level of urbanisation	0.965	2.239	-1.293	-1.506**		-0.030	
Gender (ref = female)	9.567*	5.146**					3.018*
Dutch ethnicity (ref = non-Dutch)				-2.009**			
Unknown ethnicity (ref = non-Dutch)			-14.463	6.391**			
Job (ref = unemployed)	8.000**	6.752**	-1.117				2.597**
Student (ref = unemployed)	17.728**		13.756*				
Level of education	4.810**	4.740*				-0.076**	-1.417**
Adult (ref = young adult)	-0.098			-1.307**			
Elderly (ref = young adult)				-1.463**			
Car available (ref = no car)		4.681	-0.925	-0.973**	-0.923**	0.092	
Multi person hh with children (ref = single person hh)				0.426			
Benchmark income (ref = below benchmark)						-0.098	
Above benchmark income (ref = below benchmark)	8.412**	8.032**					-2.392**
Car attitude							1.565**
Bicycle attitude					1.070*		
PT efficiency attitude				-0.677**			
General car attitude (car loving)		7.495*			-1.302*		
Cost of driving attitude			2.022**				
Accessibility attitude	-1.820	-2.118					
Level of urbanisation × Dutch ethnicity				0.664**			
Level of urbanisation × Unknown ethnicity			8.331**	-2.062**			
Level of urbanisation × Job			2.070**				
Level of urbanisation × Education						0.040**	
Level of urbanisation × Adults	-2.970**						
Level of urbanisation × Car available		2.666**	-1.361**			-0.058**	
Level of urbanisation × Multi person hh with children				-0.440**			
Level of urbanisation × Benchmark income						0.073**	
Level of urbanisation × PT efficiency attitude				0.343**			
Level of urbanisation × Car cost attitude			-0.633**				
Level of urbanisation × Accessibility attitude	1.204**	0.999**					
Adjusted R-squared value	0.101	0.133	0.122	0.052	0.120	0.043	0.013

* P <= 0.01
** P <= 0.05

The adjusted R-squared values in the last row of Table 4.3 show similar model fits as the urbanity model. Again, the BTM, walking and other model have the lowest model fits. Compared to the urbanity model, the model fits for the total, car, BTM and other modes distances have slightly improved. The model fits for train, bicycle and walking distances have stayed roughly the same.

4.2.3. General findings

The main conclusion from both MMR analyses is that the level of urbanisation indeed moderates the effects of various determinants on daily travel distance. Comparing both analyses shows that there are both differences between urban and non-urban areas as there are differences between more specific levels. Three main differences are possible, one where the strength of an effect in- or decreases with an increasing level of urbanisation, one where the direction of the effects varies between the levels of urbanisation and one where one specific level shows a stronger of weaker effect.

When looking at the modes, differences can be observed in the number of significant interactions per mode. The effects of determinants on total distance and distance by car are not significantly moderated by urbanity, but a few are moderated by level of urbanisation. Apparently, no large differences can be observed between urban and non-urban areas, but there possibly are some gradually de- or increasing differences between levels that do not follow the urbanity classification. Differences between urban and non-urban areas are present for the effects determinants have on the distance travelled by train. There, the urbanity moderates the effects of six different effects. As the level of urbanisation moderates four, there can be concluded that especially the effects on distance by train are sensitive for the built environment. Whereas the effects on train are mainly moderated by urbanity, the effects on BTM are mainly moderated by level of urbanisation. That possibly indicates differences between the metropolitan level and the other levels, as metro is only available in the higher levels of urbanisation. That just one effect of explanatory variables on cycling distance is moderated indicates that the effects on cycling are quite homogeneous in the Netherlands. Walking is less homogeneous since quite some effects on it are moderated by urbanity and level of urbanisation. That the dependent variable of distance travelled by other modes is not influenced by effects that are moderated does not come as a surprise. The wide set of modes combined in the variable reduces the predictive power, which is confirmed by the low adjusted R-squared value.

4.2.4. HIGHLIGHTED MODERATIONS

The general results show that there are quite some significant moderations by the built environment. While possibly interesting, it is not the objective of this thesis, nor possible within the time, to discuss and interpret all results in detail. Therefore, a selection of three results is made. Two sociodemographic traits and one travel attitude are selected to obtain an idea about the role of the built environment as moderator on both categories of determinants. The specific variables turn out to be significantly moderated by either urbanity, level of urbanisation or both, which gives insights in the various ways determinants can be moderated by the built environment. The significant moderation effects that are not discussed in the main text are briefly presented and discussed in Appendix F.

To better understand the effects shown in Tables 4.1 and 4.3, the effects that will be discussed are shown graphically. The differences between the levels of the built environment variable are shown with figures containing the mean predicted average daily distance in total or by a specific mode. The predicted average daily distance is the distance a respondent is predicted to travel based on its personal characteristics, the answers on the attitude questionnaires and the urbanity of its residential location. Hence, the predicted daily distance follows from the MMR equation as discussed in Chapter 3. The MMR model predicts a coefficient for all independent variables plus one constant which represents the mean value given that all variables have a value of zero. To determine the predicted daily distance for a respondent, the model-determined coefficients are multiplied with the value of the independent variable they belong to. It is important to mention that this is not limited to just the significant variables. This makes sense, as significance does not tell anything about importance, but only about the certainty of the estimation of the determined coefficient. While there cannot be ruled out that the coefficient is a result of chance, it has a probability that it does not equal zero. Further, removing variables would change the coefficients of other variables. Given the data, the calculated coefficients have the highest likelihood, and hence are all used to predict the daily distance covered by a respondent for all modes and in total.

4.3. CAR AVAILABILITY AND THE BUILT ENVIRONMENT

The first specific result relates to the effect of the independent variable of car availability on travel behaviour being moderated by the built environment. The car availability variable is a binary variable that indicates whether a respondent either has a car available at all times, or that the respondent does not always, or never, has a car available to use.

4.3.1. THE EFFECTS OF CAR AVAILABILITY ON TRAVEL DISTANCE

As can be seen in Tables 4.1 and 4.3, the effects of car availability on car, train and walking kilometres are moderated by the level of urbanisation. Urbanity only moderates the effect of car availability on train and walking kilometres, indicating that there might be differences between some levels of urbanisation which do not follow the distinction between urban and non-urban areas as used in this study.

CAR AVAILABILITY ON DAILY DISTANCE TRAVELLED BY CAR

The interaction term between car availability and level of urbanisation has a positive coefficient of 2.666. That indicates that when someone has a car available, the increase of car kilometres is higher in more urbanised areas. This positive effect of car availability becomes clear when looking at Figure 4.3. A few general observations can be made. The first is that people who have a car available at all times travel more kilometres by car than people who do not always have a car available. Secondly, when people do not (always) have a car available, the mean predicted number of daily car kilometres corresponds to the differences in distance travelled by car between the various levels of urbanisation as follows from the descriptive analysis. In the more urbanised areas, the daily number of car kilometres is low, and with decreasing urbanisation the daily distance travelled by car increases.

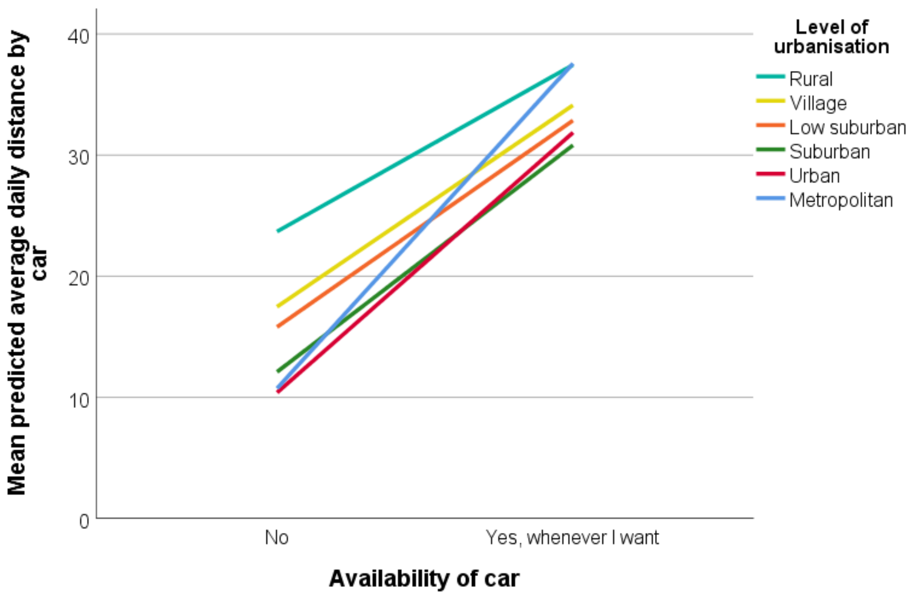

Figure 4.3: The effect of car availability on average daily distance travelled by car

The general findings are expected, however the moderation by level of urbanisation shows a surprising relationship. As mentioned, the number of car kilometres logically increases when someone always has a car available. However, this increase is significantly larger for the more urbanised areas than it is for lesser urbanised areas. Especially metropolitan inhabitants travel longer distances by car when they have a car available at all times. That increase is even so large that the predicted daily distance travelled by car for metropolitan inhabitants matches the predicted distance for rural inhabitants, whereas there is a large difference between those levels of urbanisation when there is not (always) a car available. For each level of urbanisation the growth in travelled distance increases, with a larger increase as the level of urbanisation gets higher as can be seen in Table 4.4. This does also explain why the urbanity variable does not moderate the effect of car availability on car kilometres. The suburban level is part of the non-urban level and close to both the low suburban and urban levels, thereby diminishing an apparently significant part of the difference between urban and non-urban areas.

Table 4.4: Differences in predicted daily distance between the car availability levels

Level of urbanisation	**Difference in predicted km (car available: not always vs. always)**
Rural	13.8
Village	16.6
Low suburban	17.0
Suburban	18.7
Urban	21.5
Metropolitan	26.8

CAR AVAILABILITY ON DAILY DISTANCE TRAVELLED BY TRAIN

Figure 4.4 presents the effects of car availability on train distance for all varying levels of urbanisation. For all six levels, the average daily distance travelled by train decreases when a person does always have a car available compared to not having one available (at all times). Especially urban inhabitants show a strong decline. As the effect of car availability is being moderated by urbanity and the level of urbanisation, it can be concluded that there are significant differences between the urban and metropolitan levels and the four lower levels of urbanisation. The effect in the suburban level does also show a strong decline, roughly matching the decline of metropolitan. That there still is a significant difference between urban and non-urban areas is probably caused by the smaller declines of the three lower levels, resulting in an average decline of the non-urban level that is apparently significantly different from the average decline of the combined urban and metropolitan levels. Further, the average values for all levels correspond to the descriptive statistics, the higher urbanised areas have higher means than the lower urbanised areas.

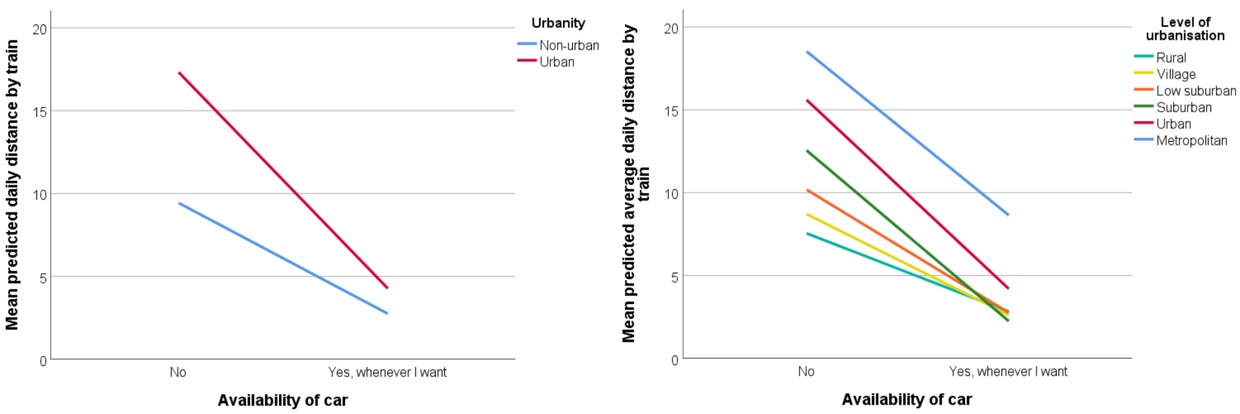

Figure 4.4: The effect of car availability on average daily distance travelled by train

The moderation that the built environment has on the general decreasing effect of car availability is that the decrease in kilometres travelled is much larger for metropolitan and especially for urban inhabitants. This is indicated by the negative coefficient the interaction effect has. For an increase in the level of urbanisation, the decrease of train kilometres when someone has a car gets larger. This matches the relationship between car availability and daily distance travelled by car. Whereas the daily distance travelled by car increases from not always having a car available to having a car available at all times, the daily distance travelled by train decreases. That does make sense given that for long distances train and car are competing alternatives. If someone would prefer the car above a train, indicated by the fact that he does have one available at all times, it is likely that he does travel less by train.

While the directions of the effect for car availability on car and train kilometres do make sense, there also is a difference. As discussed, the metropolitan level showed such strong increase when going from not having a car to having a car that it did match the car kilometres travelled by rural inhabitants. This is not the case when looking at the daily train kilometres travelled. There, metropolitan inhabitants still travel the longest distances by train, even if they always have a car available.

CAR AVAILABILITY ON DAILY DISTANCE TRAVELLED BY FOOT

When discussing the results for car availability on walking moderated by level of urbanisation as depicted in Figure 4.5, it is first important to emphasise again that walking only involves walking as main mode. For all levels of urbanisation, the distance covered by walking decreases when people have a car available, with exception of the rural level. With or without having a car available at all times, in urban areas people walk longer distances than inhabitants of non-urban areas. When looking at the right side of the figure, something interesting becomes apparent. As level of urbanisation decreases, the decline from not having a car to having a car available at all times gets weaker. For the rural level there even is an increase. Hence, the level of urbanisation results in effects of car availability with varying strengths and varying directions.

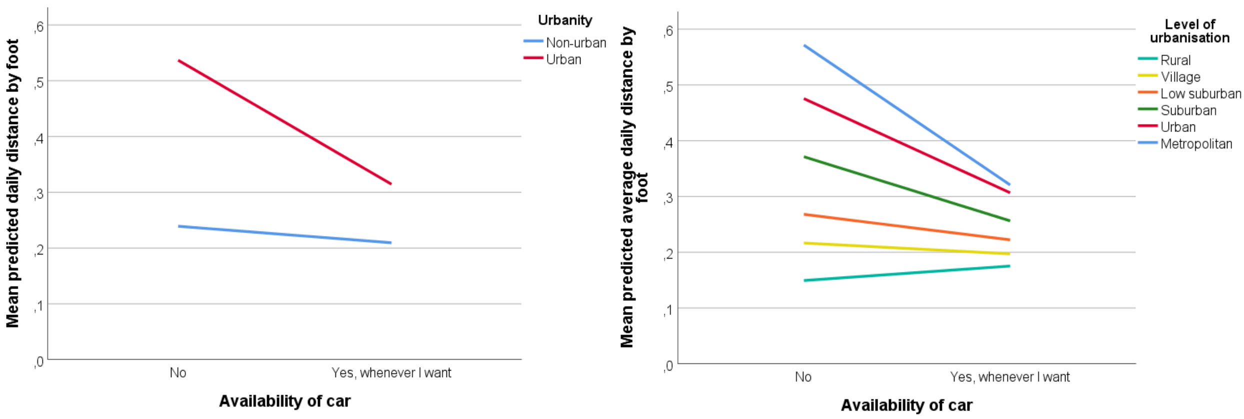

Figure 4.5: The effect of car availability on average daily distance travelled by foot

4.3.2. THEORIES ABOUT THE EFFECTS OF CAR AVAILABILITY

The results from the MMR analysis show that the effects of car availability on car, train and walking distance depend on the level of urbanisation one lives in. The effects on car and train kilometres have the same direction for all levels of urbanisation, but significantly vary in strength. The effect on walking distance varies in direction and strength. In order to create more understanding about the moderation effects, the results are linked to various related theories. This eases the interpretation of the effects, which enables the drawing of more specific conclusions. It also provides a theoretical founding, contributing to the reliability of the results.

CONSONANTS AND DISSONANTS

A possible explanation for the moderating effect of level of urbanisation on the relationship between car availability and car, train and walking kilometres could be a combination of the availability of PT, the costs of owning a car and the necessity to own a car. Having access to PT is known to reduce the odds of the decision to drive (Christiansen et al., 2017). Travelling by car is also relatively less attractive in areas with a high level of urbanisation, especially in city-centres, due to physical constraints like congestion, parking problems and low speeds (De Vos et al., 2012; Næss et al., 2020). At the same time, PT access is good in city-centres. Hence, the car has competition from PT. Only people that would use a car often would think that it is worth to own one, since the various mentioned barriers for owning a car have to be overcome. When one has a car, that person apparently really wants or needs a car, which explains the high use. Persons that do not want or need a car that much are likely to be more willingly to share one with household members, use sharing services or only use other modes. In less-urbanised areas, inhabitants are more car dependent and have less alternative travel options (Dargay, 2002). In those areas, more people always have access to a car. Table 4.5 contains the car ownership statistics of the sample in the various levels of urbanisation. As can be seen, the number of people who always have a car available is indeed much higher in the lesser urbanised areas than that it is in the more urbanised areas. Among the people that own a car in lesser urbanised areas, there are likely to be people that are not that car-minded, but have one because they are dependent on it to some extent. If available, those people would consider, or prefer, other modes of travel.

Table 4.5: Car availability in the various levels of urbanisation

Level of urbanisation	Does always have a car available	Does not always have a car available
Rural	71%	29%
Village	72%	28%
Low suburban	67%	33%
Suburban	63%	37%
Urban	47%	53%
Metropolitan	41%	59%

People that live at a location which does not correspond to their preferred travel behaviour can be called dissonants. Examples are urban inhabitants that prefer to drive by car, despite their built environment not really accommodating it, and rural inhabitants that like to travel by train, but who have to travel long distances to the nearest station. On the other hand there are consonants who live at a location that allows them to travel the way they want to travel (deVos, 2012). De Vos et al. (2012) studied the mode use of urban and rural dissonants and consonants in Ghent, Belgium. Their study showed that rural dissonants travel more by car than urban consonants, confirming the car dependency of the lesser urbanised areas.

With a focus on train use, De Vos et al. (2012) found that the difference between urban consonants and dissonants is way larger than between rural consonants and dissonants. This does correspond with the findings of this study when considering car users in cities as dissonants and people without a car available at all times as consonants. De Vos et al. (2012) did not found a similar difference in the use of cars between consonants and dissonants. Hence, the explanation for the strong increase in car kilometres for metropolitan inhabitants might be more related to the way those inhabitants use the car than the differences in use between consonants and dissonants.

While it is likely that people that always have a car available will use it more often and (hence) use the train less, it is unlikely that they will use the car as substitute for walking. The short average distances covered by walking makes that the car is not a realistic alternative. In the time one would need to park his car, the larger part of the distance would already be covered by foot, especially in urban and metropolitan areas where parking can be difficult. A more likely possible explanation could be related to the kind of people that always have a car available versus the kind of people who do not. Albeit being not that large, the difference in walking 'use' between urban consonants and dissonants is larger than the difference between rural consonants and dissonants (De Vos et al., 2012). That matches the findings from the MMR analysis, as the decrease in walking distance is larger for the higher levels than it is for the lesser urbanised areas.

DESTINATIONS OF PEOPLE WHO TRAVEL BY CAR

As Table 4.6 does show, people living in metropolitan areas who always have a car available use it more often to make trips outside their living area than inhabitants living in the other levels of urbanisation. The definition of internal/external trips is based on point of departure and arrival on PC2 level, as more accurate data were not available in the MPN data. It is explicitly not based on the Level of urbanisation (LoU) of the residential area, as that could be different within the same city due to the used definition (see Appendix E). Not only do metropolitan inhabitants make more trips to other PC2 areas, the trips they make to those areas are also much longer. That is also confirmed by the descriptive statistics of the travelled distance in Figure 4.1. The share of trips below fifty kilometres in the total distance travelled by car is way lower for urban and metropolitan inhabitants than it is for inhabitants of the lower levels of urbanisation. That the differences in car use between the levels of urbanisation are large for short trips also becomes apparent from the modal split based on frequency in Figure 4.2. Where roughly 60% of the car trips made by metropolitan inhabitants is a trip with a distance less than 20 kilometres, that is 70+% for the other levels. In short, metropolitan inhabitants use the car more often for trips to another PC2 area and travel longer distances with those trips. That internal trips are shorter for more urbanised areas does make sense given the higher densities and hence higher proximity of activities. The same high proximity of activities also allows inhabitants of the more urbanised levels to use other modes to access those activities. Based on these findings, there can be concluded that in metropolitan areas the car is more often a travel mode for long distances than it is for lesser urbanised areas. There the car is more often used for relative short distances.

Table 4.6: Car trips by people that always have a car available per level of urbanisation

LoU of residence	**Average trip distance***		**Car trip destination distribution**	
	Within a PC2 area	To another PC2 area	Within a PC2 area	To another PC2 area
Rural	7.3	33.5	60%	40%
Village	6.1	35.4	60%	40%
Low suburban	4.8	33.6	61%	39%
Suburban	5.5	31.7	56%	44%
Urban	5.3	34.5	54%	46%
Metropolitan	4.3	46.8	47%	53%

* With the distance capped at 100 km to limit the impact of very long trips

Tables 4.7 and 4.8 indeed show that the car is mainly used for trips to the lower urbanised areas and other modes (especially train) are mainly used to travel to more urbanised areas. For metropolitan inhabitants, the share of car is larger than the share of non-car when considering trips towards suburban areas or lesser urbanised areas. Of course varying per location, but in general the distance between an area and a metropolitan increases if the level of urbanisation of that area decreases. Therefore, it does make sense that metropolitan car drivers travel quite long distances, as the destinations they travel to are located relative far away. For car drivers living in lower levels of urbanisation those by car accessible destinations are more often closer, resulting in lower average travel distances.

As discussed, cars are often used to travel to lesser urbanised areas. In those areas, densities are likely to be lower, and hence activities are not within walking distance. People who do not always have a car available are more likely to use PT and travel to urban or metropolitan areas, where lots of activities can be reached within walking distance. Here, it is important to mention that this does relate to new trips, like for example getting lunch from the office. Access and egress trips are excluded in the MPN data. If included, it could be expected that the difference was even higher, as access and egress trips are mainly needed for PT. Further, people who travel by car have an own vehicle available at their destination that they can use for new trips. People who travel by PT can only walk, use PT again or take a shared-vehicle. Hence, not only the destination does limit or provide opportunities for walking, the modes one can choose from do so too. That the car indeed is used more for trips to the lower levels of urbanisation and other modes are used more often for trips to the higher levels of urbanisation becomes apparent when studying Tables 4.7 and 4.8.

The increasing walking distance for rural inhabitants who have a car available could also be a logical result from this theory. Rural areas are not suited for walking due to the relative long distances to activities. As Table 4.9 shows, for the lower levels of urbanisation the larger part of external trips originating from the home level of urbanisation goes to a higher level of urbanisation. Those areas are more suited for walking, hence offering the rural inhabitants a higher possibility for walking to new activities.

Table 4.7: Modal share of car in external trips leaving level of urbanisation of residence

LoU of residence	**LoU of destination of the external trip**					
	Rural	Village	Low suburban	Suburban	Urban	Metropolitan
Rural	90%	84%	84%	76%	66%	35%
Village	86%	87%	84%	81%	70%	44%
Low suburban	90%	80%	82%	72%	60%	45%
Suburban	86%	83%	74%	83%	66%	23%
Urban	84%	74%	58%	74%	42%	31%
Metropolitan	freq <10	50%	65%	65%	25%	26%

Table 4.8: Modal share of non-car in external trips leaving LoU of residence

LoU of residence	**LoU of destination of the external trip**					
	Rural	Village	Low suburban	Suburban	Urban	Metropolitan
Rural	10%	16%	16%	24%	34%	65%
Village	14%	13%	16%	19%	30%	56%
Low suburban	10%	20%	18%	29%	40%	55%
Suburban	14%	17%	26%	17%	34%	77%
Urban	16%	26%	42%	26%	58%	69%
Metropolitan	Freq <10	50%	35%	35%	75%	74%

Table 4.9: Destination distribution of external trips originating from the LoU of residence

LoU of residence	**Destination distribution of trips originating from LoU of residence**					
	Rural	Village	Low suburban	Suburban	Urban	Metropolitan
Rural	22%	15%	26%	19%	15%	3%
Village	19%	18%	26%	13%	18%	7%
Low suburban	10%	11%	29%	20%	23%	7%
Suburban	11%	15%	28%	18%	18%	10%
Urban	9%	9%	22%	22%	26%	12%
Metropolitan	4%	12%	23%	15%	28%	17%

LOCAL DIFFERENCES AS POSSIBLE EXPLANATION

The significant moderation effects of built environment on the effects of car availability can also be connected to differences within the levels of urbanisation. The lesser urbanised areas are likely to be more monotonous than the more urbanised areas. Urban areas (can) have traditional centres but also large living and/or business areas in the proximity of highways near or in the city. Those large differences within a level of urbanisation are less likely to be present in the lower urbanised areas. Whereas car ownership and use are low in the traditional centres, car ownership and use are high near highways (Silva et al., 2006). These differences are not directly visible in the classification of level of urbanisation, but could become visible in the strong increase in car kilometres for the metropolitan level of urbanisation.

4.4. EDUCATION AND THE BUILT ENVIRONMENT

The second result that is interesting is one related to the daily distance travelled by foot. In lots of existing travel behaviour studies walking is not included as mode of interest. In recent decades, more and more studies started to focus on active modes, indicating the relevance of also including cycling and walking in travel behaviour studies. Especially due to environmental, space and health related benefits, studying the use of active modes gained interest by scholars and policy makers.

4.4.1. THE EFFECT OF EDUCATION ON WALKING

The effect of level of education on distance travelled by walking is an example of an effect that is moderated by urbanity and as result shows different relationships for urban and non-urban areas as shown in Figure 4.6. Inhabitants of urban areas are walking longer distances as their level of education increases. Opposed to that, inhabitants of non-urban areas show a decrease in distance travelled by foot as their level of education increases. The differences between the various levels of education are not that large for inhabitants of non-urban areas, but for inhabitants of urban areas the distance travelled by foot by highly educated people is twice the distance travelled by lower educated people.

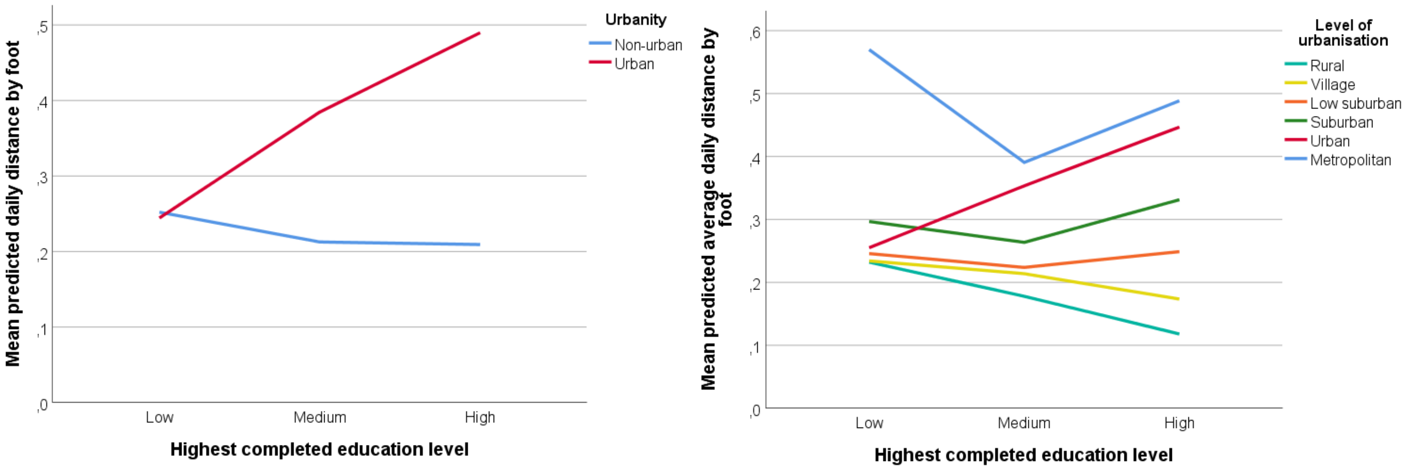

Figure 4.6: The effect of level of education on average daily distance travelled by foot

When looking at the effect of education on walking distance moderated by level of urbanisation, a few interesting observations can be made. The first and most notable observation is the effect of education on walking distance for metropolitan inhabitants. That does not follow the findings of the MMR with urbanity as moderator, as instead of an increasing distance as education increases, it first shows a decline after which it does increase. On top of that, the mean walking distance for lower educated people living in metropolitan areas is twice as high as the mean walking distance for inhabitants of other levels of urbanisation. Another observation is that the four levels of urbanisation that form the non-urban level show similar effects when going from low educated to medium educated, but show varying effects when going from medium to highly educated. The rural and village levels continue the decline, whereas the low suburban and suburban levels show an increase in daily walking distance. A third remarkable observation is that the mean walking distance of the suburban level is higher than that of the urban level for lower educated people.

4.4.2. THEORIES ABOUT THE EFFECTS OF EDUCATION

Again, the above discussed significant moderation will be coupled to existing researches. By doing so, there can be investigated whether the results make sense and how policymakers might steer them in the desired way.

UNDERSTANDING THE BENEFITS

The effect of education on walking distance for urban inhabitants follows Clark and Scott (2013) and Gao et al. (2017), among others, who state that the propensity for walking increases when education levels increase. As explanation they give that educated people might have a better understanding of the positive effects of walking than people with lower levels of education (Clark & Scott, 2013). This however requires that activities are located within walking distance, as people still make a consideration between the benefits and drawbacks of a mode. For people living in more urbanised areas, it is more likely that they have activities reachable within walking distance due to the higher activity densities in those areas. That enables the individuals that would consider walking, which increases with level of education, to do so. In less-urban areas, inhabitants with a medium or high level of education walk less than in urban areas. That finding connects to earlier studies which stated that in general people in non-urban areas walk less than people in urban areas (Berry et al., 2017). The differences in means do however not explain the differences in the effect education has on walking distance.

SPATIAL SEGREGATION

Another possible explanation might be the spatial distribution of groups with varying levels of income (and related education level) in various areas. In European cities, often the city centres are rich, surrounded by poor suburbs which on their turn are surrounded by a rich periphery (Lemoy, Raux, & Jensen, 2016). In large cities, the competition for proximity results in increasing land prices which results in segregation between various social groups (Garcia-López & Moreno-Monroy, 2018). In smaller cities and lesser urbanised areas the competition for locations near centres is less intense, leading to lower levels of income segregation (Garcia-López & Moreno-Monroy, 2018). That could be an explanation for the fact that the effect of education on walking distance does not show large differences within groups, whereas it does for urban inhabitants.

SUBSTITUTION BY CYCLING

Another explanation might be found when looking at the effect of education on the daily distance travelled by bicycle. It could be that rather than walking, inhabitants of non-urban areas cycle more rather than walk more when they have a higher level of education, since on average distances are longer. With a bicycle, it is faster to travel the longer distances to nearby activities and it is still environmentally friendly, flexible and good for your health. Figure 4.7 shows the effect of education on cycling distance. Although minor differences can be observed, no significant variations can be observed which follows the insignificant coefficient of the moderation effect between level of urbanisation and education on cycling. The general effect is that an increase in education does lead to an increase of daily distance travelled by bicycle. However, the increase for the lesser urbanised areas is not stronger than it is for the more urbanised areas. Hence, the decrease of daily distance walked is not caused by increasing use of another active mode.

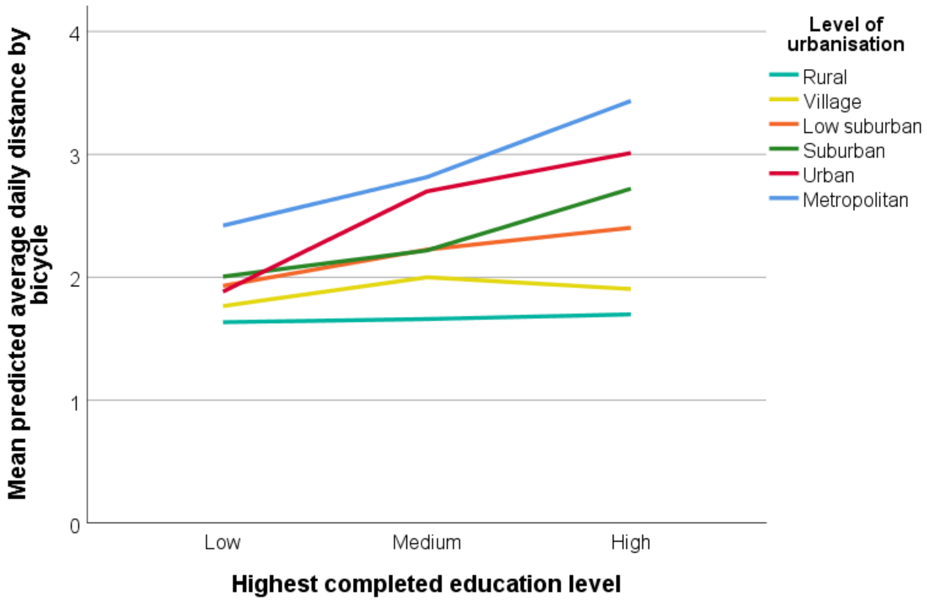

Figure 4.7: The effect of level of education on average daily distance travelled by bicycle

HABITAL CAR USE

As already discussed in the section about the effects of car availability on travel behaviour, lots of inhabitants in lesser-urbanised areas own a car. In the three lower levels of urbanisation, 60% of the trips made by car concerns a trip to a destination within the same PC2 area as the departure point. While first the expectation was that on distances where walking is a possible mode the car was not a realistic one, that might not be true. If the car indeed is an alternative for walking, even on such short distances, that could be indicated by a relation between education and car availability. If present, that would explain the slight decline of daily walked distance with increasing education. Figure 4.8 indeed shows that the four lowest levels of urbanisation show an increase in car availability with increasing education. The urban level shows a decline, which could be explained by the increased environmental awareness of higher educated people and the possibilities of using alternatives in urban areas. The effect for education on car availability for metropolitan inhabitants is strange, which likely is a result of the low sample size. Only three metropolitan inhabitants are lower educated, hence the average car availability for the low education level is not a trustworthy prediction for the actual mean for the population. That car ownership does lead to using the car for short trips could be a cause of habitual use of cars to get to local destinations (Berry et al., 2017).

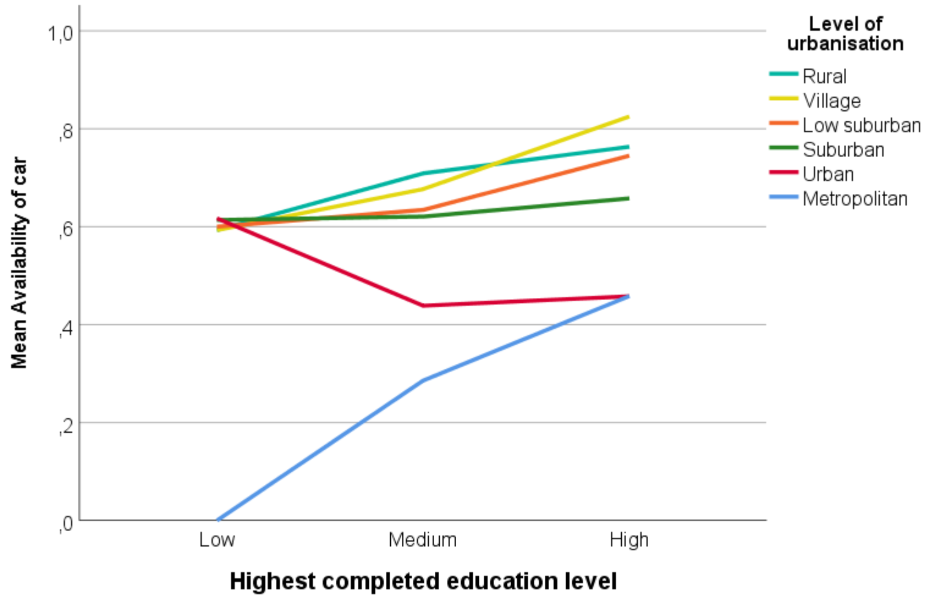

Figure 4.8: The effect of level of education on car availability

4.5. ACCESSIBILITY ATTITUDE AND THE BUILT ENVIRONMENT

The third main result is a moderation of level of urbanisation on the effect of the accessibility attitude on total, car and walking distance. The accessibility attitude measures how important accessibility was in the choice of the current residential location of a respondent. The higher, the more important accessibility was when choosing the current residential location. The attitude scores are based on the mean scores on statements related to various aspects of accessibility. This has been discussed in Chapter 3. A step-by-step description of how the attitude is constructed can be found in Appendix D.

As discussed in Chapter 3 and Appendix D, the accessibility attitude is based on the scores of five statements. From the five statements, four relate to locations (PT stations, shops and work) that can be reached by walking and/or cycling. The other one is related to car accessibility, in the terms of distance to the nearest highway entry/exit ramp. The accessibility attitude is based on the average score of the five statements. Therefore, people that mainly want to travel by car will have a low score, because they will give low ratings to four out of the five statements and a high score to only one. People that want to travel by PT will give good scores on at least two of the five statements, resulting in a higher average score. Hence, the accessibility attitudes gives an idea of the considerations people take into account when deciding where to reside.

4.5.1. THE EFFECT OF ACCESSIBILITY ATTITUDE ON TRAVEL DISTANCE

As mentioned in the introduction, the built environment moderates the effect of accessibility attitude on the daily distance travelled in total, by car and by foot.

ACCESSIBILITY ATTITUDE ON WALKING DISTANCE

The first significant moderation of the built environment on the effect of accessibility attitude on travel behaviour is one on daily walking distance. The urbanity variable interacts with accessibility of residential locations on distance travelled by foot. There, urban inhabitants travel 0.085 kilometre more per 1 unit increase of the attitude compared to non-urban inhabitants, indicated by the increasing difference as the attitude increases in Figure 4.9. Here, for both urban as non-urban inhabitants the distance by foot increases when the importance of accessibility increases. However, the slope for urban inhabitants is steeper, resulting in the positive unstandardised coefficient. People that value accessibility more are more likely to walk longer distances. This does make sense, as they are more likely to live on a location near activities, and hence are able to walk to them. As proximity of activities is higher in urban areas, it is likely that more activities are located within walking distance, and hence longer distances are covered by walking than in non-urban areas.

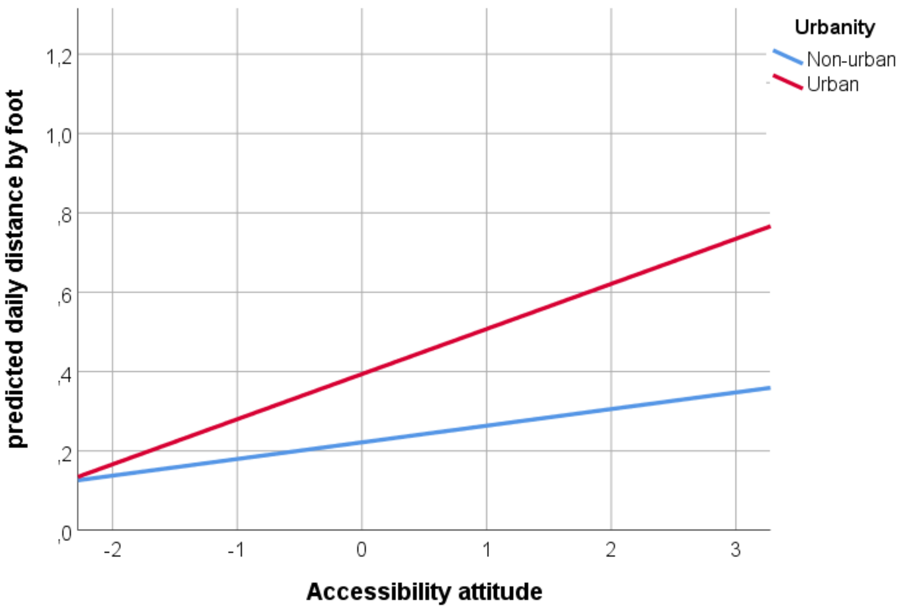

Figure 4.9: The effect of accessibility attitude on average daily distance travelled by foot

ACCESSIBILITY ATTITUDE ON TOTAL DISTANCE

Another relationship that is moderated by the level of urbanisation is that of the accessibility attitude on the average daily distance travelled for all modes combined. In Figure 4.10 a clear distinction between decreasing effects for rural, village and low suburban levels of urbanisation and increasing effects for suburban, urban and metropolitan levels of urbanisation can be observed. For the first three levels, as the accessibility attitude increases, the total distance travelled on an average day decreases. For the other three levels, an increase in the accessibility attitude results in an increase of the average daily distance travelled.

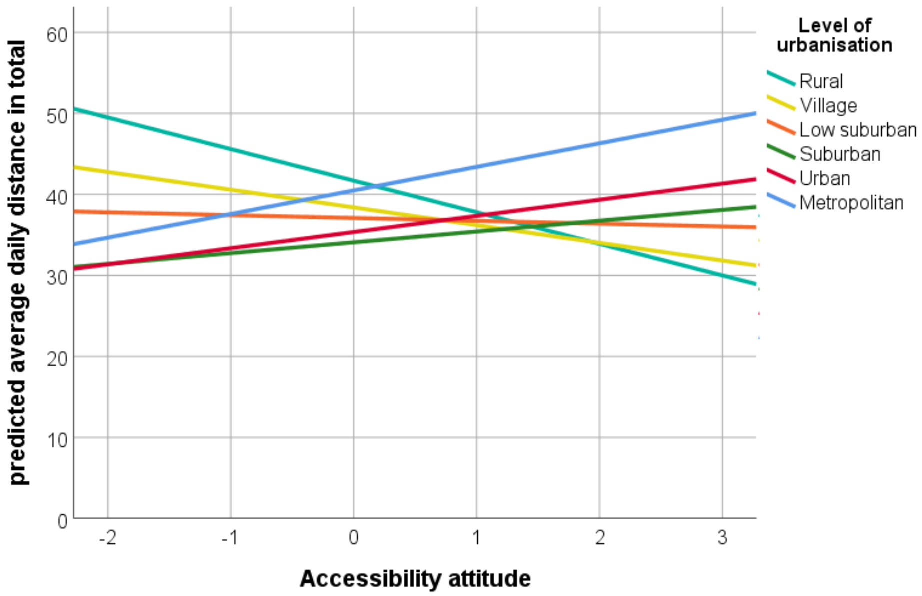

Figure 4.10: The effect of accessibility attitude on average daily distance travelled in total

ACCESSIBILITY ATTITUDE ON CAR DISTANCE

The general effect of accessibility attitude on daily distance travelled by car is that an increase in the importance of the accessibility of ones residential location results in a decrease of the distance travelled by car. When the effects are divided over the six levels of urbanisation in Figure 4.11, it becomes visible that the negative effect is stronger for the lesser urbanised areas than that it is for the more urbanised areas. With every increase in level of urbanisation, the decrease with increasing accessibility attitude gets smaller. Especially when going from rural to village, from village to low suburban and from suburban to urban quite large differences can be observed.

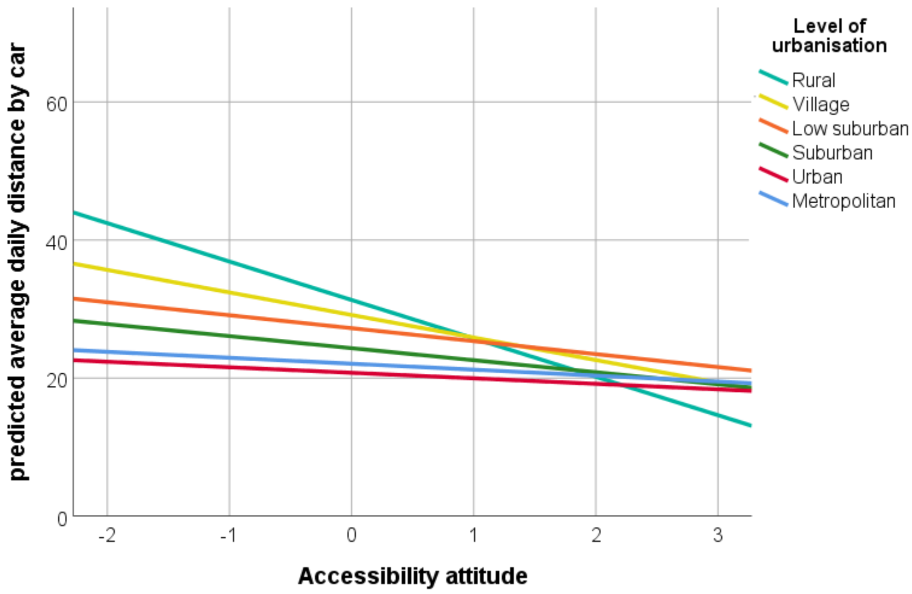

Figure 4.11: The effect of accessibility attitude on average daily distance travelled by car

4.5.2. THEORIES ABOUT THE EFFECTS OF ACCESSIBILITY

The effects of accessibility attitude are not easy to interpret. The attitude cannot be measured directly and hence is prone to varying interpretations of the statements. Why someone thinks accessibility is important or not stays unclear. However, the variety of statements is able to indicate whether someone is more oriented on PT and active modes or more on cars. These orientations can be connected to existing theories that could explain the varying effects and thereby either adding prove for that theory or discussing possible deviations.

SELF SELECTION

Since the accessibility attitude give an idea about the considerations people make when choosing their residential location„ the accessibility results can be related to the earlier discussed principle of residential self-selection. In short, people live there where they can travel they way they want to travel. According to this theory, people that want to use the car live there were accessibility by car is good. People that want to use PT to travel live there were accessibility by train and BTM is good.

In the lesser urbanised areas, people are dependent on their cars to travel long distances, as access to especially train stations is low. People that want to travel by train are not likely to choose a residential location in these levels of urbanisation. Hence, a distinction between people with high and low scores on the accessibility attitude can be made. On the one hand, there are people that mainly use the car. Those people have low scores on the accessibility attitude and travel relative long distances, as lots of activities are located relative far away. On the other hand, there are people with a relative high score on accessibility. These people could have a high score on importance of walking/cycling distance to a BTM station, shops and workplaces. As they value these statements, it is likely that they will indeed walk, cycle or use BTM to shops and their workplace. Especially with the first two modes, distances covered are low due to the low speeds. BTM, in the lesser urbanised areas mainly busses, also does have lower speeds compared to train and car due to access and egress times, waiting and transfer times and lower travel speeds. In short, people in the lesser urbanised areas with a high score on accessibility are likely to travel to locations that can be reached by walking and cycling, and therefore cover fewer kilometres than car oriented people with lower attitudes towards accessibility.

In the more urbanised areas, access to train is significantly better than it is in the lesser urbanised areas (Næss et al., 2020). People with a high attitude towards accessibility are likely to give good scores on the statements related to walking/cycling distance to jobs and shops, as the proximity of a lot of activities within close distance is a trait of urban areas. But due to the good rail network with frequent connections to all larger cities, the walking/cycling distance to the nearest train station is also likely to be part of the high scores on accessibility for inhabitants of the more urbanised areas. The train allows inhabitants of the more urbanised areas to cover long distances within relative short time. Whereas the car does this too for inhabitants of the lesser urbanised areas, it does less for people living in urbanised areas. In those areas, average speeds are lower, people have to walk longer distances to their parked car and congestion on the highways is higher, which all results in the loss of time (Næss et al., 2020). Following the travel time budget theory (TTB), those people have less time available to travel on high speed, which results in the coverage of shorter distances. The TTB follows a line of reasoning that states that people allocate a fixed portion of the time they have as the maximum amount of time they are on average willingly to spend with travelling (Ahmed & Stopher, 2014).

The results show that there indeed seems to be residential self-selection to a certain extent. Car and train are responsible for the larger part of the total travelled kilometres on a day. As Figure 4.11 shows, with increasing accessibility attitude the distance travelled by car decreases for all levels.

Figure 4.12 shows that the reverse is applicable to train kilometres. Hence, for people with lower accessibility attitudes the car is responsible for the largest share of total kilometres, whereas it is the train for people with higher scores for accessibility.

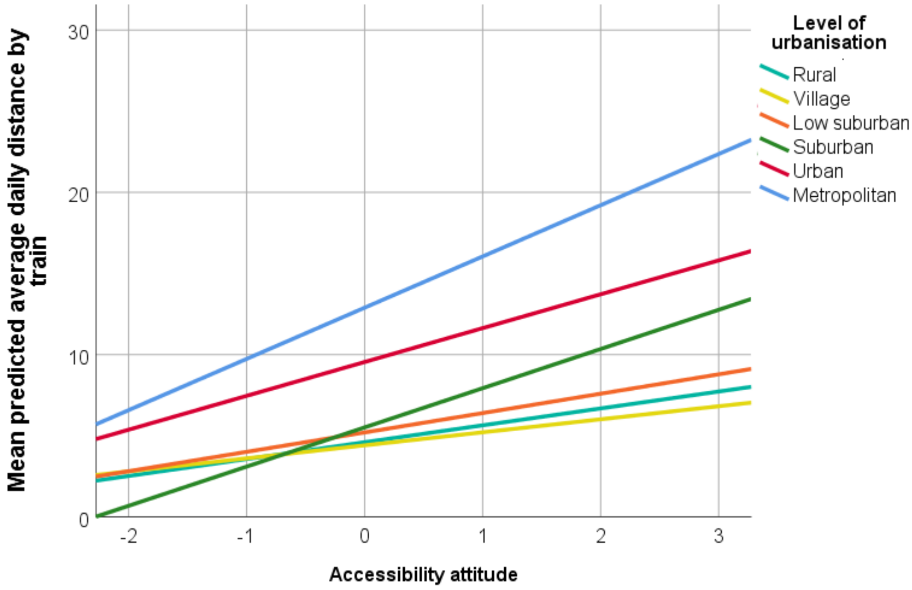

Figure 4.12: The effect of accessibility attitude on average daily distance travelled by train

The above described theory does also explain the higher increase in walking distance urban inhabitants show when the accessibility attitude increases. Three of the five statements relate to walking (or in combination with cycling) distance to various locations. It does therefore make sense that with increased accessibility attitude, the average walking distance increases. That the increase is higher for urban areas than it is for non-urban areas could relate to the higher number of activities that can be reached by walking. After all, when walking is a possible travel mode to reach a certain location more often, the average use and thereby average distance travelled by foot will increase.

The third effect of accessibility attitude that is moderated by the built environment is the one on daily car distance. As the level of urbanisation increases, the decline in car kilometres with increasing accessibility attitude gets less. The effect of accessibility attitude on distance travelled by car does follow findings from a study by Scheiner and Holz-Rau (2007). Using a definition of the accessibility attitude related to the accessibility of the nearest city centre, Scheiner and Holz-Rau (2007) found that individuals who think accessibility is important travel fewer vehicle kilometres. The same effect follows from the MMR analysis. However, the remaining question is how the differences in degree of decline between the various levels of urbanisation can be explained. Again, this could be related to the statements on which the attitude score is determined. As discussed, people with a lower accessibility attitude are likely to only value the car statement, whereas people with a high attitude likely gave good scores to the statements about PT and/or walking/cycling distance to shops and the workplace. Hence, on average people with a low attitude will use car more often, and people with higher attitudes will use the car less. The difference in decline is then a result of the possibilities to actually travel by PT and/or cycle or walk to an activity. The rural level has a lower mean for people with high attitudes towards accessibility. That could be a result of the unbalanced distribution of the attitudes for rural inhabitants. The majority has a below average attitude, and just a few inhabitants have an above average one. Because car use is such prominent in this level of urbanisation, the difference is large, which is only exaggerated by the unbalanced distribution of people with certain attitudes towards accessibility.

REVERSE CAUSALITY

As discussed in the literature review, besides residential self selection there is a theory which follows a reverse relationship. That theory does follow the line of reasoning that the built environment influences the attitudes, and by that the travel behaviour of individuals. While the statements used for the accessibility attitude specifically relate to the way attitudes were incorporated in the choice for a residential location, the presence of reverse causality cannot be excluded. After all, people have lots of other considerations besides travel when choosing a residential location. Also, reasons like the costs, scarcity of the housing market and dependency of a work location make that people do not have the freedom to select themselves wherever they want. If the number of people for which that applies is large, it could also be that the built environment influences travel behaviour via travel attitudes. As discussed, the various areas offer varying possibilities for certain modes, which could also partially explain the varying effects of accessibility on total daily distance travelled.

5

Conclusions and recommendations

Now the results have been discussed and interpreted, conclusions can be drawn. First, the main objectives of the study are recalled. Next, the method used to reach the objective is briefly summarised. Then, the main findings following from the analysis are presented. After the findings have been summed up, policy implications that can be drawn from them are stated. The chapter is finalised with limitations of this study and possibilities for future research following from these limitations and the results from this thesis.

5.1. Conclusion

In this research, the possible moderating role the level of urbanisation has on the effects of various determinants of travel behaviour on the average daily distance travelled is explored. While many aspects of travel behaviour have been studied before, there is less known about interaction, or moderation, effects between various determinants. When present but not identified, interaction effects can result in an under- or overestimation of the actual effect of the determinants. Exploring the interaction effects between various built environment variables in more depth will contribute to a more comprehensive understanding of the impacts of them on travel behaviour (Wang et al., 2011). Knowledge about possible interaction effects of the level of urbanisation on travel behaviour could help governments with designing travel policies better suited for different regions and different target groups. The focus is therefore specifically on identifying possible interaction effects rather than finding or proving determinants for travel behaviour.

There is need for having additional knowledge about the effect of determinants on travel behaviour in varying areas as various problems are present. One of the main problems is the increasing population for which new houses have to be built to accommodate them. With those increasing numbers, especially cities are getting busier and transport networks are getting more congested. Hence, there is a need for using the public space in cities in a more efficient way to keep cities accessible, liveable and attractive, as it is necessary for cities to be connected from within and to other cities in order to function (Kasraian, 2017). Further, there are nation-wide challenges related to the environment, like reducing greenhouse gasses, improving the air quality and making cities climate resistant. A relevant strategy for spatial urban developement that creates space for new inhabitants but limits the impact on the transport networks and the environment is the strategy of densification. To make sure that applied strategies have the desired effects, it is important to know how travel behaviour gets affected when the strategies are applied in various levels of urbanisation. To fill some of the gaps in current literature, the central question of this research is as follows:

“What is the role of the built environment as moderator of the effects of explanatory variables on daily travel distance?"

To answer this question, a moderated multiple regression analysis has been performed. With this analysis, the moderating effect by the level of urbanisation on effects of various attitudes and sociodemographics on the daily distance travelled could be analysed. To do so, data from the 2016 wave from the MPN travel panel were used. In this panel, 3,077 valid respondents answered questions about themselves and reported 27,898 trips in total over a three day period. Based on literature research, various determinants for travel behaviour have been identified. The built environment variable of interest is a combined population and job density based level of urbanisation. Sociodemographic characteristics from which the effects on travel distance are tested for the presence of moderation effects by the built environment concern: age, ethnicity, gender, household income, household composition, education, drivers license ownership, daily occupation and car availability. The included attitudes for which interactions with the level of urbanisation are tested are based on the scores respondents gave to various statements, and hence had to be constructed with a factor analysis. The factor analyses lead to the inclusion of mode related attitudes for car, bicycle, train, prestige for using the modes, BTM, efficiency of PT and safety of PT. With a focus on cars, attitudes about the love, costs, status and environmental impact are included. The last attitude relates to the importance of accessibility of the residential location.

Descriptive statistics gave insights in the actual travel behaviour in the various levels of urbanisation. In metropolitan and urban levels, PT use is high and car use is low, whereas that is reversed for the lower four levels of urbanisation. Based on these differences a distinction between urban and non-urban areas could be made. The MMR has been performed twice, once to identify moderating effects of an urban/non-urban classification, and once to identify moderating effects of the six level classification to obtain a higher level of detail. From these analyses follows that the built environment moderates various effects of determinants on the daily distance travelled.

Therefore, the general finding of this research is that there indeed is heterogeneity in the effects of determinants on travel behaviour dependent on the built environment. The results show that the density-based built environment variable moderates the effects of various determinants on daily travel distance. Most significant moderation effects are present in the models predicting the daily distance travelled by train and by walking. The models predicting the daily distance travelled in total, by car, by BTM and by bicycle also have a few significant moderation effects. These results show that the effects of various sociodemographic traits and travel attitudes on daily travel distance are not homogeneous, but their direction and strength is context dependent. This study proved the dependence of those effects on the job and population density of the residential location of inhabitants. Operationalised as level of urbanisation, density showed to be able to strengthen, weaken or change the direction of the effect of some explanatory variables. Here, the actual effect is larger, or smaller, than the sum of both effects directly on travel distance. Missing the interaction effects therefore will lead to under- or overestimations of the effects determinants have on travel behaviour. These results prove the ideas of Tribby and Tharp (2019), Clifton (2017), Cheng et al. (2021), Sun and Yin (2020) and Heres and Niemeier (2017) among others, who state that there is spatial heterogeneity in the relationships between the built environment and travel behaviour. The results indicate for which groups tailor-suited policies should be used to effectively achieve desired outcomes in travel behaviour. How these policies should be designed did not fall within the scope of this thesis.

Other important conclusions can be drawn from the analysis of the specific results. The higher the level of urbanisation, the higher the increase in daily distance travelled by car when someone always has a car available compared to not having a car available. This increase is so large that metropolitan inhabitants that always have a car available travel the same daily distance by car as people with a car in rural areas. Opposed to that, the difference between the rural and metropolitan levels of urbanisation for people that do not always have a car available is large. The reverse effect is present for the effect of car availability on distance by train and walking. There, the decline in kilometres when someone always has a car available compared to not having one available gets larger with increasing level of urbanisation. These results indicate that when someone buys a car to always have one available, the logical increase in car kilometres and decrease in train and walking kilometres are stronger in more urbanised areas. When the goal is to reduce car kilometres, it therefore is more efficient to make sure that metropolitan inhabitants shed a car than inhabitants of other levels. These results indicate that the full expected potential of high densities, namely less car kilometres and more by train and walking, can only be reached by people who do not always have a car available.

Another conclusion can be drawn from the significant moderation by the urbanity on the effect of education on walking distance. With increasing level of education, the average daily walking distance increases, but only for inhabitants of urban and metropolitan areas. For the rural and village levels, higher levels of education result in shorter daily walking distances. The effects of education are weak for non-urban areas, but strong in urban areas. Since the mean walking distances for lower educated are comparable over the levels of urbanisation, there can be concluded that the level of urbanisation has just limited influence on the walking behaviour of lower educated. For medium and higher educated people, the means vary more, indicating increased influence. Hence, the influence of the level of urbanisation gets stronger with increasing education. Therefore, the effects of densification strategies do show the desired direction of more walking for highly educated people, but are absent for lower educated people.

The effect of accessibility attitude on walking does show that urban environments allow the people that would like to walk to do so, much more than a non-urban environment does. Further, the results from the effects of level of urbanisation and the accessibility attitude on total and car distance show that people who value accessibility by PT and active modes travel longer distances in total when living in more urbanised areas. Despite having a higher total daily distance, the distance by car decreases for this group, proving that densification does not lead to a shorter daily travel distance, but that it does achieve a shorter travel distance by car.

5.2. POLICY IMPLICATIONS

The results discussed in Chapter 4 are relevant for policy maker. Below some policy implications and recommendations based on the results are given. The first recommendations are based on the result specific findings. Thereafter the recommendations based on the general findings of this study are given.

5.2.1. IMPLICATIONS OF THE MODERATION ON CAR AVAILABILITY

The results show that densification strategies result in the desired effects, namely less vehicle kilometres, more train kilometres and more walking. However, achieving the full potential of high densities is only possible when people do not (always) have a car available. After all, the results showed that in metropolitan areas people with always a car available travel long distances with it.

For policy maker, this implies that densification strategies should be accompanied by strategies that focus on reducing car ownership. Policy makers can discourage future car ownership by including measures that make cars slower, less convenient, more costly and more difficult to park in the design of the densification project (Buehler et al., 2017). Besides making the car less attractive to use, promoting other modes or car-sharing also proves to discourage car ownership. Studies show that 20% - 30% of the people is likely to give up the planned purchase of a car or shed a current one if a suitable car-sharing system becomes available (Liao et al., 2020; Nijland and van Meerkerk, 2017). Promoting car-sharing can for example be done by providing designated parking facilities for shared cars in the to be developed area (Liao et al., 2020). Special attention should go to reducing car ownership in metropolitan areas. Although people living in a metropolitan area with always a car available travel longer distances by train and also walk longer than their lesser urbanised counterparts, they also travel longer distances by car. Since metropolitan inhabitants show the largest difference in car, train and walking distance between having a car available or not, reducing car ownership in those areas can make large differences. There can be questioned whether promoting PT will contribute to discouraging car use in metropolitan areas, since on average metropolitan inhabitants already travel a lot by train, even those who always have a car available. Further, car ownership is already discouraged in metropolitan areas as it is slow, less convenient, more costly and difficult to park, advocating for the potential car sharing has in this level of urbanisation.

An example of a densification project that implements various measures to discourage car ownership is the Merwedekanaalzone in Utrecht. With the help of a limited number of parking places within walking distance, excellent bicycle infrastructure, mobility hubs with sharing options and good PT connections, car ownership and use is reduced to a minimum. Since the Merwedekanaalzone offers a beckoning perspective for other densification projects where space is scarce and the mobility challenge is considerable, policy maker can learn lessons from this case. As this study shows, it is important to take the local circumstances into account when looking at cases since the effects of determinants on travel behaviour are heterogeneous rather than homogeneous. Policy makers therefore can learn from the Merwedekanaalzone, but always should consider the local circumstances to optimally design measures to reduce car use and ownership.

5.2.2. IMPLICATIONS OF THE MODERATION OF EDUCATION

As walking has great benefits related to personal health and the environment, it is important to develop policies that encourage the population to walk.

The moderation of the effect of education on walking distance by urbanity shows that low education has similar effects in all levels of urbanisation, but that the effects of medium and high education heavily vary over the different levels of urbanisation. Since increasing level of urbanisation does not lead to an increase in walking distance for lower educated people but does so for medium and highly educated people, there can be concluded that densification strategies only have the desired effects on walking for medium and highly educated people. In some cities lower educational groups are forced to relocate to the outskirts of the city, which poses a threat for the prosperity lower educated people will walk, as distances to activities located in the city centre increase (van Wijk et al., 2017). In urban and metropolitan areas, policies should therefore especially focus on promoting walking amongst lower educated people. These implications do match findings from a study by Cheng et al. (2021) focused on the walking behaviour of elderly. They also argue that any measures aimed to increase walking should be tailored to local conditions.

Further, densification could lead to the loss of in both private and public green space (Lin, Meyers, & Barnett, 2015). The presence of green space influences the distance people walk on daily basis (Sarkar et al., 2015). Therefore, preserving green space should be important when designing densification projects to make sure that the (new) built environment invites people to walk. In relation with the results of car availability, transforming parking spaces into green spaces does not only lead to lower car use and more walking as result of less car ownership, it also promotes walking by facilitating a nicer walking environment. This also emphasises the importance of having insights in the heterogeneous effects of determinants on travel behaviour, as a well designed policy can have multiple beneficial effects as shown by this example.

Because rural residents tend to be less active and have poorer health, it is also important to promote walking in lesser urbanised areas (Berry et al., 2017). In those areas, car dependency is high, and presumable habitual car use for short trips is too. The main challenge in those areas is therefore to achieve that people leave the car and start making more trips by foot. Since the differences between educational groups are relatively small, no group-specific policies are necessary.

5.2.3. IMPLICATIONS OF THE MODERATION ON CAR AVAILABILITY

To keep cities attractive and liveable, car traffic should be reduced. As the results from the moderation by the level of urbanisation on the effects of the accessibility show, densification does lead to the desired effects, especially for people that do want to travel by PT and active modes. Therefore, it is important for policy makers to realise that attracting people that are committed to travel via modes supported by high densities is of importance of the success of the densification project. For greenfield developments, it is important that PT is available directly, to make sure that people that want to use PT are attracted to the houses. If not, it could be that people that own a car, and therefor are not dependent on the presence of PT, settle in the neighbourhood. While it is possible that they change their behaviour due to to new experiences, they likely will still use the car a lot. Therefore, it is important to consider mobility strategies as separate part of densification strategies, but as something that is vital for the success of the strategy.

5.2.4. IMPLICATIONS OF THE PRESENCE OF MODERATION EFFECTS

This study shows that there is heterogeneity in the way various determinants influence daily travelled distances in various levels of urbanisation. In general, it is important to acknowledge that not all determinants have the same effect in each area. As moderation effects by the built environment could result in under- or overestimation of the effects of these determinants, it is important to take them into account when predicting the effects of policy measures. The spatial heterogeneity of the relationships between determinants of travel behaviour and travel behaviour implies that interventions should tailored to local conditions. The MMR analysis proves to be a relative easy way to explore such heterogeneity in the effects of various determinants on travel behaviour.

5.3. DISCUSSION

Although this study found some interesting results, there are some limitations that should be acknowledged when interpreting the results. Therefore, the main limitations of this study will be briefly discussed. Resolving some of the limitations could be part of future researches. This section will only point out the limitations, how to resolve some of them will be discussed in the following section discussing future research opportunities.

5.3.1. METHODOLOGICAL LIMITATIONS

A first limitation is related to the method that is used to identify possible moderation effects of the built environment on the effects of other travel behaviour determinants. The moderated multiple regression analysis allows identifying moderation effects between independent variables and a moderating variable. As that is the main goal of this thesis, the method suits the study. However, in essence a moderation effect is just an interaction between two independent variables. A theoretical underpinning is necessary to point out the moderator variable. The MMR is not able to tell which variable is influencing the other in an interaction term. By giving possible explanations and using other studies, a theoretical founding is created for the interaction effects to be moderating effects by the built environment on other variables. This is however not supported by the statistical analysis, as cross-sectional data has been used. With cross-sectional data, no causality can be proved as the temporal precedence requirement is not met. For causality to be proven, it is necessary that the cause comes before the effect. With cross-sectional data that cannot be proved, because the independent variables are measured at the same time as the dependent variables. As result, it could be that some variables are related, but not necessarily have a cause-effect relationship.

5.3.2. DATA LIMITATIONS

There are also a few limitations related to the data that are used. As mentioned before, the sample did not form a perfect representation of the population. Groups that are underrepresented are among others low-educated, people with a non-Dutch ethnicity and elderly. Further, just a small part of the respondents lives in a metropolitan area. That is not surprising given that it is the same in the population. However, due to the small sample size, the under representation of some groups becomes extra large in the metropolitan level. For example, there are just three people with a low level of education, four elderly, ten students and fourteen respondents belonging to a multi-person household with children that live in a metropolitan area. While the most of these follow the same distribution as the distribution of the levels of the variables in other levels of urbanisation, the low absolute numbers make that the results are sensitive for outliers. This can for example be seen in the results of the moderation by the level of urbanisation of the effect of education on walking distance (see Figure 4.6). There, the mean predicted walking distance for metropolitan inhabitants is very high, and it does not follow the expected effect. Likely, that is a result of just having three low educated metropolitan respondents. Hence, some results for especially the metropolitan level of urbanisation should be carefully interpreted.

Another limitation of the data concerns one of the modes. In both the MMR models with urbanity and level of urbanisation as moderators, the model with BTM as dependent variable has considerable lower adjusted R-squared values than some of the other dependent variables. Hence, the set of independent variables is not able to explain a lot of variance of the dependent variable. A cause could be that combining bus, tram and metro distances in a single variable leads to a combination that is difficult to predict as it does not occur (that often) in reality. Metro is available in just two cities (and some smaller surrounding cities), while busses are available in the entire county. When combining those modes and tram, it is not clear whether the distance is travelled by which mode. As TOD can also be applied in the proximity of metro stations, but also near tram and bus stops, the results of the analysis with BTM can be very relevant. Given the limitations, the results should be interpreted with care to prevent that strategies are applied in locations where they do not have the (full) desired effects.

The above limitations came with the choice of the MPN data. Something that was deliberately chosen for is to replace the level of urbanisation variable in the MPN data with another classification. That classification has advantages in the form of a wider area of interest surrounding the residential location, a more disaggregated scale (PC4 versus municipality) and the inclusion of jobs. Especially that last one, the inclusion of jobs, could be a topic of discussion. On one hand it is an advantage. Take for example an inner city, there the number of inhabitants might be lower than just outside the city centre, but which is just as urbanised, or even more due to the presence of activities. Without including jobs, concentrations of houses are classified as more urbanised, whereas those areas might be considered less urbanised as inner-city centres with less inhabitants but with more activities. On the other hand, the inclusion of jobs can also cause distorted classifications. The central business district of an area might get the same classification as the inner city, but does form an entirely different built environment. Shops and other activities are located further away, which does lead to completely different travel behaviour. The main question can be whether the observed effects of the built environment, both the direct effect on travel distance as the moderations of other effects, are a result of the combined density, or are more related to either the population or the job density. It could be that one of them is determining the major part of the effects, whereas the other just has limited influence. That is supported by existing studies which found different moderation effects of both population density (Guo et al., 2007) and employment density (Bhat & Guo, 2007). When considering the results with relation to urban policies, there should be acknowledged that the used definition applies to jobs and houses, and hence might yield different results for new developments with houses -or jobs- only.

5.3.3. CONCEPTUAL LIMITATIONS

The objective of this thesis was to explore possible heterogeneity in the way determinants of travel behaviour influence travel behaviour in varying spatial areas. To do so, a moderated multiple regression analysis was used that allowed to identify possible moderation effects. This method uses a relative simple structure, as also indicated in the conceptual model. As the same conceptual model shows, the relationships between the various determinants and travel behaviour are more complex than three independent categories of determinants independently influencing travel behaviour. To use travel attitudes in this cross-sectional study, there is assumed that they are stable personal dispositions. Due to the complexity, the assumption that attitudes are stable and because it is not necessary given the objective of this study, the more complex relationships between categories of determinants were not included in this study. While the inclusion of travel attitudes as explanatory variable partially accounts for the self-selection problem, under- or overestimations of the effects on the daily travelled distance cannot be excluded. However, when the effect is significant it can be expected that the built environment variable and/or attitudes indeed exert some influence on their own (Mokhtarian & Cao, 2008).

Another conceptual limitation is that the level of urbanisation is based on the residential location. That is interesting as a considerable amount of trips is made within the same level of urbanisation and the living environment does determine the travel alternatives one has for home bound trips (for example having a train station in the near proximity). On the other hand, it can also distort some findings, as it might not be the built environment of the residential location that influences the travel distance and mode choice, but the location of the destination or the departure point when someone is in another level of urbanisation. For example, a rural inhabitant could drive to his work to an urban area and from there make new trips by foot. The choice to walk is then based on his current location rather than his residential location. That destinations indeed play a role became apparent in the interpretation of the results. Although possibly distorting some findings, the choice of residential location as built environment of relevance can be validated by the fact that it does shape the travel possibilities (e.g. mode-use, destination) for the majority of the trips.

A third conceptual limitation is the used definition of accessibility. Based on the statements of the MPN, an accessibility related attitude could be constructed. That attitude uses a definition of accessibility that relates to the shortest distance to various activities from a fixed location, in this case the residential location. Besides location-based, Geurs and Van Wee (2004) identified three other measures of accessibility: infrastructure-, person- and utility-based. Further, within location-based measures differences are possible. For example, rather than measuring the distance to the nearest of an activity it is possible to measure the number of activities that can be reached within a certain time or is located within a certain distance. That last one is especially interesting when considering the reasons for living in or nearby a city. Rather than being close to a certain activity, cities offer the advantage that lots of activities can be reached within a certain travel time. Not only is the density of activities higher, so is the density of PT stops which increases the distance one can travel in limited time. Such definition would also be more interesting in the context of differences between areas with various levels of urbanisation. The distance to nearest activity can be the same in urban as non-urban areas, but the number of activities reachable within a travel time or distance cannot, or at least less often. Concluded, the used definition of accessibility was limited by the questions included in the used panel data. Including possibilities to analyse other measures of accessibility in panel studies could provide additional insights in differences between urban and non-urban areas and the role of the built environment in those differences.

5.4. FUTURE RESEARCH POSSIBILITIES

As the literature review showed, the focus on determinants of travel behaviour moderating other variables is one that is not extensively studied yet. Since travel behaviour is a very complex phenomenon, all new insights could help to understand it better. For policy maker, knowing how variables interact could help with designing more tailor-suited policies and focus on areas where those are needed and/or efficient. As the discussion showed, there are a few important limitations of this study. Those limitations open some possibilities for future research.

5.4.1. STUDYING OTHER TRAVEL BEHAVIOUR INDICATORS

This study had a sole focus on average daily distance travelled by various modes and in total as travel behaviour indicators. That is just one category of the many indicators that provide valuable information about the travel behaviour of people. For example, looking at trip frequency could provide additional knowledge about the influence of various variables on the modal choice of people. The frequency-based modal split in Figure 4.2 validates a replication of this study with trip frequency as dependent variable. The modal split shows that there are large difference in use frequency between the various levels of urbanisation. Also, differences can be observed in the shares of car trips with certain distances. An additional advantage of using average daily trip frequency rather than daily distance is that access and egress trips can be considered. This was not possible for the distance, since no distances were reported for the access and egress trips. Identifying possible heterogeneity in the effects of determinants on trip frequency could provide valuable knowledge about the relationships between density and trip frequency. That information could be linked to the results of this study to find out whether certain long daily distances are a result of a single long trip or multiple short ones. Although with 4,190 trips the MPN sample of access and egress trips is relatively small, it would also be interesting to differentiate for main and access/egress trips. That would especially be interesting in relation to TOD, as it could help to accurately predict the effects of the development on the infrastructure near the PT node.

5.4.2. STUDYING SPECIFIC FINDINGS

Another opportunity for future research relates to the specific results. This study has been an exploratory study to the possible existence of moderation effects of the built environment on effects of sociodemographics and travel attitudes on travel behaviour. Various significant moderation effects were found, and the most interesting ones are discussed. Instead of performing an exploratory study towards moderation effects, it will be interesting to focus on specific moderation effects. Knowing that there is an effect provides valuable knowledge for literature and policy makers, but it is also important to know the why and how of the effects. That way, it is easier to steer the travel behaviour of people, as tailor-suited policies can be implemented to accurately achieve the desired effects. An interesting example would be a specific focus on car ownership and use among metropolitan inhabitants. The descriptive statistics in Figure 4.1 show, the share of short (< 20 km) trips by car is way lower for metropolitan and urban inhabitants than it is for inhabitants of the lesser urbanised areas. Further, the results showed that when metropolitan inhabitants have a car available, the average daily travelled distance by car is high. A future study could apply a combined quantitative and qualitative approach combining questionnaires and interviews to understand the drivers behind metropolitan car ownership and use. Thereby, possible opportunities for steering policies can be identified, such that the full potential of high density can be achieved in an efficient way.

5.4.3. STUDYING BUILT ENVIRONMENT ON A DIFFERENT SCALE

This study focused on the differences in travel behaviour between levels of urbanisation. It might also be interesting to study heterogeneity of travel behaviour on a lower spatial scale. Studying differences of travel behaviour and a possible moderating role of local built environment variables could provide information about the influence of the design of neighbourhoods, local infrastructure and other built environment characteristics. In other words, the influences of other D's of the framework by Cervero and Kockelman (1997) and Ewing and Cervero (2010) could be studied when using a smaller spatial scale. Since the problems of much needed (urban) development and sustainability are concentrated in cities, such local approach should focus on urban and metropolitan areas. By accurately assessing the effects of new developments in urban neighbourhoods, policy makers have the possibility to maximise the number of houses without putting too much pressure on the existing transport system. An example is the Merwedekanaalzone project, where the number of houses to be built would not have been possible without implementing a wide set of measures focused on reducing car ownership and use. There, mobility measures are not only necessary due to the urban development, they also determine the development opportunities. Less car use per inhabitant increases the development potential, after all, more inhabitants give the same traffic pressure on balance (Kwantes, 2018).

5.4.4. STUDYING INTERACTION EFFECTS OVER TIME

As mentioned in the discussion, MMR is not able to provide information about the moderator variable in an interaction between two independent variables. Nor is MMR able to identify causal relationships between possible determinants of travel behaviour and actual observed travel behaviour. Future studies could use different methods to study the moderating role of built environment on travel behaviour. An example of a method that could be used is longitudinal Structural equation modelling (SEM). With this approach, one can test the causal relationships between independent variables and the dependent variable. The results from this study can be used as starting point to investigate possible interactions in a more targeted way. A possible future longitudinal study is able to use longitudinal data from the MPN. Using longitudinal data provides the opportunity to compare the travel behaviour of respondents in one year with that of another year. That could especially be interesting when the respondent moved in that period. That way, there can be studied what the effects of the new built environment on the travel behaviour are while accounting for known changes in sociodemographics (for example age or income). In relation to urban development strategies as densification and TOD, it would be interesting to study whether the new inhabitants travel as expected.

Recently the data set from the 2018 wave from the MPN has been published. That creates the possibility to perform a longitudinal analysis between 2014 and 2018, investigating possible differences in this four year period. Another advantage of using SEM is that more complex structures can be included. According to Kasraian, Maat, and van Wee (2017), it is very likely that travel behaviour is affecting land use over time, possibly via travel attitudes. This is one of the grey lines in the conceptual model in Figure 2.5. By applying SEM, the heterogeneity of determinants on travel behaviour can be studied with the theories of residential self-selection and reverse causality directly included rather than mitigated by the inclusion of travel attitudes.

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A

Scientific paper

The paper can be found on the next pages.

Discouraging Car Ownership to Fully Achieve the Potential of Densification Strategies

Bongers, T.M.

Abstract

The influence of the built environment on travel behaviour has been studied extensively. To date, most studies focused on homogeneous effects of the built environment on travel behaviour indicators. Less attention is paid to possible heterogeneity in the effects dependent on other variables. This study applies moderated multiple regression on Netherlands Mobility Panel data to analyse possible heterogeneity of the effects of a density based built environment variable on daily travel distance, dependent on the car availability of persons. Controlled for travel attitudes and various sociodemographic traits, the results show that increased density leads to shorter daily travel distances by car and longer distances by train and walking. However, those effects are weaker for people who always have a car available compared to people who do not (always) have a car available. An exception is formed by metropolitan inhabitants. When having a car available they travel long distances with it, which goes against the generic effect of density. The findings provide support for densification as spatial strategy to develop sustainable urban transport, but also emphasises the need for accompanying policies aimed at reducing car ownership, especially in metropolitan areas. They as well advance the understanding of the relationships built environment and travel behaviour.

Keywords: Built environment – Car availability – Travel distance – Moderation – Density

1 INTRODUCTION

Aiming for more sustainable travel behaviour is a major topic in (urban) mobility (Banister, 2008). Transportation is one of the larger contributors to greenhouse gas emissions, which are known to contribute to climate change and have an instantaneous impact on the environment and human health (Van Fan et al., 2018). Challenges related to the environment do not limit themselves to the reduction of greenhouse gasses, but also include improving the air quality and making cities climate resistant. Besides this major challenge, nations are facing challenges in terms of urbanisation, accessibility and liveability. Cities are growing, which increases the need for houses and puts additional pressure on transportation networks. Hence, there is a need for using the public space in cities in a more efficient way to keep them accessible, liveable and attractive, as it is necessary for cities to be connected in order to function (Kasraian, 2017).

In the field of spatial urban development, the strategy of densification has been considered as the most relevant approach for sustainable urban development (Næss et al., 2020; Haaland and van Den Bosch, 2015). Compact urban development provides accessibility to activities by proximity rather than high mobility.

Therefore, densification has benefits such as less car driving, lower energy consumption and other social aspects of sustainability (Næss et al., 2020). Given the persistently high level of car use, cars are responsible for a large part of the energy usage and greenhouse gas emissions in cities (Magdolen et al., 2021; Newman, 2017). Not only are cars responsible for a large part of the greenhouse gas emissions, they also take up valuable space and cause noise pollution, congestion and accidents (Greene & Wegener, 1997). Since it has various advantages, it is desirable to reduce private vehicle use in cities and encourage people to use other modes with less externalities (Woods & Masthoff, 2017). Wittwer and Hubrich (2016) did found that car ownership influences car use to a great extent. It does not only influence the mode choice of people, but also the chosen destinations and thus the distances travelled (Wittwer & Hubrich, 2016). This suggests that urban planning policies should not only focus on influencing car use directly by measures of increasing density and diversity, but also on indirect measures through car ownership. Making policies to reduce car use and ownership is not easy since both vary over space and hence one-size-fits-all designs should not be the solution to reduce car dependency (X. Wang et al., 2018).

That one-size-fits-all designs are not the solution is not only applicable to reducing car dependency. The success of spatial and transport strategies is not systematic, uniform or predetermined, but depends on local circumstances and policies (Chapple and Loukaitou-Sideris (2019) via Papagiannakis et al., 2021; X. Wang et al., 2018). After all, daily travel behaviour is very complex, multi-faced and it is influenced on multiple scales like individual, household, local and societal (Elldér, 2015). Within these levels people's travel behaviour is influenced by transport infrastructure networks, land use patterns, sociodemographic traits and attitudes towards travel modes (Kasraian, 2017). As example, while having various benefits, densification can also lead to more and/or longer trips and also cause a shift of efficiency gains to other places or sectors (Maat et al., 2005; Næss et al., 2020).

Given the varying effects of densification strategies, it is important to study the effects of density on travel behaviour to accurately assess the effectiveness of the spatial strategy. The relationship between built environment and travel behaviour has received considerable scientific attention recent decades (D. Wang et al., 2011). In these studies, the effects of variables influencing travel behaviour are often considered to be direct and homogeneous (Bhat & Guo, 2007). However, there are indications that rather than having one single effect, density and other explanatory variables can have multiple, different, effects on travel behaviour dependent on the status of another variable (Clifton, 2017). When another variable influences the effects of another variable on travel behaviour, also called moderation, the results of mobility and spatial strategies can deviate from the expected results. In these cases, the decisions of individuals have different behavioural outcomes based on variations in context, resulting in over- or underestimations of the effects of transport or spatial strategies (Zhang & Zhang, 2020).

Just a few studies looked at more complex, indirect, relationships of decision-maker characteristics on the response to the built environment (Bhat & Guo, 2007). Since it is especially the interaction between socioeconomic factors and urban form which is central to understanding people's travel decision making, including interaction effects is valuable in explaining travel behaviour (Badoe & Miller, 2000). Within those studies, car ownership is often a dependent or mediating variable, either affected by built environment and other explanatory variables or affected by built environment and thereby influencing travel behaviour. However, there is a gap in the attention that is paid to heterogeneity of the effects of density on travel behaviour dependent on car ownership. While higher density is related to less car ownership, there still is a group that does own a car. As there is heterogeneity in the effects density has on travel behaviour (Cheng et al., 2021), it is interesting to study whether car ownership has a moderating role on these effects, possibly causing the heterogeneity. After all, car ownership is known to be an important determinant of travel patterns (Potoglou & Kanaroglou, 2008). Further, due to a lack of data, most studies do not include travel attitudes as possible determinants of travel behaviour. Thirdly, in studies that include moderation effects attention is mainly paid to a single travel behaviour indicator, often being a single mode or motive. Focusing on a single mode has the limitation that it does not capture the interdependency between travels by different modes (Guan et al., 2020). Therefore, this study will not only look at the travelled distance by car, but also by other modes to capture mode interdependency.

To overcome the limitations of previous studies, this paper studies the interaction effects of car availability with density on the daily travel distance for various modes. There is controlled for various other sociodemographics and travel attitudes to improve the explanatory power of the model and mitigate the residential self-selection problem (see next section). The general aim is to unravel the possible presence of moderation effects by car availability on the effects of built environment.

To achieve the aim of this study, data from the Netherlands mobility panel are used. A multiple moderated regression analysis is applied on that data to identify the possible presence of moderating effects of car availability on the effects of density on travel behaviour. The data and the measurements will be elaborated on in Section 3.

The organisation of this paper is as follows: the next section provides an overview of existing literature with special attention to moderation effects and heterogeneity; the third section explains the method that is applied and the data that are used; the fourth section describes the results and the last section summarises the main findings and their implications and discusses the limitations of this paper.

2 LITERATURE REVIEW

There are many studies that focused on the various relationships between travel behaviour and the built environment (Van Acker & Witlox, 2010). These focused on different relationships, used different types of data, included various sets of variables and have other differences. This section discusses some of the existing literature on built environment and travel behaviour.

2.1 Travel behaviour and the built environment

Following the theory by Wegener about the land-use transport relationship, also known as the Wegener cycle, land use is known to influence travel behaviour (Wegener & Fürst, 2004). In literature, land use is often referred to as built environment (Kasraian et al., 2016). By a definition from Kaklauskas and Gudauskas (2016), the built environment refers to the human-made surroundings that provide the setting for human activity in which people live, work and recreate on a day-to-day basis. In travel research the influences of built environment on travel behaviour have often be named with words beginning with a 'D'. The terminology started with three main D's *Density*, *Diversity* and *Design* (Cervero & Kockelman, 1997). Later, the D's were elaborated by the addition of *Destination accessibility* and *Distance to transit* (Ewing & Cervero, 2010). That results in the following five categories of variables influencing travel behaviour:

- Density
- Diversity
- Design
- Destination accessibility
- Distance to transit

Ewing and Cervero (2010) give an explanation of the five D's, which is summarised here. *Density* concerns a variable of interest per unit of area, often being population, dwelling units and jobs. Here, population and jobs are sometimes combined into an overall activity density. *Diversity* generally concerns the number of different land uses in an area. Most of the times diversity is included as an entropy measure. *Design* focuses more on the characteristics of the street network of an area, being for example number of intersections or average block size. The fourth D, *Destination accessibility*, relates to the distance to various activities. Hence, it is often measured as number of activities reachable within a certain time or distance, or as distance to the nearest activity location of a certain activity type. The fifth D, *Distance to transit*, can be seen as a specification of the *Destination accessibility* with transit being the activity of focus.

Given the spatial scale on which the problems discussed in the introduction are relevant, this study will use density as built environment variable. The other D's are mainly relevant for lower spatial scales (Ewing & Cervero, 2010). Further, including multiple D's creates the risk of overestimating their influence as they influence each other (Handy, 2018). Some authors argue that job and population densities have just limited influence on travel behaviour (Ewing & Cervero, 2010). However, Næss (2012) found that on higher geographical scales density does influence travel behaviour. With relation to the effects, it is generally assumed that in high density neighbourhoods the use of sustainable means of transport such as walking, cycling and public transport is high, which comes at the expense of car use (Ewing and Cervero, 2010; Saelens and Handy, 2008). Further, in high-density areas people make shorter trips and spend less time travelling (Van Acker & Witlox, 2010). However, Maat et al. (2005) found that densification can also lead to more and longer trips.

Clifton (2017) argues that the significance, magnitude and signs of the relationship between built environment and travel behaviour might differ for different economic, demographic and other social groups. Heres and Niemeier (2017) pointed out that built environment variables might interact with other factors, as underlying structure for the heterogeneity. This idea of interactions between built environment and travel behaviour has not been widely studied yet (Sun and Yin, 2020; Clifton, 2017; Zhang and Zhang, 2020). This paper will therefore focus on the interaction effects of density on travel behaviour.

Next to the already discussed direct relationships of built environment with travel behaviour, a few indirect relationships are present. One of them is residential self-selection (RSS), where people locate themselves at locations where they can travel the desired way. The danger of RSS is that when it is present, the influence of built environment on travel behaviour is likely to be overestimated (Mokhtarian & Cao, 2008). In those cases, findings related to differences in travel behaviour might be more a matter of residential choice than travel choice (Mokhtarian & Cao, 2008). Explicitly accounting for the influences of attitudes by including them as explanatory variables with direct influence on travel behaviour is a way to account for the self-selection problem (Mokhtarian & Cao, 2008).

2.2 Travel behaviour and travel attitudes

In the transport domain, attitudes are generally regarded as more or less stable personal dispositions, which makes them effective for explaining past and future travel behaviour (Kroesen & Chorus, 2018). This is based on the notion that people act rationally, which assumes that behaviour follows from attitudes. Considering attitudes as stable dispositions allows to use them to explain travel behaviour on which data are collected in the same year as the attitudes are collected.

The influence of attitudes along with the influence of other variables was tested in various studies (S. Handy et al., 2010). According to findings from among others Prillwitz and Barr (2011) Kitamura et al. (1997), and de Abreu e Silva (2014), attitudes are to a certain extent important determinants for daily mobility. Categories of attitudes that were identified in these studies relate to mode specific, residential location, parking, pricing, environmental and social attitudes (de Abreu e Silva, 2014; Prillwitz and Barr, 2011; Lindelöw et al., 2017). That attitudes add value to models is also stated by Van Wee et al. (2002) who found that adding attitudinal variables to a model with sociodemographics and built environment variables increases the explanatory power of the model on travel behaviour. By doing so, some of the trends between social and spatial aspects might be partially explained (Harms et al., 2014).

In short, travel attitudes have direct effects on travel behaviour which increases the explanatory power of models when included. Besides these direct effects, they also account for the residential self-selection problem, indicating the importance of explicitly including them.

2.3 Sociodemographics and travel behaviour

Having access to a car is without doubt one of the main factors influencing travel behaviour (Wittwer & Hubrich, 2016). It is intuitively evident that persons that have one available will use a car more often than people without a car (Wittwer & Hubrich, 2016). Therefore, car ownership is considered to be an important determinant of household travel behaviour (Potoglou & Kanaroglou, 2008). Car ownership is not only directly influencing travel behaviour, it is also interconnected with residential location (Potoglou & Kanaroglou, 2008).

Given its importance, several studies use car ownership as an independent variable in order to explain travel behaviour. Findings from these studies indicate that on average households with several cars travel more often by car than households without cars (Dieleman et al., 2002) and travel longer distances than people that have to rely on slower modes (Van Acker & Witlox, 2010).

For most aspects of travel patterns sociodemographic variables are at least as important as built environment variables (Dieleman et al., 2002; van de Coevering et al., 2021), so it is important to include various other sociodemographics to control for their effects. In general, quite some studies looked at the effects of various sociodemographic characteristics on travel behaviour. Sociodemographic characteristics that are included in lots of studies on travel behaviour include age, gender, income, ethnicity, occupation, education, household size, household composition, number of children, driver license ownership, (household) car ownership (in varying combinations in among others Ma et al. (2014); Stead and Marshall (2001) and Bird et al. (2018)).

Some studies on the effects of sociodemographics on travel behaviour did find insignificant or opposing effects when looking at the effects in different cities (Ng & Acker, 2018). It is essential to see the individual as embedded in neighbourhood, region and larger society (Hanson, 2010). Saelens et al. (2003) argue that it is likely that people with varying characteristics could be affected by land use in different ways. One of the studies that did look into this is one by Salon et al. (2019). They observed that prior studies did have inconsistency in the indicated associations between travel behaviour and built environment characteristics. On one hand that could be a result of variety in methods and data. On the other hand, there could be heterogeneity in the underlying relationships. For that reason, Salon et al. (2019) studied the relationships between built environment and travel behaviour, cycling in specific, separately for different population groups. Their findings indeed indicated a substantial heterogeneity in the relationship between built environment and travel behaviour between genders, adults and children and children of varying ages. Given their possible presence, there is controlled for interactions between other sociodemographics and density too.

3 METHODOLOGY

3.1 Moderated multiple regression

To identify the possible presence of moderating effects of car availability on the effects of density on daily travel distance, a moderated multiple regression (MMR) analysis has been conducted. A MMR is an addition to the standard multiple linear regression (MLR) that can be used to predict a dependent variable with multiple independent variables. To capture the moderating effects of a variable, an interaction term is added to the simple additive model MLR uses (see Eq. 1).

$$Y = \beta_0 + \beta_1 X + \beta_2 Z + \beta_3 XZ + e \tag{1}$$

where:
β = Estimated coefficients
Y = Dependent variable
X & Z = Independent variables
XZ = Interaction term between X and Z
e = Estimated residual

Moderation effects are symmetrical because $X \cdot Z = Z \cdot X$. Therefore, it is necessary to label either car availability or built environment as moderator based on conceptual considerations (Aguinis & Gottfredson, 2010). When the effect is significant, the respective moderator and independent variable between which the moderation is significant should be included in the model, even when their main effect is insignificant (Seltman, 2015). When the moderation is significant, two different effects can arise: synergy and antagonism. In the first, the signs of the coefficients of the moderation and the direct effect are the same. This indicates a strengthening effect where the whole is more than the sum of the single parts (Seltman, 2015). When the signs have opposite directions, the term antagonism is used to indicate that the total effect is less effective than the sum of the individual effects.

To ease the interpretation of the coefficients, mean-centring has been applied to all variables without a meaningful zero point. The zero-point is relevant in MMR, because the interpretation of the coefficients depends on a meaningful zero-point and the intercept corresponds to the value of the dependent variable when all independent variables have a value of zero (Dalal & Zickar, 2012). With mean-centring, the mean of a variable is subtracted from all observations, such that the mean becomes zero.

3.2 Data and measures

The MMR analysis is conducted with data from the Netherlands Mobility Panel (MPN). The MPN is a yearly panel survey on individual and household travel with as main objective to establish short-run and long-run dynamics in the travel behaviour of individuals and households (Hoogendoorn-Lanser et al., 2015). The MPN uses an activity-based travel diary along with household, individual and additional questionnaires to collect data about the respondents and their travel behaviour. Every two years, the additional questionnaire collects data about the opinions of respondents towards the use of various modes, the car in general and the importance of accessibility for their current residential location by presenting them with different statements. More information about the MPN can be found in Hoogendoorn-Lanser et al. (2015). This study uses data from the fourth wave (conducted in the autumn of 2016), since that is the most recent year available with the additional questionnaire included.

The 2016 questionnaire has been filled in by 9,293 individuals, from which 3,077 proved to be valid after cleaning the data. The 3,077 valid respondents completed the individual and additional surveys, and someone from their household completed the household survey. In addition, some respondents were removed to ensure that all included respondents have meaningful data on all relevant variables. The 3,077 respondents registered 27,898 unique trips in the three days the travel diary collected data from.

3.2.1 Built environment variable

The built environment variable is based on density since that is the 'D' that is most interesting on a relative high spatial scale. Rather than using the density based level of urbanisation variable included in the MPN, a level of urbanisation variable based on job and population density is used. The combined job and population density is calculated by summing the number of jobs and inhabitants within cycling distance (3 km) of a location. With *metropolitan* that classification adds an extra level that classifies highly urbanised areas. The level of urbanisation one resides in is based on the mean level of urbanisation of the four digit postcal code of the area of residence.

Table 1 Descriptive statistics of the independent variables (N=3,077)

Independent variable	Measurement	MPN 2016
Age	17-30 [%]	23.1
	30-60 [%]	58.5
	60+ [%]	18.5
Ethnicity	Native Dutch ethnic origin [%]	7.0
	Non-Dutch ethnic origin [%]	92.3
	Unknown ethnic origin [%]	0.7
Gender	Male [%]	45.4
	Female [%]	54.6
Household income	Below national benchmark [%]	16.9
	National benchmark [%]	18.4
	Above national benchmark [%]	51.3
	Unknown [%]	13.4
Level of education	Low [%]	17.7
	Medium [%]	41.3
	High [%]	41.0
Drivers licence	Does have one [%]	92.0
	Does not have one [%]	8.0
Daily occupation	Working [%]	64.6
	Student / attending school [%]	9.2
	Unemployed [%]	26.3
Household composition	Single-person hh[%]	20.1
	Multi-person hh[%]	27.5
	Multi-person hh + children [%]	52.4
Car availability	Always a car available [%]	64.8
	Not (always) a car available [%]	35.2
Level of urbanisation	Metropolitan [%]	3.1
	Urban [%]	12.5
	Suburban [%]	14.6
	Low suburban [%]	30.3
	Village [%]	19.6
	Rural [%]	19.9
Car attitude	Mean (SD)	4.14 (0.58)
Bicycle attitude	Mean (SD)	3.82 (0.69)
Train attitude	Mean (SD)	3.30 (0.94)
BTM attitude	Mean (SD)	2.71 (0.89)
Prestige attitude	Mean (SD)	2.27 (0.89)
PT efficiency attitude	Mean (SD)	2.44 (0.89)
PT safety attitude	Mean (SD)	3.72 (0.76)
Car loving	Mean (SD)	3.76 (0.76)
Cost-sensitive	Mean (SD)	2.48 (0.97)
Environmental scepticism	Mean (SD)	2.34 (0.85)
Status sensitive	Mean (SD)	2.72 (0.95)
Accessibility attitude	Mean (SD)	2.45 (1.05)

3.2.2 Travel attitudes

Factor analysis was used to identify travel attitudes of respondents. Since travel attitudes are latent variables, three factor analyses were applied to the three categories of statements included in the MPN. The statements were

Table 2 Summary of the factor analysis

Factor	Example statement (statement loading most highly on the factor)	Number of statements loading on the factor	CA
Car attitude	Travelling by car is pleasurable	6	.845
Cycling attitude	Cycling is pleasurable	6	.848
Train attitude	Travelling by train is pleasurable	3	.891
BTM attitude	Travelling by BTM is pleasurable	3	.912
Prestige of using modes	Travelling by train increases status	4	.803
PT efficiency attitude	Travelling by train is flexible	4	.856
PT safety	Travelling by train is safe	2	.752
Car loving	Driving a car offers many advantages compared to the use of other transport modes	5	.737
Cost-sensitive	Due to costs, it is difficult for me to own a car	4	.781
Environmental scepticism	It is pointless to worry about the environment, because there is nothing you can do about it on your own	3	.719
Car scepticism	With the environment in mind, in the past year I have consciously tried to drive a car less	4	.561
Status sensitive	A car says a lot about someone's personal taste / sense of style	2	.711
Accessibility attitude	A short walking distance to a BTM station was an important factor for the choice of my current residential location	5	.825

measured by a 5-point Likert-type scale ranging from (1) strongly disagree to (5) strongly agree. The 28 mode-use statements, 21 general car related statements and 5 accessibility related statements were objected to a principal components analysis with Varimax rotation. The results of the factor analysis are summarised in Table 2. The Cronbach's Alpha (CA) in the last column provides a measure of reliability of the factor, where a value of 0.8 or higher is considered good and reflects high internal consistency ((George & Mallery, 2013), cited in Gliem and Gliem (2003)). The *car scepticism* factor is not included in further analysis because of its low CA.

3.2.3 Sociodemographic variables

The data from the MPN questionnaire are used to include the following sociodemographic variables in the analysis: age, ethnicity, gender, household income, level of education, drivers license ownership, daily occupation, household composition and car ownership. As every level of categorical variables results in a separate interaction term with the built environment variable, the number of levels per variable is reduced where possible. Table 1 contains information about the levels each variable has and their presence in the data.

Car ownership is operationalised as car availability because that does tell something about the actual ability to use a car rather than just having one (and potentially having to share it with household members). That follows a line of reasoning that argues that availability is more important than private ownership (Van Acker et al., 2014).

3.2.4 Outcome variables

The dependent variable will be average daily distance travelled in total and by specific mode. It is interesting to not only study the moderating effect of car availability on the effects of built environment on car distance, but on distances for other modes too as car availability also affects levels of multimodality and thereby distances travelled by other modes (Heinen, 2018).

The variable is computed by taking the average of the aggregated distance travelled in total and by mode as captured in the three day long travel diary. To obtain a representative results that is relevant for understanding daily travel patterns, various trips were removed from the data. Tours, trips with a foreign origin or destination and occupational trips (not the same as commuting trips) were removed since those trips are driven by other choices than regular travel choices that people make to travel to their job or shops et cetera.

Table 3 Descriptive statistics of the daily distance travelled

	Car	Train	BTM	Bicycle	Walking	Other	Tot.
Metropolitan	20.3	15.7	2.7	3.4	0.5	1.1	43.8
Urban	20.9	10.8	1.3	2.8	0.4	0.6	36.8
Suburban	26.4	5.6	0.8	2.6	0.3	0.9	36.7
Low suburban	25.8	5.5	0.9	2.1	0.2	1.3	35.8
Village	31.7	3.1	0.8	2.3	0.3	1.6	39.8
Rural	35.0	4.6	1.2	1.6	0.2	2.5	45.1

Table 3 describes the descriptive statistics of the average daily distance travelled by each mode for inhabitants of the various levels of urbanisation. With decreasing level of urbanisation, the daily distance travelled by car increases, and the distance travelled by train, BTM, bicycle and walking decreases. The total average daily distance travelled is high for the metropolitan, village and rural levels, and quite comparable for the levels in between.

4 RESULTS

The results of the MMR analysis are shown in Table 4. This table presents the estimated coefficients of the independent variables. In the table, only variables with significant (P <= 0.05) coefficients are shown. Exceptions are the insignificant direct effects of variables that also have a significant interaction effect with level of urbanisation. Showing these provides additional insights in the effect of the interaction. Insignificant variables are not shown in the table, but are still included in the model, as removing them would change the coefficients of other variables since these are based on the maximum likelihood given the inclusion of all variables.

Table 4 Coefficients of the MMR analysis moderated by LoU

Variable	Car	Train	Walking
Intercept	5.135	5.086	0.403*
Level of urbanisation	2.239	-1.293	-0.030
Gender (ref = female)	5.146*		
Unknown ethnicity (ref = non-Dutch)		-14.463	
Job (ref = unemployed)	6.752*	-1.117	
Student (ref = unemployed)		13.756*	
Level of education	4.740*		-0.076*
Car availability (ref = not (always))	4.681	-0.925	0.092
National benchmark (ref = below national benchmark)			-0.098
Above national benchmark (ref = below national benchmark)	8.032*		
General car attitude	7.495*		
Cost of driving attitude		2.022*	
Accessibility attitude	-2.118		
Level of urbanisation × Unknown ethnicity		8.331*	
Level of urbanisation × Job		2.07*	
Level of urbanisation × Education			0.040*
Level of urbanisation × Car available	2.666*	-1.361*	-0.058*
Level of urbanisation × Benchmark income			0.073*
Level of urbanisation × Cost of driving attitude		-0.633*	
Level of urbanisation × Accessibility attitude	0.999*		
Adjusted R-squared value	0.133	0.122	0.043

* P <= 0.05

The results indicate that there are significant interaction effects between car availability and level of urbanisation in the models for daily distance travelled by car, train and walking. The models for total distance and distance by BTM, bicycle and other modes did not show a significant interaction between car availability and level of urbanisation and hence will not be discussed in more detail.

In the last row the adjusted R-squared values are given. These values indicate the proportion of the variance of the dependent variables that is explained by the independent variables, accounted for the number of variables. The R-squared value ranges from zero, explaining nothing, to one, explaining the full variance. Even with a wide set of variables from which is known from literature that they have some influence on travel behaviour, the share of explained variance is pretty low. This is not uncommon in (cross-sectional) travel behaviour studies (Scheiner & Holz-Rau, 2007). It suggests that there is a considerable amount of knowledge missing about predicting travel behaviour (Krizek, 2003). The car and train distance models score comparably well. The walking model just has an adjusted R-squared value of 0.043, which is considered to be low.

4.1 Car availability × LoU on car distance

The MMR analysis reveals that there is a significant interaction term between car availability and level of urbanisation of 2.666 (p <= 0.05). That indicates that when someone has a car available, the increase of car kilometres is higher in denser areas. Since the main effects of car availability (4.681) and level of urbanisation (2.239) are also positive, the interaction effects strengthens the effect. Figure 1 visualises this effect. With increasing level of urbanisation, the increase in daily distance travelled by car gets larger. Whereas the mean predicted car distances travelled by people that do not always have a car available follow the descriptive statistics, this is not the case anymore for the means of people that always have a car available. The car use of metropolitan inhabitants is even such high that the predictive mean does match the car use levels of rural inhabitants.

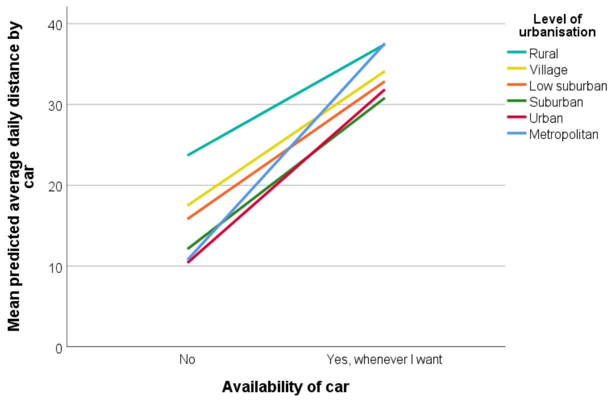

Figure 1. The effect of car availability on average daily distance travelled by car

4.2 Car availability × LoU on train distance

The main effects of car availability and level of urbanisation on train distance are respectively -0.925 and -1.293.

The interaction term between both has a coefficient of -1.361 (P <= 0.05), indicating that the interaction strengthens the negative effect as the signs are the same. Figure 2 shows that the mean distance travelled by train is indeed lower for people who always have a car available, compared to people who do not. The different effects for the levels of urbanisation show that the higher the level, the stronger the decline. The means for people who do not always have a car available gradually increase with level of urbanisation. For people who always have a car available a clear distinction between the four lesser urbanised levels, the urban level and the metropolitan level can be observed.

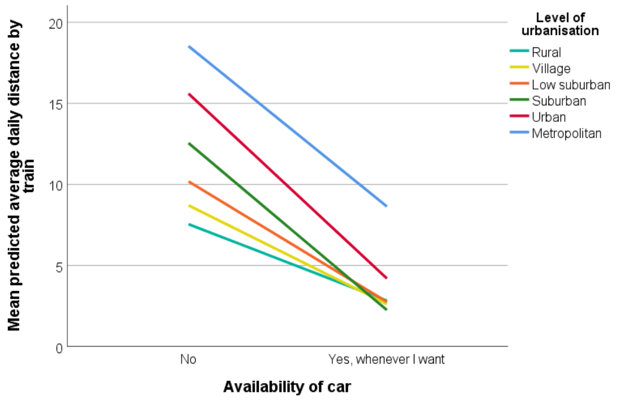

Figure 2. The effect of car availability on average daily distance travelled by train

4.3 Car availability × LoU on walking distance

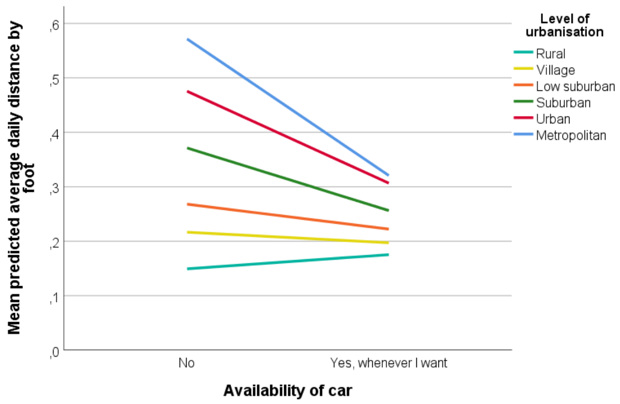

Figure 3. The effect of car availability on average daily distance travelled by foot

The direct effects of car availability and level of urbanisation show opposing signs with respectively coefficients of 0.092 and -0.030. The interaction term between both has a coefficient of -0.058 (P <= 0.05), indicating a stronger decline in walking distance in higher levels of urbanisation. Given the varying signs of the main effects, it is expected that some levels have effects of a different direction than the effects in other levels of urbanisation. Figure 3 visualises these effects. As can be seen, the effects indeed have different directions. For the lowest level of urbanisation, always having a car available results in an increase in the daily walking distance, whereas it does result in a decline for the other levels. With increasing urbanisation, the decline in walking distance gets larger.

5 DISCUSSION

The results show that the effect of density on travel distance depends on the car availability of an individual. For people that do not own a car the effects on travel distance by car, train and walking are clear. Higher densities, in the form of higher levels of urbanisation, do lead to shorter daily distances travelled by car and longer distances travelled by train and walking.

For people that always have a car available, the differences in travelled distances with car, train and foot between the levels of urbanisation are smaller and in some cases do not follow a logical order. That latter is the case when looking at distance travelled by car, where the mean of people that always have a car available living in metropolitan areas does match the mean of those with always a car living in rural areas. For train distance, the mean distance for people that always have a car available is roughly the same for the four lower levels of urbanisation. There is a clear distinction between those levels and the urban and metropolitan level, which despite stronger declines still have considerable higher means. With respect to walking distances, the influence of built environment is also weaker for people who always have a car. There, the differences between means of the levels of urbanisation are way smaller, but they do follow a relative linear effect in the sense that increasing density does lead to higher walking levels. However, that effect is significantly smaller than it is for people that do not always have a car available.

The results show that densification strategies result in the desired effects, namely less vehicle kilometres, more train kilometres and more walking. However, achieving the full potential of high densities is only possible when people do not (always) have a car available. For policy makers, this implies that densification strategies should be accompanied by strategies that focus on reducing car ownership. In so called green-field development, where new developments take place on sites where no houses are present, policy makers can discourage future car ownership by including measures that make cars slower, less convenient, more costly and more difficult to park in the design of the densification project (Buehler et al., 2017). Besides making the car less attractive to use, promoting other modes or car-sharing also proves to discourage car ownership. Studies show that 20% - 30% of the people is likely to give up the planned purchase of a car or shed a current one if a suitable car-sharing system becomes available (Liao et al., 2020; Nijland and van Meerkerk, 2017). Promoting car-sharing can for example be done by providing designated parking facilities for shared cars in the to be developed area (Liao et al., 2020).

At densification projects on brown-field sites that used to have other purposes or on locations where low-density buildings are replaced by high-rise buildings (Haaland & van Den Bosch, 2015), it can be more difficult to apply the before-mentioned measures since there is less space available. At those areas, the introduction of (more) paid parking could stimulate the use of other modes or car-sharing, and thereby discouraging car ownership (and availability) (Liao et al., 2020).

Special attention should go to reducing car ownership in densification projects in metropolitan areas. Although people living in a metropolitan area with always a car available travel longer distances by train and also walk longer than their lesser urbanised counterparts, they also travel longer distances by car. Since metropolitan inhabitants show the largest difference in car, train and walking distance between having a car available or not, reducing car ownership in metropolitan areas can make large differences. There can be questioned whether promoting PT will contribute to discouraging car use, since on average metropolitan inhabitants travel a lot by train, even those who always have a car available. Further, in general, car ownership in metropolitan areas already is discouraged as it is slow, relatively inconvenient, relatively costly and difficult to park.

6 CONCLUSION

The purpose of this paper was to explore the possible moderating role of car availability on the effects of built environment on daily travel distance. Obtaining more insights in the way density influences travel distance helps understanding the effects of spatial strategies like densification. Nowadays, densification is one of the most relevant spatial strategies (Næss et al., 2020). It is known to have benefits as less car driving and lower energy consumption (Næss et al., 2020), thereby contributing to achieving more sustainable travel behaviour. However, the effects of densification strategies are not systematic, uniform or predetermined, but depends on local circumstances.

In order to analyse heterogeneity in the effects of density on travel distance a MMR analysis was performed on data from the 2016 wave of the Netherlands Mobility Panel. In line with the main idea of the present paper, the results indicate that the influence of density on travel behaviour depends on whether someone does always have a car available or not. In particular, the effects of density on daily distance travelled by car, train or walking are sensitive to the car availability of individuals. The effects of density on travel distance revealed to be weaker for people that always have a car available than they are for people who do not (always) have a car available. This is important knowledge for policy makers, as considering the effects of density on travel distance to be homogeneous would result in under- or overestimates of the effects of densification strategies. Further, there was found that metropolitan inhabitants travel long distances by car when they have one available at all times. That does not go at the expense of distance travelled by train, since that is still high. Hence, the challenge in metropolitan areas is to reduce car ownership, but without (large) opportunities for solutions focused on promoting PT.

Some limitations of this study should be recognised. These limitations can form opportunities for future research. First, car availability is operationalised as binary variable with always or not (always) a car available as options. In reality, there are more options, like the absence of a car in the household or just one car for multiple persons requiring coordination between household members before the car can be used. Since this study showed the presence of an interaction between car availability and density, it could be interesting to explore the identified relationship in more detail by using a more elaborate definition of car availability. Especially since car-sharing is on the rise, including the use of it as option could provide more information about the influence of density on travel distance, in general and in areas with car sharing options.

Secondly, car ownership, operationalised as car availability, is included as independent variable of travel distance. The results showed that it significantly interacts with the level of urbanisation. However, Van Acker and Witlox (2010) found that car ownership also has a mediating role on the relationship of built environment on car use. Future research could use structural equation modelling to analyse moderating and mediating effects at the same time and create more understanding about the specific role of car ownership in relation with the built environment (Sardeshmukh & Vandenberg, 2017).

Other future research could focus on the drivers of metropolitan inhabitants that always have a car available. By, for example, applying questionnaires or interviews, knowledge could be obtained about why they own a car (as implied by the fact that a car is always available), they use it that often and possible conditions on which they would shed their cars. As this study showed that the effects of discouraging car ownership are especially large for metropolitan inhabitants, being able to respond to the motivations of this group helps achieving a more sustainable transport system.

Taken together, findings from this study provide support for densification strategies to reduce car use. As this study shows that the effects of densification are enhanced by car availability, reducing car ownership along applying densification strategies should be of major importance for policy makers to achieve the full potential of high density areas. Further, the findings advance the understanding of associations between the built environment and travel behaviour.

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B

DATA PREPARATION

As discussed in Chapter 3, the MPN collects information of individuals and households. As these are collected in various questionnaires, they are provided in separate files. To prepare these files for the moderated multiple regression analysis, several steps have to be performed. This appendix describes the preparation and structuring of the data. The steps of merging and cleaning the data are visually presented in Figure B.1. The various phases in the figure will be discussed below.

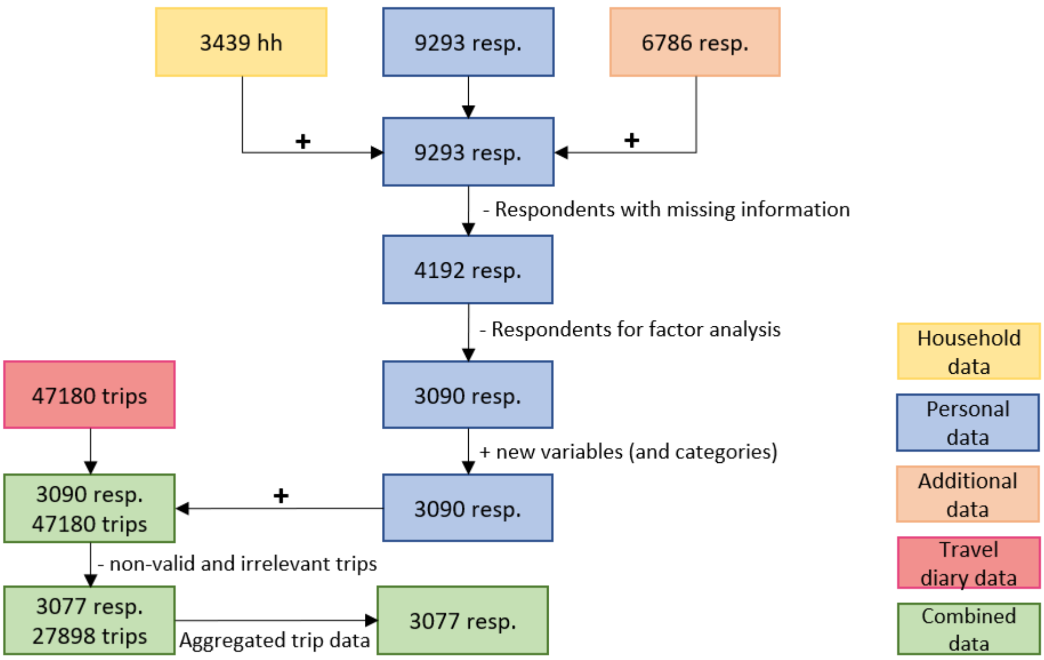

Figure B.1: Overview of the merging and cleaning of the various data sets

Step 1 - Merging of data from questionnaires

The first step is to merge the files containing personal and household information. As the level of analysis is individual, the household data is added to the individual data. This was done in statistical software SPSS via the *Data - Merge files - Add variables* option. The data from the *HHdata* file was added to the *Pdata* file by one-to-many merge based on the unique household ID variable *HHID*. The next part of the merging step is to merge the person data with the individual additional data within the *Pdata_bijzonder* (Pdata_special) which is collected in even years. This is done via the same command as the household merging, with a one-to-one merge based on personal identification number *PERSID* as key variable. By doing so, the answers to the additional questions are added to the individual they belong to.

Step 2 - Cleaning and filtering

Not all households and individuals did fill in all the necessary questionnaires. In order to analyse the data correctly, it is necessary to only consider individuals that filled in the questionnaires correctly and belong to a household that did so too. For that reason, the merged data are cleaned. This is done after the merging because of an error in the data file containing the answers on the additional questionnaire. When comparing the variable indicating the validity of the individual, a difference was noted between the variable in the regular person data and the same variable in the additional data. Whereas the validity variable indicates that 4,359 individuals completed the questionnaire and diary in the standard questionnaire, the same variable in the additional data indicates that 3,593 completed both the questionnaires and the diary. A cross-tab analysis showed that for 2,644 individuals the validity variables did not correspond (see Table B.1). Inquiries at the KiM confirmed that the data set indeed contained an error (de Haas, personal communication, April 12, 2021). KiM researcher de Haas confirmed that the validity variable in the standard data is correct. Therefore, the validity variable in the additional data was not included in the merging of both data sets.

Table B.1: Cross tab analysis of the two person validity variables

		Person completed the survey - additional' person data		**Total**
		Person completed the questionnaire but not the diary	Person completed the questionnaire and the diary	
Person completed the survey - 'standard' person data	Person completed the questionnaire but not the diary	1,489	940	2,429
	Person completed the questionnaire and the diary	1,704	2,653	4,357
	Total	3,193	3,593	6,786

First, individuals that did not complete the questionnaire and/or did not complete the travel diary were removed from the data. As no questions were asked to persons younger than 12 years old, those are removed from the data too. From the 9,293 individuals in the data, 4,359 did fill in both questionnaires and the travel diary.

Second, individuals belonging to households with missing data are removed from the data set. This is done by looking at the *HH_VALID* variable which indicates whether the individual belongs to a household in which the household questionnaire was filled in correctly. From the 4,359 remaining individuals, 151 belong to a household that did not fill in the household questionnaire. As this results in missing data for various variables, those individuals are removed from the data, leaving 4,208 valid respondents. As the focus of the analysis is on individual travel behaviour rather than behaviour of households, respondents belonging to a household from which not all household members did fill in the questionnaires are still included in the analysis as long as they completed the questionnaires and travel diaries.

Further, two respondents were removed as for an unknown reason they did not answer all questions of the additional questionnaire, but were not marked as non-valid. The same applies for fourteen respondents from which a part of the household questionnaire is missing, despite the household being marked as valid. In total, 5,101 respondents turned out to be non-valid, leaving 4,192 respondents in the data.

Step 3 - Preparing the data for factor analyses
A third step of data cleaning is necessary to prepare the data for the factor analysis (see Chapter 3 and Appendix D) on the mode-use, car and accessibility statements. Respondents had the option to fill in that they do not have an opinion about a certain statement. That option formed the sixth option on top of the five level Likert scale. It does however not mean that it is worse than strongly disagreeing. Therefore, 'no opinion' was replaced by 'somewhat agreeing, somewhat disagreeing', the middle option of the five levels. This option resembles the no opinion option as it does not indicate a (strong) preference towards agreeing or disagreeing. This works for respondents that have answered 'no opinion' limited times. However, when a person has no opinion on a lot of statements, this method could cause the results to be less reliable. Especially when a person has no opinion on all statements of a single mode this would lead to inconsistent results. This could be the case when a person has never used a mode because it is not an available option. Hence, respondents who did not have an opinion on all seven mode-use statements of a specific mode and respondents that did not have an opinion on at least ten statements from various modes were removed from the data to assure viable results. The same was done with respondents who had no opinion on ten or more of the general car statements. Further, respondents who filled in the same answer on all statements, or had just one deviating answer, were removed from the data. This act is also known as straightlining and it is likely that those respondents did not fill in the questionnaire seriously, thereby reducing the quality of the data (Olde Kalter, Harms, & Geurs, 2015). The final step of preparing the data for the factor analysis is the removal of respondents with an age of 16 years or younger, as those were not asked about their opinion on several of the car statements. Combined, these three steps resulted in the removal of 1,102 respondents, leaving 3,090 ones that filled in everything correctly, seriously and did have an opinion on sufficient statements to correctly analyse the attitudes.

For the factor analysis of the housing statements (see Appendix D) less respondents are used. There, respondents had the option to say that the statement does not apply to them. That could be because they have not chosen their living residence themselves, for example because they got assigned one or are living with their parents. As the statement is not applicable it cannot be replaced by the neutral option. For that reason, 'not applicable' answers were temporarily removed from the data. Thereafter the factor analysis is performed without respondents having at least one 'not applicable'. This is the case for 2,402 respondents. Afterwards, the factor score is calculated for all respondents having a maximum of one 'not applicable'. To do so, the factor score is calculated as mean of the statements without having 'not applicable' as answer.

Step 4 - Adding a variable and changing the levels of categorical variables
Not all data in the data set containing data from the personal, additional and household questionnaires are relevant within the scope of this thesis. Hence, irrelevant variables are deleted. On the other hand, a new variable is added. The *STEDGM6* variable contains a different classification of the level of urbanisation of areas. Why this variable is used and how it is obtained is discussed in Section 3.3.4 and Appendix E. The variable is added via the same command as used before, and based on the household ID as key variable.

Besides adding and removing some variables, some other variables were re-categorised. This was done to either reduce the number of levels, especially ones with a low number of respondents, and to better match classifications used by Statistics Netherlands. The new categorisation of household composition is based on the three levels Statistics Netherlands uses: *single person household*, *multi-person household* and *multi-person household with children*. Education is re-coded into three categories, being low, medium and high. This reduces the number of levels, matches the definition by Statistics Netherlands and makes the categories easier to understand by readers not familiar with the Dutch education system. Another variable from which some levels were merged is the daily occupation. Here, the various reasons for being unemployed, including retirement, were combined, just as is done with people having various types of jobs. Students and people attending school form the third category. The last variable that is adjusted is age. Three levels of age were created, being young adults (17-30 years), adults (30-60 years) and elderly (60+ years).

Step 5 - Merging the travel diary data and personal data

In the end, it is necessary to have the average daily distances travelled per mode and in total for all valid respondents. The first step to obtain those values is to merge the travel diary data with the set of valid respondents. This is done by *one-to-many merging* as respondents can make multiple trips. After doing so, a combination of 47,180 trips and 3,090 respondents is obtained. Some of the trips in the data are not really trips as respondents did not make a trip on a specific day. These 'trips' are included, as not making a trip also tells something about the travel behaviour of people.

Step 6 - Cleaning the travel diary data

Just as the personal and household data, the travel diary data has to be cleaned before it can be used. In the complete travel diary data 47,180 trips are included. From this initial number, various trips are removed for various reasons that will be discussed below briefly.

First, trips made by non-valid respondents are removed. This results in the loss of 12,893 trips.

Second, occupational trips are removed. For those trips, distance is reported in a different variable than for 'regular' trips. Travel decisions made for occupational trips are likely to be driven by other aspects than personal characteristics, attitudes and the built environment. Therefore, they are less interesting within the scope of this study and hence they are not included in the analysis. It is important to stress that occupational trips concern trips that are made as part of a job, like delivering parcels or driving a taxi. Hence, they do not include trips that are made to get to a workplace from home or vice versa, these will be referred to as commuting trips. Occupational trips also do not concern trips that someone makes as part of a job, like visiting a customer for a meeting. Here, the trip is not the job it self, like is the case for a delivery guy or taxi driver.

Thirdly, trips that either have an origin or destination, or both, outside the Netherlands are removed. This is done as the focus of this study is 1) on the Netherlands and 2) on daily travel patterns. A large part of the trips originating from or departing to another county is likely to concern recreational vacation trips or incidental (long) business trips. Due to the removal of the 348 trips with a foreign origin or destination the number of trips made could be underestimated for areas close to the border, which mainly are less urbanised areas. In those areas, trips across the border can be for commuting or shopping and hence be part of daily travel patterns. However, the number of foreign trips is rather low, so no problems are expected to arise. On top on trips with an origin or destination abroad, 85 vacational trips within the Netherlands are also removed.

Fourthly, 1,178 tours are removed from the data. Tours are mainly made for recreational purposes like a round of walking or cycling or walking the dog. As these tours have different drivers than trips made for other purposes, they are not included. After all, here mobility is the goal, whereas mobility is a means to fulfil other purposes in the scope of this study.

Fifthly, nineteen trips from which the mode or distance has been marked by the MPN researchers are removed. The researchers marked trips that seemed to have an incorrect mode or distance for domestic trips. As the data also contain variables indicating whether certain other variables like travel distance, time or mode have been corrected by the researchers, those are compared with the marked trips to prevent that trips that are marked but have been corrected are removed. As travel duration is not relevant within the scope of this study, trips with a marked travel duration were not removed. Travel distance and mode are relevant, so trips with a marked distance and/or mode are removed to be sure that no incorrect information is included in the analysis.

The final step of cleaning the data is to remove n-1 trips that are part of a trip existing out of n segments. The MPN reports those trips as different segments. For example, segment 1 is cycling to a station, segment 2 is travelling by train to another station, and segment 3 is walking to the final destination. However, the respondents did not have to report the distance for all segments separately, only the overall distance is reported. Therefore, it is not possible to include the access and egress trips in the analysis. Since the main mode for all trip segments is the same, being train in the example, the trip would be included three times in the analysis. As that would lead to an overestimation of the distance travelled by especially train, those trips have to be removed. In the MPN data, those trips are indicated by a displacement variable which indicates whether a trip is a new trip or part of another trip. The removal of these trips results in a loss of 4,190 trips.

In total, all steps of cleaning the data combined results in the removal of 19,282 non-valid trips. In the end, 27,898 trips remain. Besides losing trips, the above data cleaning also results in the loss of thirteen respondents. Those respondents did not make any valid trips, and hence have no valid travel data to analyse.

Step 7 - Merging travel diary data and personal and household questionnaires
Now the valid respondents have been matched to the valid trips, the final step is to aggregate information from all trips made by each respondent. After doing so, the daily distance travelled can be analysed.

It is interesting to not only look at the total average daily distance travelled, but also include the average daily distance travelled by each mode. Therefore, the data are aggregated for each mode separately. This is done for trip frequency too, as that information is used to show the modal split based on frequency. By doing so, a comparison with other Dutch travel studies can be made, to get an idea about the representativeness of the travel behaviour of the sample.

After aggregating the relevant travel diary data, the aggregated distances were divided by the number of days to obtain the average daily distance travelled in total and by each mode for each respondent.

C

Sample representativeness

This Appendix contains information about the representativeness of the sample that is obtained from the MPN data after cleaning it (see Appendix B). For the sociodemographics and built environment variables there is checked to what extent the sample matches the population. As no population data are available for the attitudes, those cannot be compared.

Sociodemographics

The distribution of variables in the population is based on various statistics by Statistics Netherlands and originates from 2016, just as the used MPN wave does.

Ethnicity and household income both have an unknown category. To be able to compare the other levels with the real distribution, the percentages were recalculated based on a total without the unknown option. Therefore, the percentages given in Table C.1 deviate from the percentages used in Table 3.6 in the main text.

When looking at the results of the comparison between the sample and the population in Table C.1, a few differences between sample and population can be observed. The first large difference can be observed within the age variable. There, the share of people of 60+ years is eleven percent points smaller in the sample than it is in the population. Another large difference between the sample and population is the share of people with a non-Dutch ethnic origin. Whereas that group forms 22% of the Dutch population, just 7.2% of the sample has a non-Dutch ethnic origin. When looking at gender, the sample has a small over-representation of females, but as the difference is not that large no problems will be expected. Larger differences are present in the annual gross household income, where especially the category containing household incomes surrounding the national benchmark is deviating from the population. For the education variable, low educated people turn out to be less present in the sample than may be expected based on the distribution in the population. The same applies for people that do not have a drivers license. It makes sense that those people are less represented in the sample as they are more likely to have answered 'no opinion' on multiple statements related to car-use, and hence are removed from the data. The distribution of daily occupation is relatively good, only the number of students is somewhat higher than in the population. That is probably caused by the fact that some students have part-time jobs, and hence are included in that category in the population data. The percentages of the population are roughly calculated based on data from Statistics Netherlands, as the exact percentages are not available. The second last variable, the household composition, also has some differences between the sample and the populatoin. The share of single person households is lower and the share of multi-person households with children is higher than could be expected based on the distribution in the population. The distribution of the last variable also has some relative large deviations from the population. Whereas around 50% of the population above 18 years does own a car, this is 65% in the sample. Again, that could be a result of the removal of respondents which answered ’no opinion’ on the car statements multiple times.

Table C.1: Comparison of the distribution of sociodemographics in the sample with reality

Variable	**Measurement**	**Presence [%]**	
		Sample	Population
Age	17-30	23.1	19.9
	30-60	58.5	50.0
	60+	18.5	30.1
Ethnicity	Native Dutch ethnic origin	92.8	77.9
	Non-Dutch ethnic origin	7.2	22.1
	Unknown ethnic origin	-	-
Gender	Male	45.4	49.2
	Female	54.6	50.8
Household income	Below national benchmark	19.5	22.6
	National benchmark	21.2	14.2
	Above national benchmark	59.3	63.2
	Unknown income	-	-
Level of education	Low	17.7	30.0
	Medium	41.3	36.0
	High	41.0	34.0
Drivers license	Person does have a drivers license	92.0	79.1
	Person does not have a drivers license	8.0	20.9
Daily occupation	Working	64.6	*60.6*
	Student / attending school	9.2	*3.1*
	Unemployed	26.3	*36.4*
Household composition	Single person household	20.1	37.6
	Multi-person household	27.5	29.0
	Multi-person household with children	52.4	33.4
Car availability	Person does always have a car available	64.8	47.4
	Person does not (always) have a car available	35.2	52.6

Built environment

As discussed in Chapter 3, the level of urbanisation is the built environment variable that will be used to explore possible moderation effects. For the comparison of the sample with the population, data from the creator of the variable are used. The presence of each level in the sample and the population can be found in Table C.2. The sample has a small percentage of respondents living in metropolitan areas, but that resembles the population. One level that does not accurately resemble the population is the low suburban. With 30%, the share of the level is almost twice as large as the share in the population. This over-representation does mainly come at the expense of an accurate representation of the rural level, which share is almost 8 percentage points lower than its share in the population.

Table C.2: Comparison of the distribution of the level of urbanisatoin in the sample with the population

Variable	**Measurement**	**Presence [%]**	
		Sample	Population
Level of urbanisation	Metropolitan	3.1	5.3
	Urban	12.5	14.7
	Suburban	14.6	14.5
	Low suburban	30.3	16.5
	Village	19.6	20.9
	Rural	19.9	28.1

The level of urbanisation variable is also used as binary variable to identify differences between urban and non-urban areas. Table C.3 shows that the sample does not differ that much from the population.

Table C.3: Comparison of the distribution of urbanity in the sample with the population

Variable	**Measurement**	**Presence [%]**	
		Sample	Population
Urbanity	Urban	15.6	20.0
	Non-urban	84.4	80.0

Travel behaviour

It not only is interesting to compare the sample with the population to check its reliability, but it also is to compare the output of the sample in terms of travel behaviour to the observed travel behaviour of the population. As no travel behaviour data are available for the entire Dutch population, data from the large yearly travel study OViN is used. While the OViN has some limitations on its own, it is a study that gives a good indication of the travel behaviour in the Netherlands. Table C.4 shows the modal splits based on distance and frequency from the sample used in this study and the OViN (2016).

A few differences can be observed when comparing the travel behaviour in the sample with the travel behaviour according to the OViN. The first is a large difference of the modal share of train in the MPN and OViN. In the modal split based on distance the gap is 6 percent points. Apparently people in the sample travel longer distances by train than people in the OViN sample. They also travel more often by train, given the double share based on frequency, although the difference might be smaller (or larger) due to limited significance. This probably is a result of the fact that the MPN does only focus on the main mode. Hence, the access and egress distance to a station are added to the actual distance travelled by train, resulting in a higher share in the modal split based on distance and a higher number of travelled kilometres. Another difference is that in the sample, respondents travel shorter distances by bike than the respondents in the OViN sample. Whereas the share based on frequency is equal, the share based on distance is 3 percent points lower. This is likely to be a result of the activity based approach of the MPN, which is able to collect shorter trips more accurately, and again the exclusion of access and egress trips. A last difference is the absence of information about walking in the OViN sample. As it is included in the *other* category, no good comparison is possible.

In general, the MPN sample shows comparable travel behaviour as the respondents in the OViN study did. The only difference is related to the use of train. This is useful to know when interpreting results related to the daily distance travelled by train. Further, as only the totals are compared, it might be that there are differences between the travel behaviour following from the sample and actual travel behaviour within the various levels of urbanisation. As the OViN uses a different classification of urbanisation, it cannot be used as comparison for the travel behaviour in various levels of urbanisation.

Table C.4: Comparison of the modal split descriptive statistics with data from OViN (Jorritsma et al., 2016)

Modal split based on ...	**Distance**		**Frequency**	
Mode	Sample	OViN	Sample	OViN
Car	72%	72%	53%	47%
Train	15%	9%	4%	2%
BTM	3%	3%	2%	3%
Bicycle	6%	9%	27%	27%
Walking	1%	-	12%	-
Other	4%	7%	3%	21%

D

FACTOR ANALYSIS

As discussed in Chapter 3, a factor analysis is needed to identify whether there are variables that measure different aspects of a same underlying variable, as could be the case with the statements in the MPN data. This appendix will discuss how the factor analyses have been conducted.

Step 1 - Checking the sample
Before the factor analysis can be performed, the data have to be made ready. As respondents had the option to fill in 'no opinion' on the statements on which factor analysis is applied, some adjustments had to be made. Further, there was checked whether respondents did fill in the questionnaire seriously. An elaborate description of both steps of data cleaning can be found in Appendix B. After cleaning the data, 3,090 respondents remained in the sample that is used for the factor analysis. There has to be checked whether this sample size is large enough to find reliable estimates. Various rules of thumb are available to check whether sample sizes are large enough (Finch, 2013). A convenient option is the Kaiser-Meyer-Olking (KMO) measure of sampling adequacy in SPSS. For the mode-use statements the KMO-value is 0.875, indicating that the sample size is large enough. For the general car statements the KMO value is 0.795, which also is an acceptable value. The KMO value for the accessibility statements is also good with a value of 0.840.

Step 2 - Correlation matrix
To check whether the similar statements indeed could be related and measure some of the same underlying variable, all correlations between the statements were analysed. All pairs with at least a weak relationship (a correlation greater than 0.3 or lower than -0.3) were marked.

MODE USE STATEMENTS

As can be seen in Table D.1, all mode-use statements have at least one weak or stronger correlation with at least one other statement. Further, some clusters of statements which correlate can be observed, indicating the presence of underlying variables. The sole purpose of this table is to show that there are correlations between the mode-use statements by marking them. The table does not intend to provide information about the specific variables and correlations, explaining the lack of readability.

Table D.1: Correlation matrix of the mode-use statements

Statement	A1	A2	A3	A4	A5	A6	A7	T1	T2	T3	T4	T5	T6	T7	B1	B2	B3	B4	B5	B6	B7	F1	F2	F3	F4	F5	F6	F7
A1 I find travelling by car to be comfortable	1.000	0.528	0.506	0.467	0.581	0.613	0.178	-0.130	-0.129	-0.208	0.064	-0.193	-0.139	-0.043	-0.109	-0.105	-0.172	0.009	-0.136	-0.110	-0.060	-0.055	0.004	-0.062	0.020	0.041	0.010	-0.024
A2 I find travelling by car to be relaxing	0.528	1.000	0.365	0.513	0.354	0.700	0.302	-0.165	-0.159	-0.117	-0.068	-0.130	-0.157	0.052	-0.103	-0.067	-0.106	-0.052	-0.111	-0.092	0.052	-0.017	-0.018	-0.052	0.055	-0.048	-0.027	0.055
A3 Travelling by car saves me time	0.506	0.365	1.000	0.374	0.534	0.447	0.177	-0.135	-0.126	-0.232	0.011	-0.222	-0.122	-0.014	-0.111	-0.105	-0.168	-0.013	-0.163	-0.110	-0.028	-0.086	-0.014	-0.103	0.018	-0.015	-0.029	0.005
A4 Travelling by car is safe	0.467	0.513	0.374	1.000	0.367	0.509	0.270	-0.082	-0.093	-0.104	0.040	-0.119	-0.090	0.063	-0.043	-0.047	-0.086	0.074	-0.073	-0.045	0.049	-0.013	-0.001	-0.053	0.185	-0.028	-0.011	0.053
A5 I find travelling by car to be flexible	0.581	0.354	0.534	0.367	1.000	0.460	0.116	-0.085	-0.085	-0.188	0.123	-0.207	-0.087	-0.060	-0.108	-0.112	-0.160	0.048	-0.133	-0.105	-0.091	-0.059	0.030	-0.078	0.049	0.138	0.030	-0.044
A6 Travelling by car is pleasurable	0.613	0.700	0.447	0.509	0.460	1.000	0.286	-0.134	-0.137	-0.147	0.002	-0.148	-0.117	0.027	-0.091	-0.079	-0.127	-0.011	-0.106	-0.059	0.017	-0.054	-0.033	-0.086	0.030	-0.029	-0.010	0.017
A7 Travelling by car gives me prestige	0.178	0.302	0.177	0.270	0.116	0.286	1.000	-0.101	-0.117	0.008	-0.128	-0.016	-0.113	0.436	-0.072	-0.052	0.006	-0.130	-0.011	-0.077	0.376	-0.058	-0.128	-0.036	-0.021	-0.139	-0.143	0.433
T1 I find travelling by train to be comfortable	-0.130	-0.165	-0.135	-0.082	-0.085	-0.134	-0.101	1.000	0.720	0.460	0.452	0.515	0.742	0.236	0.562	0.510	0.383	0.383	0.433	0.536	0.173	0.207	0.170	0.130	0.149	0.156	0.182	0.042
T2 I find travelling by train to be relaxing	-0.129	-0.159	-0.126	-0.093	-0.085	-0.137	-0.117	0.720	1.000	0.420	0.442	0.473	0.735	0.212	0.478	0.536	0.347	0.342	0.393	0.505	0.145	0.192	0.199	0.145	0.122	0.176	0.201	0.037
T3 Travelling by train saves me time	-0.208	-0.117	-0.232	-0.104	-0.188	-0.147	0.008	0.460	0.420	1.000	0.216	0.648	0.481	0.274	0.391	0.365	0.573	0.218	0.502	0.384	0.239	0.164	0.063	0.190	0.093	0.064	0.073	0.100
T4 Travelling by train is safe	0.064	-0.068	0.011	0.040	0.123	0.002	-0.128	0.452	0.442	0.216	1.000	0.243	0.436	0.078	0.263	0.234	0.169	0.605	0.216	0.259	0.013	0.071	0.143	0.085	0.150	0.238	0.162	-0.062
T5 I find travelling by train to be flexible	-0.193	-0.130	-0.222	-0.119	-0.207	-0.148	-0.016	0.515	0.473	0.648	0.243	1.000	0.539	0.274	0.444	0.417	0.527	0.243	0.634	0.446	0.239	0.186	0.091	0.193	0.122	0.064	0.090	0.096
T6 Travelling by train is pleasurable	-0.139	-0.157	-0.122	-0.090	-0.087	-0.117	-0.113	0.742	0.735	0.481	0.436	0.539	1.000	0.238	0.508	0.523	0.383	0.379	0.437	0.590	0.177	0.211	0.188	0.124	0.146	0.168	0.213	0.055
T7 Travelling by train gives me prestige	-0.043	0.052	-0.014	0.063	-0.060	0.027	0.436	0.236	0.212	0.274	0.078	0.274	0.238	1.000	0.209	0.201	0.224	0.078	0.218	0.216	0.777	0.095	0.031	0.056	0.059	-0.032	0.021	0.600
B1 I find travelling by BTM to be comfortable	-0.109	-0.103	-0.111	-0.043	-0.108	-0.091	-0.072	0.562	0.478	0.391	0.263	0.444	0.508	0.209	1.000	0.764	0.554	0.442	0.559	0.783	0.302	0.195	0.111	0.153	0.128	0.107	0.126	0.044
B2 I find travelling by BTM to be relaxing	-0.105	-0.067	-0.105	-0.047	-0.112	-0.079	-0.052	0.510	0.536	0.365	0.234	0.417	0.523	0.201	0.764	1.000	0.512	0.416	0.528	0.783	0.299	0.160	0.127	0.128	0.107	0.094	0.126	0.059
B3 Travelling by BTM saves me time	-0.172	-0.106	-0.168	-0.086	-0.160	-0.127	0.006	0.383	0.347	0.573	0.169	0.527	0.383	0.224	0.554	0.512	1.000	0.279	0.711	0.554	0.304	0.147	0.073	0.205	0.086	0.079	0.085	0.083
B4 Travelling by BTM is safe	0.009	-0.052	-0.013	0.074	0.048	-0.011	-0.130	0.383	0.342	0.218	0.605	0.243	0.379	0.078	0.442	0.416	0.279	1.000	0.321	0.435	0.131	0.093	0.096	0.109	0.198	0.174	0.111	-0.060
B5 I find travelling by BTM to be flexible	-0.136	-0.111	-0.163	-0.073	-0.133	-0.106	-0.011	0.433	0.393	0.502	0.216	0.634	0.437	0.218	0.559	0.528	0.711	0.321	1.000	0.571	0.290	0.171	0.093	0.194	0.095	0.111	0.103	0.073
B6 Travelling by BTM is pleasurable	-0.110	-0.092	-0.110	-0.045	-0.105	-0.059	-0.077	0.536	0.505	0.384	0.259	0.446	0.590	0.216	0.783	0.783	0.554	0.435	0.571	1.000	0.304	0.192	0.138	0.139	0.126	0.107	0.162	0.049
B7 Travelling by BTM gives me prestige	-0.060	0.052	-0.028	0.049	-0.091	0.017	0.376	0.173	0.145	0.239	0.013	0.239	0.177	0.777	0.302	0.299	0.304	0.131	0.290	0.304	1.000	0.094	0.014	0.075	0.052	-0.037	0.006	0.537
F1 I find cycling to be comfortable	-0.055	-0.017	-0.086	-0.013	-0.059	-0.054	-0.058	0.207	0.192	0.164	0.071	0.186	0.211	0.095	0.195	0.160	0.147	0.093	0.171	0.192	0.094	1.000	0.654	0.457	0.464	0.457	0.662	0.245
F2 I find cycling to be relaxing	0.004	-0.018	-0.014	-0.001	0.030	-0.033	-0.128	0.170	0.199	0.063	0.143	0.091	0.188	0.031	0.111	0.127	0.073	0.096	0.093	0.138	0.014	0.654	1.000	0.369	0.427	0.521	0.820	0.201
F3 Cycling saves me time	-0.062	-0.052	-0.103	-0.053	-0.078	-0.086	-0.036	0.130	0.145	0.190	0.085	0.193	0.124	0.056	0.153	0.128	0.205	0.109	0.194	0.139	0.075	0.457	0.369	1.000	0.305	0.451	0.378	0.176
F4 Cycling is safe	0.020	0.055	0.018	0.185	0.049	0.030	-0.021	0.149	0.122	0.093	0.150	0.122	0.146	0.059	0.128	0.107	0.086	0.198	0.095	0.126	0.052	0.464	0.427	0.305	1.000	0.405	0.433	0.175
F5 I find cycling to be flexible	0.041	-0.048	-0.015	-0.028	0.138	-0.029	-0.139	0.156	0.176	0.064	0.238	0.064	0.168	-0.032	0.107	0.094	0.079	0.174	0.111	0.107	-0.037	0.457	0.521	0.451	0.405	1.000	0.542	0.106
F6 Cycling is pleasurable	0.010	-0.027	-0.029	-0.011	0.030	-0.010	-0.143	0.182	0.201	0.073	0.162	0.090	0.213	0.021	0.126	0.126	0.085	0.111	0.103	0.162	0.006	0.662	0.820	0.378	0.433	0.542	1.000	0.191
F7 Cycling gives me prestige	-0.024	0.055	0.005	0.053	-0.044	0.017	0.433	0.042	0.037	0.100	-0.062	0.096	0.055	0.600	0.044	0.059	0.083	-0.060	0.073	0.049	0.537	0.245	0.201	0.176	0.175	0.106	0.191	1.000

Car statements

When looking at the correlation matrix for the general car possession and use statements in Table D.2, there can be noticed that four variables are not at least weakly (a correlation greater than 0.3 or below -0.3) correlated with any other variables. Again, the table does not intend to provide information about the specific variables and correlations, explaining the lack of readability.

Table D.2: Correlation matrix of the general car statements

Statement	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 The car gives me the freedom to go wherever I want	1.000	-0.068	0.122	0.396	-0.079	-0.265	-0.158	-0.033	-0.217	0.032	-0.066	0.076	0.309	-0.069	0.026	0.407	-0.118	-0.131	0.316	-0.002	0.032
2 I only use a car if it is really necessary	-0.068	1.000	-0.171	-0.211	0.412	0.286	0.222	0.094	0.153	0.094	-0.030	-0.085	-0.189	-0.063	-0.065	-0.196	0.208	0.248	-0.417	0.184	-0.188
3 It does not make sense to not drive a car in order to benefit the environment, because other people continue to drive their cars	0.122	-0.171	1.000	0.212	-0.233	-0.068	0.087	0.159	0.066	-0.015	0.138	0.077	0.135	0.175	0.103	0.150	-0.171	-0.081	0.260	-0.364	0.617
4 I cannot manage without a car	0.396	-0.211	0.212	1.000	-0.137	-0.375	-0.204	-0.103	-0.307	-0.120	0.000	0.086	0.264	-0.013	0.066	0.368	-0.180	-0.116	0.537	-0.143	0.174
5 With the environment in mind, in the past year I have consciously tried to drive a car less	-0.079	0.412	-0.233	-0.137	1.000	0.283	0.205	0.057	0.129	0.125	0.031	-0.025	-0.159	0.005	-0.018	-0.195	0.262	0.294	-0.262	0.260	-0.242
6 Due to costs, I opt to travel by public transport and bicycle instead of by car	-0.265	0.286	-0.068	-0.375	0.283	1.000	0.434	0.326	0.490	0.139	0.137	0.003	-0.176	0.071	0.016	-0.303	0.240	0.243	-0.392	0.136	-0.060
7 Due to high costs, I drive less with the car than I actually want	-0.158	0.222	0.087	-0.204	0.205	0.434	1.000	0.456	0.559	0.110	0.195	0.022	-0.072	0.103	0.064	-0.122	0.098	0.183	-0.191	0.003	0.078
8 My current financial situation is a reason to postpone the purchase of a (new) car	-0.033	0.094	0.159	-0.103	0.057	0.326	0.456	1.000	0.586	0.109	0.150	0.016	0.014	0.093	0.042	-0.022	0.042	0.104	-0.045	-0.021	0.117
9 Due to costs, it is difficult for me to own a car	-0.217	0.153	0.066	-0.307	0.129	0.490	0.559	0.586	1.000	0.105	0.212	0.008	-0.096	0.114	0.046	-0.170	0.088	0.161	-0.259	0.001	0.050
10 I would consider selling my (second) car if my financial situation worsened	0.032	0.094	-0.015	-0.120	0.125	0.139	0.110	0.109	0.105	1.000	0.010	0.019	0.012	0.004	0.024	-0.029	0.072	0.074	-0.022	0.072	-0.029
11 My friends advised me to purchase a car	-0.066	-0.030	0.138	0.000	0.031	0.137	0.195	0.150	0.212	0.010	1.000	0.134	-0.019	0.188	0.150	-0.036	0.047	0.121	-0.008	-0.081	0.112
12 A car says a lot about someone's personal taste / sense of style	0.076	-0.085	0.077	0.086	-0.025	0.003	0.022	0.016	0.008	0.019	0.134	1.000	0.164	0.117	0.551	0.123	0.078	0.069	0.123	0.046	0.091
13 Driving a car is fun	0.309	-0.189	0.135	0.264	-0.159	-0.176	-0.072	0.014	-0.096	0.012	-0.019	0.164	1.000	0.033	0.147	0.404	-0.162	-0.114	0.318	-0.059	0.117
14 My friends believe that the traffic congestion problem in the Netherlands is greatly exaggerated	-0.069	-0.063	0.175	-0.013	0.005	0.071	0.103	0.093	0.114	0.004	0.188	0.117	0.033	1.000	0.154	-0.026	-0.005	0.199	0.028	-0.135	0.228
15 A car says a lot about a person's status in society	0.026	-0.065	0.103	0.066	-0.018	0.016	0.064	0.042	0.046	0.024	0.150	0.551	0.147	0.154	1.000	0.098	0.072	0.065	0.093	0.014	0.152
16 Driving a car offers many advantages compared to the use of other transport modes	0.407	-0.196	0.150	0.368	-0.195	-0.303	-0.122	-0.022	-0.170	-0.029	-0.036	0.123	0.404	-0.026	0.098	1.000	-0.183	-0.168	0.421	-0.025	0.117
17 In order for accessibility to be improved, it is necessary to sharply reduce car use	-0.118	0.208	-0.171	-0.180	0.262	0.240	0.098	0.042	0.088	0.072	0.047	0.078	-0.162	-0.005	0.072	-0.183	1.000	0.214	-0.241	0.337	-0.129
18 My friends believe that you must only use a car when it is really necessary	-0.131	0.248	-0.081	-0.116	0.294	0.243	0.183	0.104	0.161	0.074	0.121	0.069	-0.114	0.199	0.065	-0.168	0.214	1.000	-0.152	0.146	-0.075
19 If I have to go somewhere, I nearly always go by car	0.316	-0.417	0.260	0.537	-0.262	-0.392	-0.191	-0.045	-0.259	-0.022	-0.008	0.123	0.318	0.028	0.093	0.421	-0.241	-0.152	1.000	-0.240	0.252
20 The environment will benefit if people drive cars less	-0.002	0.184	-0.364	-0.143	0.260	0.136	0.003	-0.021	0.001	0.072	-0.081	0.046	-0.059	-0.135	0.014	-0.025	0.337	0.146	-0.240	1.000	-0.398
21 It is pointless to worry about the environment, because there is nothing you can do about it on your own	0.032	-0.188	0.617	0.174	-0.242	-0.060	0.078	0.117	0.050	-0.029	0.112	0.091	0.117	0.228	0.152	0.117	-0.129	-0.075	0.252	-0.398	1.000

As those three variables are not correlated with any other variables, it is unlikely that they will explain variance of the same underlying factor. For that reason, they are not included in further analyses. In Table D.3 the updated correlation matrix without those statements can be found. Again, correlations of 0.3 and higher and -0.3 and lower are marked. As can be seen, now all variables have at least one weak or stronger correlation with at least one other variable and some clusters of variables correlating with each other can be identified.

Table D.3: Correlation matrix of the general car statements with three variables removed

Statement	1	2	3	4	5	6	7	8	9	12	13	15	16	17	19	20	21
1 The car gives me the freedom to go wherever I want	1.000	-0.068	0.122	0.396	-0.079	-0.265	-0.158	-0.033	-0.217	0.076	0.309	0.026	0.407	-0.118	0.316	-0.002	0.032
2 I only use a car if it is really necessary	-0.068	1.000	-0.171	-0.211	0.412	0.286	0.222	0.094	0.153	-0.085	-0.189	-0.065	-0.196	0.208	-0.417	0.184	-0.188
3 It does not make sense to not drive a car in order to benefit the environment, because other people continue to drive their cars	0.122	-0.171	1.000	0.212	-0.233	-0.068	0.087	0.159	0.066	0.077	0.135	0.103	0.150	-0.171	0.260	-0.364	0.617
4 I cannot manage without a car	0.396	-0.211	0.212	1.000	-0.137	-0.375	-0.204	-0.103	-0.307	0.086	0.264	0.066	0.368	-0.180	0.537	-0.143	0.174
5 With the environment in mind, in the past year I have consciously tried to drive a car less	-0.079	0.412	-0.233	-0.137	1.000	0.283	0.205	0.057	0.129	-0.025	-0.159	-0.018	-0.195	0.262	-0.262	0.260	-0.242
6 Due to costs, I opt to travel by public transport and bicycle instead of by car	-0.265	0.286	-0.068	-0.375	0.283	1.000	0.434	0.326	0.490	0.003	-0.176	0.016	-0.303	0.240	-0.392	0.136	-0.060
7 Due to high costs, I drive less with the car than I actually want to	-0.158	0.222	0.087	-0.204	0.205	0.434	1.000	0.456	0.559	0.022	-0.072	0.064	-0.122	0.098	-0.191	0.003	0.078
8 My current financial situation is a reason to postpone the purchase of a (new) car	-0.033	0.094	0.159	-0.103	0.057	0.326	0.456	1.000	0.586	0.016	0.014	0.042	-0.022	0.042	-0.045	-0.021	0.117
9 Due to costs, it is difficult for me to own a car	-0.217	0.153	0.066	-0.307	0.129	0.490	0.559	0.586	1.000	0.008	-0.096	0.046	-0.170	0.088	-0.259	0.001	0.050
12 A car says a lot about someone's personal taste / sense of style	0.076	-0.085	0.077	0.086	-0.025	0.003	0.022	0.016	0.008	1.000	0.164	0.551	0.123	0.078	0.123	0.046	0.091
13 Driving a car is fun	0.309	-0.189	0.135	0.264	-0.159	-0.176	-0.072	0.014	-0.096	0.164	1.000	0.147	0.404	-0.162	0.318	-0.059	0.117
15 A car says a lot about a person's status in society	0.026	-0.065	0.103	0.066	-0.018	0.016	0.064	0.042	0.046	0.551	0.147	1.000	0.098	0.072	0.093	0.014	0.152
16 Driving a car offers many advantages compared to the use of other transport modes	0.407	-0.196	0.150	0.368	-0.195	-0.303	-0.122	-0.022	-0.170	0.123	0.404	0.098	1.000	-0.183	0.421	-0.025	0.117
17 In order for accessibility to be improved, it is necessary to sharply reduce car use	-0.118	0.208	-0.171	-0.180	0.262	0.240	0.098	0.042	0.088	0.078	-0.162	0.072	-0.183	1.000	-0.241	0.337	-0.129
19 If I have to go somewhere, I nearly always go by car	0.316	-0.417	0.260	0.537	-0.262	-0.392	-0.191	-0.045	-0.259	0.123	0.318	0.093	0.421	-0.241	1.000	-0.240	0.252
20 The environment will benefit if people drive cars less frequently	-0.002	0.184	-0.364	-0.143	0.260	0.136	0.003	-0.021	0.001	0.046	-0.059	0.014	-0.025	0.337	-0.240	1.000	-0.398
21 It is pointless to worry about the environment, because there is nothing you can do about it on your own	0.032	-0.188	0.617	0.174	-0.242	-0.060	0.078	0.117	0.050	0.091	0.117	0.152	0.117	-0.129	0.252	-0.398	1.000

Accessibility statements

As can be seen in Table D.4, all statements have at least a weak correlation with all other variables. Hence, all statements will be included in the factor analysis. Furthermore, this might indicate that there is just one factor underlying the statements. The factor analysis is still performed such that this expectation can be proved.

Table D.4: Correlation matrix of the accessibility statements

Statement	H1	H2	H3	H4	H5
H1 Presence of train station	1.000	0.653	0.439	0.447	0.563
H2 Presence of BTM stop	0.653	1.000	0.435	0.497	0.589
H3 Distance to highway entry or exit	0.439	0.435	1.000	0.303	0.446
H4 Cycling distance to workplace	0.447	0.497	0.303	1.000	0.478
H5 Walking/cycling distance to shops	0.563	0.589	0.446	0.478	1.000

Step 3 - Type of analysis

There are various ways factor analyses can be performed. Among the options are varying extraction methods and various ways of rotation. The used methods will be discussed briefly below.

Extraction method

There are various extraction methods which can be used in different situations with different goals. The factor analyses of the mode use, car and accessibility statements are performed with Principal axis factoring (PAF) as extraction method. PAF is a method that aims to identify latent constructs based on the covariance between items (Aguiar, Vasconcelos, & Barreiro, 2019). It seeks the least number of factors that explain the common variance of a set of variables. Rather than principal component analysis, an other often used extraction method, PAF is only focused on shared variance and not on sources of error for individual measurements (Mabel & Olayemi, 2020).

Rotation of the factor matrix

The factor matrix was rotated with the varimax method to make the results easier to interpret. Varimax is an orthogonal rotation method that minimises the number of factors a variable has a high loading on, and maximises the number of factors a variable has zero or small loading on (Abdi, 2003). This is done by iteratively searching for a rotation of the original factors until the variance of the loadings is maximised (Abdi, 2003). As varimax uses an iterative process, the number of iterations can be changed. The initial setting of 25 iterations proved to be sufficient for all three factor analyses, as convergence was reached in six iterations.

Step 4 - Determine the number of factors to retain

The fourth step is to determine how many factors should be extracted. There are various rules of thumb for determining the optimal number of factors:

- Retain factors with an eigenvalue larger than 1;
- Keep the factors that account for 70-80% of the variance;
- Make a scree plot and keep all factors before the breaking point (Finch, 2013).

Mode-use statements

The various rules of thumb show varying results for the mode-use statements. As can be seen in Figure D.1, the breaking point in the scree plot indicates that five factors would suffice. However, as can partially be seen in the scree plot and more clear in Table D.5 there are six factors with an eigenvalue higher than 1. An eigenvalue of 1 or higher indicates that the factor explains more variance than the single observed variables do, indicating that it represents an underlying factor. Retaining six factors however does not meet the rule of thumb that the number of factors should explain between 70 and 80% of the variance. To reach at least 70% an additional factor is needed.

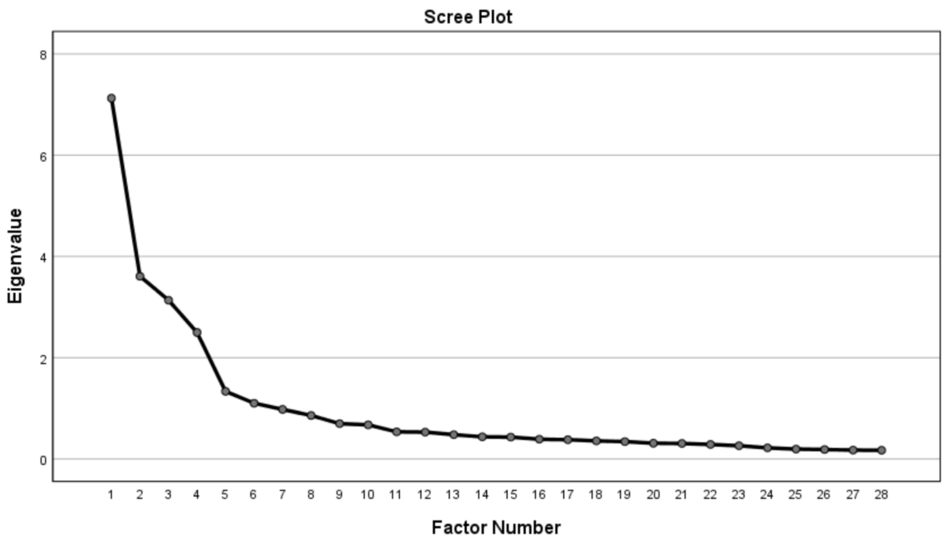

Figure D.1: Scree plot of the mode use statements factor analysis

Table D.5: Explained variance by number of factors for the mode use statement factor analysis

Factor	Total	Initial eigenvalues	
		% of variance	Cumulative %
1	7.116	25.416	25.416
2	3.612	12.899	38.315
3	3.130	11.179	49.494
4	2.502	8.937	58.431
5	1.339	4.782	63.213
6	1.103	3.940	67.153
7	0.978	3.493	70.646

As the rules of thumb showed varying results for the factor analysis of the mode use statements, the varying number of factors were analysed. Retaining seven factors turned out to give the best results for the factor analysis on mode use statements. The principal axis factor extraction with varimax rotation and retaining seven factors yields the results in Table D.6. Factor loadings below 0.5 were removed from the table to make it easier to interpret the factors. This value is arbitrarily chosen as there are no strict guidelines. Since every variable has a factor loading of at least 0.5 at one of the factors, that boundary value was chosen to make the interpretation easier. This does not mean that the variables only have a factor loading on one factor.

Table D.6: Rotated factor matrix of the mode use statements factor analysis

	Factor						
Mode use statement	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Cycling is pleasurable	.853						
Cycling is relaxing	.839						
Cycling is comfortable	.771						
Cycling is flexible	.656						
Cycling is safe	.548						
Cycling saves time	.522						
Travelling by car is pleasurable		.816					
Travelling by car is comfortable		.770					
Travelling by car is relaxing		.728					
Travelling by car is flexible		.633					
Travelling by car is safe		.632					
Travelling by car saves time		.599					
Travelling by BTM is pleasurable			.804				
Travelling by BTM is relaxing			.786				
Travelling by BTM is comfortable			.775				
Travelling by train gives prestige				.878			
Travelling by BTM gives prestige				.793			
Cycling gives prestige				.712			
Travelling by car gives prestige				.553			
Travelling by train is flexible					.674		
Travelling by train saves time					.654		
Travelling by BTM saves time					.648		
Travelling by BTM is flexible					.645		
Travelling by train is pleasurable						.736	
Travelling by train is relaxing						.718	
Travelling by train is comfortable						.695	
Travelling by train is safe							.713
Travelling BTM is safe							.658

Extraction method: Principal Axis Factoring

One downside of having seven factors is that the seventh factor covers only two variables. Normally, at least three variables are expected to be included in a factor. However, the Cronbach's alpha (CA) of the factor is 0.754. The CA is a measure that indicates the internal consistency of a group of variables, thereby it is considered to be a measure of reliability. The CA values for the eight factors can be found in Table D.7. The first six factors all have a CA of greater than 0.8, which can be considered as boundary value for good internal consistency. A value between 0.7 and 0.8 is generally considered to be acceptable. Sometimes, a value of 0.9 is too high, as it indicates that the variables measure the same information. To check whether this is the case, the correlations between the three statements of factor 3 were checked. All of the correlations had a value between 0.75 and 0.8. While indicating a strong correlation, this is considered to be low enough to retain the factor as the CA is just over 0.9.

Table D.7: Internal factor consistency of factors identified by the mode use factor analysis

Factor	Cronbach's Alpha
1	0.848
2	0.845
3	0.912
4	0.803
5	0.856
6	0.891
7	0.752

Car possession and use statements

For the car possession and use related statements, the various rules of thumb also show different results. When looking at the scree plot in Figure D.2, it is not that easy to determine the breaking point, but it seems to be around six factors. Following from the scree plot too, five factors should be retained when using the eigenvalue rule of thumb. When using the rule of thumb about the percentage of variance explained, eight factors should be retained as shown in Table D.8.

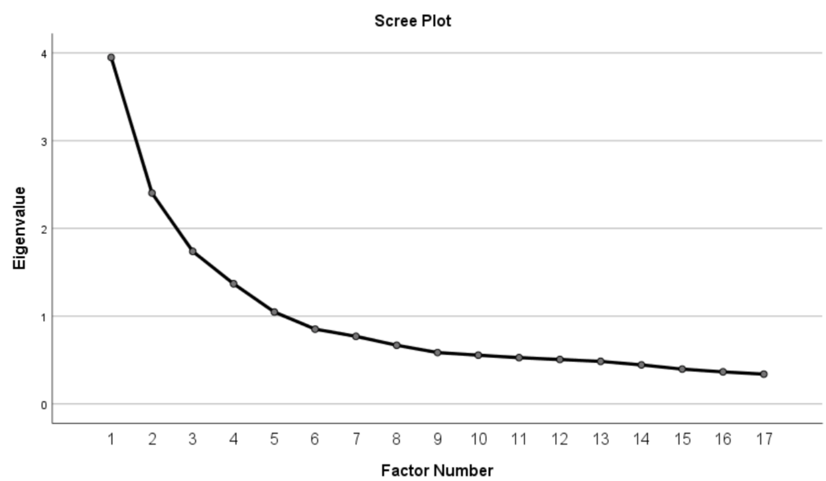

Figure D.2: Scree plot of the car possession and use statements factor analysis

Table D.8: Explained variance by number of factors for the car statements factor analysis

Factor	Total	Initial eigenvalues	
		% of variance	Cumulative %
1	3.951	23.243	23.243
2	2.399	14.112	37.356
3	1.738	10.222	47.577
4	1.370	8.061	55.639
5	1.048	6.167	61.805
6	0.849	4.995	66.800
7	0.770	4.529	71.329

After investigating solutions with five, six and eight factors, retaining five factors seemed to make the most sense. By applying varimax rotation and sorting the variables based on factor size, Table D.9 was obtained. To make the table easy to interpret, again there was tried to choose a boundary value such that all statements load on at least one factor. This value proved to be 0.400. Hence, all values below 0.400 were removed to obtain an easy to interpret factor matrix.

To check whether the factor have sufficient internal consistency, which is especially necessary as one of the factors has just two factors, the Cronbach's alpha value is determined for all factors. The results of the check for internal consistency can be found in Table D.10. Before the values could be requested in SPSS, one of the statements has to be adjusted. To test the internal consistency, the variables loading high on a factor have to share the same direction. This is not the case for the fourth factor as one of the statements has a negative direction. To solve this, the loading of that statements is turned into a positive loading by turning around the scores. Where 1 was strongly disagreeing and 5 was strongly agreeing, after turning around the scale it was the other way around. By doing so, the three loadings of the statements from which shared variance is captured by factor 3 now have the same direction. The Cronbach's alpha values show that the factors are all acceptable, with an exception of factor 3. As the value of 0.561 is considerably lower than the generally acceptable value of 0.7, this factor will not be included in further analyses.

Table D.9: Rotated factor matrix general car statements factor analysis

	Factor				
General car statement	**1**	**2**	**3**	**4**	**5**
Due to costs it is difficult for me to own a car	.825				
My current financial situation is a reason to postpone the purchase of a car	.694				
Due to high costs I drive less car than I actually want to	.657				
Due to costs I use PT and bicycle instead of cars	.452				
Driving a car offers many advantages compared to other modes		.634			
The car gives me the freedom to go wherever I want		.574			
I cannot manage without a car		.560			
If I have to go somewhere I nearly always go by car		.519			
Driving a car is fun		.463			
With the environment in mind in the past year I have tried to drive less			.626		
I only use a car if it is really necessary			.583		
In order for accessibility to be improved it is necessary to sharply reduce car use			.432		
My friends believe that you only must use a car when it is really necessary			.402		
It is pointless to worry about the environment, as there is nothing you can do about it on your own				.758	
It does not make sense to not drive a car in order to benefit the environment because other people continue to drive				.736	
The environment will benefit if people drive cars less frequent				-.469	
A car says a lot about someone's personal taste					.738
A car says a lot about a person's status in society					.721

Extraction method: Principal Axis Factoring

Table D.10: Internal factor consistency of factors identified by the car statement factor analysis

Factor	**Cronbach's Alpha**
1	0.781
2	0.737
3	0.561
4	0.719
5	0.711

ACCESSIBILITY STATEMENTS

The scree plot (see Figure D.3) for the accessibility statements supports what already was expected based on the correlation matrix, there is just one underlying variable for the five accessibility statements. This one factor does 'only' explain 59 % of the variance (see Table D.11, but as the other rules of thumb clearly indicate an one factor solution, the 'lower' variance is accepted. That this is indeed a good choice becomes apparent when looking at the factor matrix in Table D.12. All statements have a high loading on the factor and the factor has high internal consistency with a CA of 0.825.

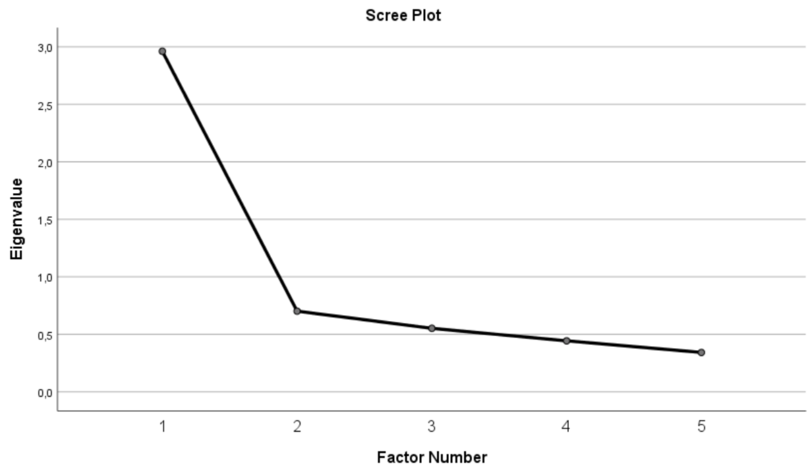

Figure D.3: Scree plot of the accessibility statements

Table D.11: Explained variance by number of factors for the accessibility statements

Factor	Total	Initial eigenvalues	
		% of variance	Cumulative %
1	2.961	59.224	59.224
2	.701	14.028	73.252

Table D.12: Factor matrix of the accessibility statements

	Factor
Accessibility statement	**1**
The presence of a BTM station withing walking distance was an important factor in my choice to reside at my current address	.812
The presence of a train station within walking or cycling distance was an important factor in my choice to reside at my current address	.775
A short walking and/or cycling distance to shops was an important factor in my choice to reside at my current address	.752
The cycling distance to my workplace was an important factor in my choice to reside at my current address	.599
A short distance to a highway entry or exit ramp was an important factor in my choice to reside at my current address	.555

Extraction method: Principal Axis Factoring

Step 5 - Generating factor scores

Before the identified factors can be used in further analyses, scores must be created to represent each individual's placement on the factors (DiStefano, Zhu, & Mindrila, 2009). There are multiple ways to create factor scores: refined methods using technical analyses and non-refined methods involving non-sophisticated procedures (DiStefano et al., 2009). This study will use the non-refined method of summing scores of items with a factor loading above a cut-off value. By doing so, only the most relevant statements covered by a factor are included in the factor score. The cut-off value to be used is an arbitrary decision. For reasons of simplicity, the cut-off values are chosen such that every statements has a high factor loading on exactly one factor, following the varimax rotation. For the mode-use statements and distance variables, this results in a cut-off value of 0.5, for the car statements a value of 0.4 is used. After the scores of all statements loading on a factor have been summed, the average is computed. This is done to retain the scale metric of the original statements, allowing for easier interpretation (DiStefano et al., 2009). In this case, the statement related factors will follow the same five level Likert scale as used on the individual statements. The scale will be followed in the sense that 1 is strongly disagreeing and 5 is strongly agreeing. The scores will not be rounded to the nearest integer, as that results in the unnecessary loss of information.

The factor scores are calculated in SPSS with *transform- compute variable* with the numeric expression being the mean of the included statements. Following step 4, seven factors are generated for the mode-use statements, four for the car statements and one for the accessibility statements.

E

Level of Urbanisation

The level of urbanisation included in the MPN data is the same as the one used by Statistics Netherlands. It has five different levels and is based on address density. For all addresses, the address density is calculated based on the number of addresses within a radius of 1 kilometre around that address divided by the area of the circle. Subsequently, the average address density of an area can be determined by taking the average address density of all addresses within that area. The size of the area can for example be the postal code-4 level or a municipality. Based on the five levels of varying urbanity the area is then classified. Figure E.1 visualises the method by Statistics Netherlands to determine the level of urbanisation.

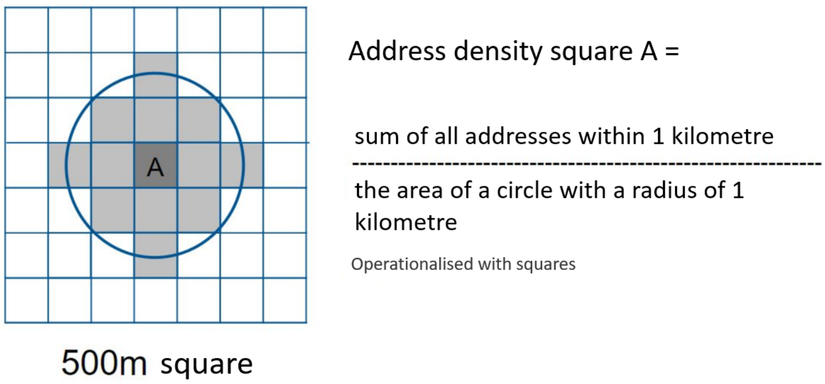

Figure E.1: Level of urbanisation based on address density (adaptation of (Kager, personal communication, May 21 2021)

As mentioned, the method of Statistics Netherlands uses a square of 1 kilometre. When using small spatial scales to classify areas, like for example squares of 500x500 meter, this leads to a classification which does not necessarily make sense when considering mobility. The left side of Figure E.2 shows the classification of a section of the Netherlands around Amsterdam. As can be seen, the centres of quite some cities and villages are classified as highly urbanised. The centres of villages like Bussum (34,000 inhabitants) and Huizen (41,000 inhabitants) have the same level of urbanisation as the city centre of Amsterdam. However, one can expect major differences between them in terms of mobility. When looking at municipality level, the few squares with high levels of urbanisation are cancelled out with squares outside the city/village centres. That however could result in classifications that do not resemble the variations within a municipality. For example, a large city within a large municipality with also a lot of small villages gets a lower level of urbanisation than might be expected, and the smaller villages get a higher level of urbanisation than might be expected.

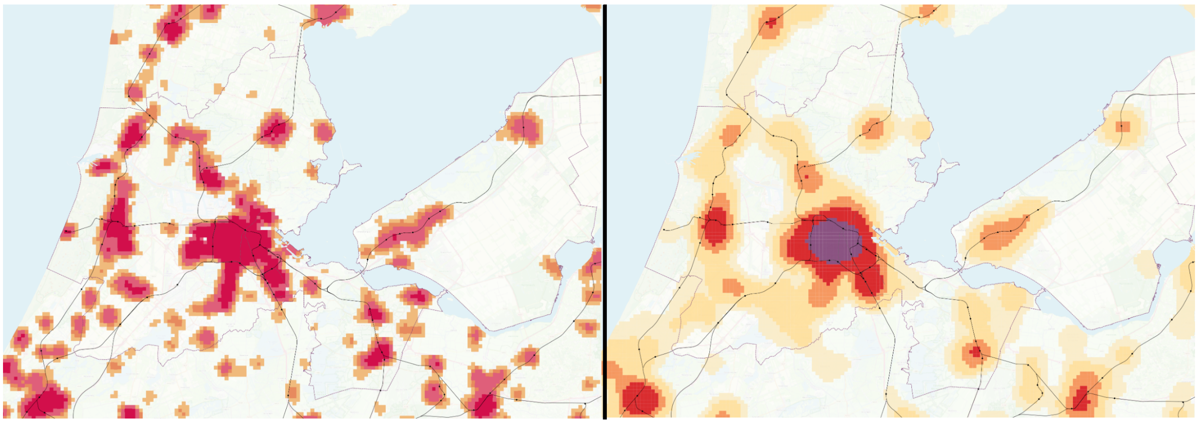

Figure E.2: Comparison of the two methods to determine the level of urbanisation (adaptation of (the five level classification of Statistics Netherlands on the left, the six level classification by Studio Bereikbaar on the right) (Kager, personal communication, May 21 2021)

When using the level of urbanisation for a study with focus on mobility another method of classification might be a better choice. An alternative method is one developed by Studio Bereikbaar. Their definition of level of urbanisation is based on the number of houses and jobs that can be reached within cycling distance, which is assumed to be 3 kilometres. Here, the weight of jobs and houses between 1.5 and 3 kilometre linearly decreases, as visualised in Figure E.3. Instead of five, this classification uses six classes: rural, village, low suburban, suburban, urban, metropolitan. The results of this classification on squares of 500x500 meter can be seen in the right hand of Figure E.2. When considering mobility, this classification appears to make more sense, as there are clear differences between very large cities, smaller cities, villages and rural areas. Further, the classification is available on postal code 4 (PC4) level rather than the municipality level of the Statistics Netherlands classification included in the MPN. PC4 areas are areas that in general are smaller than municipalities, and follow another mapping. Hence, a postal code can cover parts of multiple municipalities, and a municipality contains (parts of) various PC4 areas. By having a more disaggregated scale, the accuracy of the level of urbanisation increases.

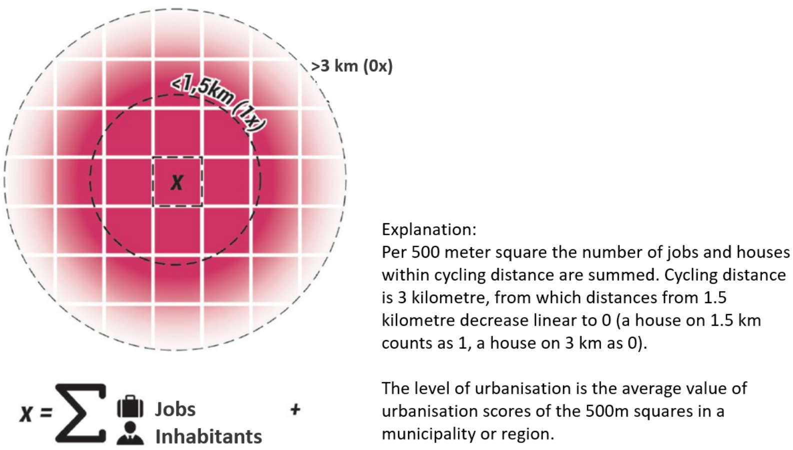

Figure E.3: Level of urbanisation based on jobs and inhabitants (adaptation of (Kager, personal communication, May 21 2021)

F

FULL RESULTS MMR ANALYSIS

The significant results of the MMR analyses with urbanity and level of urbanisation as moderator variables have been discussed in the main text. This appendix shows the step-by-step results of the analyses. In both analyses, the different groups of independent variables have been added step-by-step to be able to investigate changes in coefficients and the significance of them when more variables are added. In the first model, only the level of urbanisation is included as independent variable. In the second model the sociodemographic variables are added to the model. The third model includes all attitudes. The fourth model is the last and includes the moderation effects of level of urbanisation with all included independent variables. After the full model results have been presented, the significant moderation effects following from both models will be discussed briefly.

F.1. RESULTS OF THE MMR ANALYSIS WITH URBANITY AS MODERATOR

Tables F.1, F.2 and F.3 present the full results of the MMR analysis. Significant coefficients ($P <= 0.05$ or $P <= 0.01$) are marked with (an) asterisk(s). The intercepts indicate the mean value for a dependent variable given that all independent variables have a value of zero. Hence, the intercepts in model 1 indicate the mean distance travelled (in total or by specific mode) for inhabitants of non-urban areas. Model 1 also shows that there are no significant differences between urban and non-urban areas when looking at the total average daily distance travelled, but that there are differences between the modes used to do so. Model 2 makes clear that there are quite a lot of differences in travel behaviour between individuals with different sociodemographic characteristics. Further, there are some attitudes that also explain some of the dependent variables as proven by model 3. Remarkably, adding the sociodemographics and attitudes does turn the coefficients of urbanity insignificant.

Table F.1: MMR with urbanity - models 1 and 2

Model	Independent variables	Total	Car	Train	BTM	Bicycle	Walking	Other
1	Intercept	38.270*	28.561*	4.869*	0.855*	2.059*	0.219*	1.705*
	Urbanity (ref = non-urban)	-0.433	-7.479*	6.468*	0.632**	0.792*	0.216*	-1.062
2	Intercept	10.324**	-1.123	5.185**	2.717*	2.099*	0.415*	1.031
	Urbanity (ref = non-urban)	-2.684	-5.350*	2.817*	0.226	0.297	0.186*	-0.861
	Gender (ref = female)	10.506*	6.754*	1.906*	-0.183	0.172	-0.027	1.883*
	Dutch ethnicity (ref = non-Dutch)	3.929	2.033	1.868	-0.633	0.289	-0.015	0.388
	Unknown ethnicity (ref = non-Dutch)	4.232	-4.090	3.874	1.841	-0.061	-0.017	2.684
	Job (ref = unemployed)	11.504*	7.546*	2.516**	-0.038	0.351	-0.095**	1.224**
	Student (ref = unemployed)	14.518*	-0.083	13.092*	1.349*	0.728**	-0.154**	-0.414
	Level of education	5.077*	3.490*	1.803*	-0.025	0.332*	0.011	-0.536
	Drivers license (ref = no license)	4.914	3.628	1.327	-0.276	0.093	-0.080	0.222
	Adults (ref = young adult)	-4.610**	-1.247	-2.990*	-0.990*	0.568*	0.041	0.008
	Elderly (ref = young adult)	-10.998*	-7.250*	-3.916**	-0.873**	1.024*	0.145*	-0.128
	Car available (ref = no car available)	5.194*	14.127*	-6.254*	-0.827*	-1.663*	-0.072**	-0.118
	Multi person hh (ref = single person hh)	-1.958	1.343	-2.494**	-0.661**	-0.603*	-0.072	0.530
	Multi person hh with children (ref=single person hh)	-7.096*	-2.973	-3.956*	-0.424	-0.200	-0.080**	0.537
	Benchmark (ref = below benchmark)	4.443	4.352**	0.667	0.594	-0.234	0.036	-0.972
	Above benchmark (ref = below benchmark)	8.591*	8.259*	1.423	0.940*	-0.384	0.046	-1.692*
	Unknown income (ref = below benchmark)	5.366**	7.427*	-1.527	0.960*	-0.207	-0.025	-1.263

* P <= 0.01
** P <= 0.05

Table F.2: MMR with urbanity - model 3

Model	Independent variables	Total	Car	Train	BTM	Bicycle	Walking	Other
3	Intercept	18.474*	10.322**	2.292	2.327*	1.747*	0.352*	1.435
	Urbanity (ref = non-urban)	-1.767	-2.964	1.595	0.203	0.024	0.160*	-0.785
	Gender (ref = female)	9.639*	5.893*	1.632**	-0.120	0.299**	-0.015	1.949*
	Dutch ethnicity (ref = non-Dutch)	2.987	1.144	2.150	-0.593	0.044	-0.017	0.260
	Unknown ethnicity (ref = non-Dutch)	3.710	-4.179	4.044	1.791	-0.539	-0.020	2.614
	Job (ref = unemployed)	10.633*	6.359*	2.744**	0.042	0.343	-0.092**	1.237**
	Student (ref = unemployed)	14.174*	1.127	11.805*	1.304*	0.377	-0.182*	-0.257
	Level of education	3.663*	2.769*	1.236**	0.048	0.165	-0.001	-0.555
	Drivers license (ref = no license)	3.227	0.429	2.531	-0.196	0.446	-0.049	0.066
	Adults (ref = young adult)	-6.163*	-2.768	-2.793**	-0.983*	0.337	0.040	0.003
	Elderly (ref = young adult)	-12.093*	-7.162*	-4.773*	-1.005**	0.608**	0.118**	0.121
	Car available (ref = no car available)	3.860**	9.573*	-3.690*	-0.741*	-0.904*	-0.017	-0.362
	Multi person hh (ref = single person hh)	-2.513	-0.144	-1.671	-0.619**	-0.423	-0.058	0.401
	Multi person hh with children (ref=single person hh)	-7.065*	-3.947**	-3.193*	-0.425	0.074	-0.059	0.486
	Benchmark (ref = below benchmark)	3.349	2.869	0.919	0.636	-0.157	0.047	-0.965
	Above benchmark (ref = below benchmark)	7.128*	6.473*	1.683	1.049*	-0.422	0.051	-1.705**
	Unknown income (ref = below benchmark)	4.851	6.108**	-0.889	1.023*	-0.112	-0.012	-1.266
	Car attitude	-0.241	-0.436	-0.549	0.014	-0.008	-0.026	0.763
	Bicycle attitude	1.594	0.653	-0.008	-0.137	1.016*	0.019	0.052
	BTM attitude	-4.541*	-2.467**	-2.732*	0.418*	0.070	0.027	0.143
	Prestige attitude	-0.505	0.065	-0.477	-0.182	-0.028	0.000	0.118
	Train attitude	3.025*	2.291**	0.677	0.050	0.062	-0.017	-0.038
	PT efficiency attitude	-1.799	-2.856*	1.671*	-0.065	-0.405*	-0.005	-0.139
	PT safety attitude	3.722*	1.732	2.536*	-0.087	0.034	0.004	-0.496
	General car attitude (car loving)	2.086	5.902*	-2.694*	0.035	-1.260*	-0.048**	0.151
	Cost of driving attitude	-1.514	-2.394*	0.722	0.196	0.007	0.017	-0.063
	Environmental attitude (environmental sceptisicsm)	-0.755	-0.519	0.076	0.105	-0.004	-0.032**	-0.382
	Status sensitive	0.519	0.043	0.778	-0.015	0.058	0.010	-0.354
	Accessibility attitude	0.154	-0.576	0.566	0.006	0.062	0.033**	0.063

* P <= 0.01
** P <= 0.05

Table F.3: MMR with urbanity - model 4

Model	Independent variables	Total	Car	Train	BTM	Bicycle	Walking	Other
4	Intercept	18.456*	10.040**	2.655	2.952*	1.612*	0.403*	0.796
	Urbanity (ref = non-urban)	-8.605	-5.516	-3.781	-2.986	1.101	-0.068	2.645
	Gender (ref = female)	9.457*	5.596*	1.535	-0.127	0.341**	-0.029	2.141*
	Dutch ethnicity (ref = non-Dutch)	2.368	1.349	1.056	-0.897**	0.190	-0.062	0.732
	Unknown ethnicity (ref = non-Dutch)	-1.356	-4.159	-3.224	2.667**	-0.577	-0.039	3.977
	Job (ref = unemployed)	9.152*	5.771*	1.824	-0.080	0.310	-0.103*	1.430**
	Student (ref = unemployed)	15.136*	0.276	13.247*	1.445*	0.301	-0.171**	0.037
	Level of education	3.857*	3.005*	1.382**	0.037	0.201	-0.021	-0.749**
	Drivers license (ref = no license)	2.055	0.646	1.634	-0.470	0.417	-0.046	-0.126
	Adults (ref = young adult)	-4.286	-1.528	-2.175	-0.997*	0.276	0.027	0.111
	Elderly (ref = young adult)	-10.999*	-6.463**	-4.608*	-1.024**	0.634	0.098	0.363
	Car available (ref = no car available)	3.962**	8.250*	-2.456**	-0.684*	-0.934*	0.025	-0.239
	Multi person hh (ref = single person hh)	-0.683	1.481	-1.992	-0.454	-0.518**	-0.017	0.816
	Multi person hh with children (ref=single person hh)	-5.460**	-2.879	-3.341*	-0.128	-0.026	-0.025	0.939
	Benchmark (ref = below benchmark)	2.658	1.221	2.267	0.328	-0.040	-0.014	-1.103
	Above benchmark (ref = below benchmark)	6.823*	5.964*	2.374	0.737**	-0.263	0.030	-2.020*
	Unknown income (ref = below benchmark)	3.788	4.308	0.090	0.777	0.102	-0.018	-1.470
	Car attitude	-0.032	0.254	-0.974	-0.032	-0.005	-0.049	0.774
	Bicycle attitude	1.788	0.494	0.223	-0.062	0.999*	0.023	0.111
	BTM attitude	-4.100*	-2.765**	-1.960*	0.421**	0.042	0.028	0.134
	Prestige attitude	-0.330	0.485	-0.748	-0.133	-0.093	-0.008	0.166
	Train attitude	2.177	1.843	0.392	-0.039	-0.017	-0.018	0.016
	PT efficiency attitude	-1.870	-2.154	0.989	-0.188	-0.264**	-0.011	-0.242
	PT safety attitude	4.460*	2.449**	2.472*	0.014	0.101	0.008	-0.583
	General car attitude (car loving)	2.676	5.989*	-2.161*	0.001	-1.313*	-0.052**	0.212
	Cost of driving attitude	-1.101	-2.043**	0.911	0.142	0.017	0.007	-0.135
	Environmental attitude (environmental sceptisicsm)	-0.349	-0.233	0.277	0.069	-0.007	-0.033	-0.424
	Status sensitive attitude	0.056	-0.097	0.444	-0.041	0.106	0.006	-0.362
	Accessibility attitude	-0.213	-0.794	0.387	0.024	0.039	0.023	0.108
	Urban × Adults	-7.404	-6.405	-1.304	0.502	0.201	0.093	-0.491
	Urban × Elderly	-1.109	-2.496	2.687	0.719	-0.616	0.187	-1.591
	Urban × Male	2.859	2.973	1.596	-0.020	-0.141	0.140	-1.689
	Urban × Dutch ethnicity	1.540	-1.247	3.594	1.502	-0.681	0.213	-1.842
	Urban * Unknown ethnicity	21.219	-1.113	30.473*	-3.378	-0.183	0.128	-4.708
	Urban × Benchmark income	2.750	7.829	-6.840**	1.337	-0.885	0.365*	0.945
	Urban × Above benchmark income	1.145	1.326	-2.609	1.198	-0.942	0.086	2.086
	Urban × Unknown income	6.494	10.396	-4.857	1.128	-1.441**	-0.020	1.288
	Urban × Education	-1.112	-1.063	-1.494	0.172	-0.138	0.143**	1.269
	Urban × Drivers license	2.958	-2.054	3.856	0.773	0.036	-0.020	0.367
	Urban * Job	10.611	5.134	6.172**	0.880	0.213	0.017	-1.807
	Urban × Student	-0.351	5.649	-3.763	-0.272	-0.005	-0.020	-1.940
	Urban × Multi person hh	-8.535	-6.366	-0.579	-0.434	0.462	-0.165	-1.453
	Urban × Multi person hh with children	-7.133	-4.666	0.907	-1.869**	0.471	-0.122	-1.853
	Urban × Car available	1.335	8.058	-6.379**	0.016	0.175	-0.266*	-0.269
	Urban × Car attitude	-0.726	-3.628	2.985	0.201	0.126	0.132	-0.542
	Urban × Bicycle attitude	-1.879	0.794	-1.681	-0.479	-0.052	-0.020	-0.440
	Urban * BTM attitude	-3.376	1.125	-4.814*	0.017	0.212	-0.019	0.103
	Urban × Prestige attitude	-1.625	-3.489	1.751	-0.230	0.434	0.062	-0.154
	Urban × Train attitude	5.054	2.453	1.750	0.606	0.539	0.020	-0.313
	Urban × PT efficiency attitude	1.023	-3.374	3.901**	0.742	-0.976*	0.007	0.723
	Urban × PT safety attitude	-5.857	-5.061	-0.154	-0.730	-0.280	-0.016	0.384
	Urban × General car attitude (car loving)	-3.503	-1.358	-2.561	0.318	0.143	0.070	-0.115
	Urban × Cost of driving attitude	-2.263	-1.217	-1.832	0.396	-0.057	0.041	0.406
	Urban × Environmental scepticism	-2.619	-2.193	-1.018	0.100	0.046	0.000	0.446
	Urban × Status sensitive	2.197	1.044	1.266	0.141	-0.261	0.033	-0.026
	Urban × Accessibility attitude	1.902	0.987	1.192	-0.202	0.102	0.073**	-0.250

* P <= 0.01
** P <= 0.05

The set of independent variables is not equally good in explaining the variance of the various dependent variables as indicated by the adjusted R-squared values in Table F.4. As travel behaviour is a complex phenomenon, it was not expected that the models would have very high R-squared values. However, the values for BTM, walking and other are really low, indicating that the sets of independent variables explains just a small part of the variance. For BTM this could be a result of merging three modes, just as is done for the 'other' category but with more modes. Merging quite different modes, in terms of availability, speed and capacity, among others, could create mean values that do not resemble any of the modes. The low score for walking could be explained by the fact that the focus of this study is on differences between various levels of urbanisation. This is a relative high spatial scope whereas walking is only used for short distances and therefore might better match with a study focusing on local travel behaviour, with more spatial detailed built environment variables. Further, it is interesting to see that model 4 does only result in an increased adjusted R-squared value for train, BTM and walking distance. When looking at Table F.3 that does make sense given that these have significant moderation effects, whereas the others have none, with exception of cycling distance.

Table F.4: Adjusted R-squared values for the full urbanity MMR analysis

Model	Total	Car	Train	BTM	Bicycle	Walking	Other
1	0.000	0.005	0.012	0.002	0.005	0.013	0.001
2	0.084	0.106	0.091	0.034	0.043	0.032	0.009
3	0.096	0.130	0.114	0.036	0.120	0.040	0.009
4	0.095	0.129	0.123	0.037	0.119	0.049	0.004

F.2. RESULTS OF THE MMR ANALYSIS WITH LOU AS MODERATOR VARIABLE

To test whether besides differences between urban and non-urban areas there also are differences between the levels within an urban or non-urban area, a MMR analysis is performed with level of urbanisation as moderator. In Table 4.3 the results of the MMR are given for all dependent variables. In model 1, the intercepts present the mean distance travelled in total or by a specific mode when the level of urbanisation has a value of 0, which equals to the rural level. With increasing urbanisation, the total distance travelled decreases, and so does the distance travelled by car. On the other hand, the distances travelled by train, BTM, bicycle and walking increase as the urbanisation increases. When adding the sociodemographics in model 2 and the attitudes in model 3, the level of urbanisation becomes insignificant for train, BTM and bicycle. As no moderation effect is significant in the model with bicycle as dependent variable and the level of urbanisation is neither significant, there could be concluded that cycling levels are not significantly different between various levels of urbanisation in the Netherlands. Another remarkable observation is that the direction of the coefficient for level of urbanisation is changed when adding the interaction effects to the model. Instead of the logical negative direction, the coefficient turns positive, and also insignificant. That is something that can be observed more often when adding interaction variables to a main model. As the coefficient is conditional on the other coefficients, it is not surprising that the main level of urbanisation variable turns insignificant and is counter intuitive.

Table F.5: MMR with level of urbanisation - models 1 and 2

Model	Independent variables	Total	Car	Train	BTM	Bicycle	Walking	Other
1	Intercept	40.980*	32.898*	3.022*	0.753*	1.649*	0.147*	2.510*
	Level of Urbanisation	-1.464**	-2.904*	1.508*	0.106	0.282*	0.056*	-0.512*
2	Intercept	15.308**	3.686	4.589	2.823*	1.684*	0.372*	2.155
	Level of urbanisation	-1.964*	-2.353*	0.649**	0.005	0.176**	0.044*	-0.485**
	Gender (ref = female)	10.471*	6.712*	1.918**	-0.183	0.175	-0.026	1.874*
	Dutch ethnicity (ref = non-Dutch)	3.263	1.477	1.870	-0.656	0.342	-0.015	0.245
	Unknown ethnicity (ref = non-Dutch)	4.118	-4.202	3.890	1.838	-0.051	-0.016	2.658
	Job (ref = unemployed)	11.637*	7.636*	2.534**	-0.031	0.341	-0.094**	1.251**
	Student (ref = unemployed)	14.586*	0.032	13.039*	1.346**	0.721**	-0.158**	-0.394
	Level of education	5.294*	3.627*	1.844*	-0.013	0.316**	0.014	-0.494
	Drivers license (ref = no license)	4.683	3.448	1.316	-0.285	0.111	-0.080	0.174
	Adults (ref = young adult)	-4.662**	-1.218	-3.055**	-0.999*	0.570**	0.037	0.004
	Elderly (ref = young adult)	-11.222*	-7.224**	-4.108**	-0.903**	1.036*	0.133**	-0.156
	Car available (ref = no car available)	4.703**	13.779*	-6.308*	-0.850*	-1.626*	-0.075**	-0.216
	Multi person hh (ref = single person hh)	-2.573	0.968	-2.618**	-0.697**	-0.558**	-0.080**	0.411
	Multi person hh with children (ref=single person hh)	-8.328*	-3.827	-4.112*	-0.485	-0.107	-0.089**	0.291
	Benchmark (ref = below benchmark)	4.590	4.528**	0.619	0.594	-0.248	0.033	-0.936
	Above benchmark (ref = below benchmark)	8.616*	8.322*	1.385	0.937**	-0.388	0.043	-1.683**
	Unknown income (ref = below benchmark)	5.144	7.191**	-1.481	0.958**	-0.188	-0.022	-1.315

* P <= 0.01
** P <= 0.05

Table F.6: MMR with level of urbanisation - model 3

Model	Independent variables	Total	Car	Train	BTM	Bicycle	Walking	Other
3	Intercept	22.711*	13.610**	2.300	2.433*	1.585**	0.329*	2.456
	Level of urbanisation	-1.739**	-1.596**	0.245	-0.005	0.060	0.033*	-0.475**
	Gender (ref = female)	9.637*	5.891*	1.633**	-0.120	0.299**	-0.015	1.949*
	Dutch ethnicity (ref = non-Dutch)	2.389	0.731	2.097	-0.616	0.068	-0.019	0.127
	Unknown ethnicity (ref = non-Dutch)	3.687	-4.199	4.046	1.791	-0.538	-0.020	2.607
	Job (ref = unemployed)	10.763*	6.428*	2.777**	0.050	0.337	-0.090**	1.261**
	Student (ref = unemployed)	14.163*	1.154	11.770*	1.298**	0.378	-0.185**	-0.252
	Level of education	3.826*	2.846**	1.285**	0.060	0.158	0.003	-0.526
	Drivers license (ref = no license)	3.218	0.443	2.510	-0.200	0.447	-0.051	0.068
	Adults (ref = young adult)	-6.155**	-2.726	-2.829**	-0.988*	0.338	0.037	0.013
	Elderly (ref = young adult)	-12.439*	-7.297**	-4.906**	-1.034**	0.625**	0.107**	0.067
	Car available (ref = no car available)	3.644**	9.467*	-3.752*	-0.755**	-0.894*	-0.021	-0.401
	Multi person hh (ref = single person hh)	-3.072	-0.452	-1.799	-0.652**	-0.398	-0.067	0.295
	Multi person hh with children (ref=single person hh)	-8.164*	-4.594**	-3.402**	-0.484	0.121	-0.073	0.267
	Benchmark (ref = below benchmark)	3.505	3.002	0.909	0.638	-0.163	0.045	-0.925
	Above benchmark (ref = below benchmark)	7.106**	6.463**	1.675	1.047*	-0.421	0.050	-1.708**
	Unknown income (ref = below benchmark)	4.644	5.924**	-0.867	1.021**	-0.105	-0.009	-1.321
	Car attitude	-0.235	-0.473	-0.507	0.021	-0.009	-0.022	0.755
	Bicycle attiude	1.650	0.708	-0.019	-0.138	1.014*	0.017	0.068
	BTM attitude	-4.524*	-2.433**	-2.753*	0.415**	0.070	0.024	0.152
	Prestige attitude	-0.578	0.009	-0.479	-0.184	-0.026	0.000	0.101
	Train attitude	2.847**	2.154**	0.675	0.046	0.068	-0.016	-0.081
	PT efficiency attitude	-1.576	-2.724**	1.712**	-0.053	-0.414*	-0.003	-0.095
	PT safety attitude	3.788*	1.777	2.542*	-0.084	0.031	0.004	-0.481
	General car attitude (car loving)	1.748	5.661*	-2.716*	0.023	-1.247*	-0.048**	0.074
	Cost of driving attitude	-1.573	-2.458**	0.741	0.198	0.009	0.019	-0.082
	Environmental attitude (sceptisicsm)	-0.763	-0.525	0.077	0.105	-0.004	-0.032	-0.384
	Status sensitive attitude	0.557	0.080	0.770	-0.016	0.056	0.009	-0.343
	Accessibility attitude	0.481	-0.311	0.556	0.012	0.050	0.030**	0.145

* P <= 0.01
** P <= 0.05

Table F.7: MMR with level of urbanisation - model 4

Model	Independent variables	Total	Car	Train	BTM	Bicycle	Walking	Other
4	Intercept	15.942	5.135	5.086	5.455*	2.535**	0.403**	-2.672
	Level of Urbanisation	0.965	2.329	-1.293	-1.506**	-0.321	-0.030	1.786
	Gender (ref = female)	9.567*	5.146**	1.028	0.047	0.377	-0.049	3.018*
	Dutch ethnicity (ref = non-Dutch)	2.412	3.865	-1.539	-2.009**	-0.001	-0.091	2.188
	Unknown ethnicity (ref = non-Dutch)	-10.822	-5.169	-14.463	6.391**	-0.968	-0.029	3.416
	Job (ref = unemployed)	8.000**	6.752**	-1.117	-0.352	0.218	-0.098	2.597**
	Student (ref = unemployed)	17.728**	0.549	13.756*	1.460	0.220	-0.132	1.875
	Level of education	4.810**	4.740**	1.524	-0.120	0.159	-0.076**	-1.417**
	Drivers license (ref = no license)	1.274	0.449	2.531	-1.205	-0.284	-0.028	-0.189
	Adults (ref = young adult)	-0.098	0.718	-1.381	-1.307**	0.208	0.040	1.623
	Elderly (ref = young adult)	-5.116	-1.929	-4.312	-1.463**	0.665	0.022	1.902
	Car available (ref = no car available)	2.434	4.681	-0.925	-0.973**	-0.923**	0.092	0.481
	Multi person hh (ref = single person hh)	2.213	4.475	-3.262	-0.092	-0.776	0.008	1.861
	Multi person hh with children (ref=single person hh)	-2.412	-0.705	-3.981	0.426	-0.207	0.037	2.018
	Benchmark (ref = below benchmark)	0.579	-0.718	2.197	-0.267	-0.053	-0.098	-0.483
	Above benchmark (ref = below benchmark)	8.412**	8.032**	2.562	0.297	-0.084	-0.003	-2.392**
	Unknown income (ref = below benchmark)	2.920	3.789	0.137	0.129	0.237	-0.084	-1.287
	Car attitude	-0.739	-2.111	0.025	-0.113	-0.045	-0.059	1.565**
	Bicycle attiude	3.224	1.106	0.238	0.190	1.070*	0.022	0.598
	BTM attitude	-2.983	-2.620	-1.128	0.280	0.082	0.014	0.390
	Prestige attitude	-0.723	0.881	-1.706	-0.052	-0.300	0.011	0.445
	Train attitude	0.379	0.411	0.179	0.059	-0.116	0.021	-0.175
	PT efficiency attitude	-1.032	-0.145	0.121	-0.677**	-0.090	-0.036	-0.204
	PT safety attitude	1.793	0.271	1.790	0.070	0.318	0.007	-0.663
	Cost of driving attitude	4.291	7.495*	-1.393	-0.263	-1.302*	-0.067	-0.180
	Car costs attitude (cost sensitive)	0.361	-1.443	2.022**	0.061	0.031	-0.004	-0.307
	Environmental attitude (sceptisicsm)	-1.770	-1.128	-0.071	0.034	0.038	-0.018	-0.624
	Status sensitive attitude	0.449	1.330	-0.168	-0.181	0.211	0.016	-0.759
	Accessibility attitude	-1.820	-2.118	0.067	-0.010	-0.074	0.012	0.303
	Level of urbanisation × Male	0.082	0.397	0.378	-0.083	-0.036	0.021	-0.595
	Level of urbanisation × Dutch ethnicity	0.022	-1.367	1.570	0.664**	0.019	0.035	-0.900
	Level of urbanisation × Unknown ethnicity	6.464	0.320	8.331**	-2.062**	0.162	0.008	-0.296
	Level of urbanisation × Job	1.507	-0.065	2.070**	0.230	0.080	0.000	-0.808
	Level of urbanisation × Student	-1.647	0.047	-0.582	-0.038	0.069	-0.021	-1.123
	Level of urbanisation × Education	-0.626	-1.043	-0.198	0.109	0.013	0.040**	0.453
	Level of urbanisation × Drivers license	0.602	-0.243	0.037	0.435	0.294	-0.007	0.085
	Level of urbanisation × Adults	-2.970**	-1.935	-0.514	0.201	0.080	0.004	-0.806
	Level of urbanisation × Elderly	-3.389	-2.836	0.064	0.256	-0.007	0.058	-0.924
	Level of urbanisation × Car availability	1.025	2.666**	-1.361**	0.141	0.020	-0.058**	-0.384
	Level of urbanisation × Multi person hh	-2.029	-1.821	0.487	-0.189	0.172	-0.027	-0.650
	Level of urbanisation × Multi person hh with children	-2.172	-1.388	0.264	-0.440**	0.139	-0.047	-0.700
	Level of urbanisation × Benchmark income	1.138	1.596	-0.698	0.403	-0.079	0.073**	-0.157
	Level of urbanisation × Above benchmark income	-0.932	-1.048	-0.450	0.287	-0.191	0.024	0.448
	Level of urbanisation × Unknown income	0.612	0.915	-0.505	0.398	-0.192	0.037	-0.041
	Level of urbanisation × Car attitude	0.441	1.040	-0.208	0.049	0.025	0.017	-0.482
	Level of urbanisation × Bicycle attitude	-0.957	-0.298	-0.164	-0.160	-0.034	-0.001	-0.299
	Level of urbanisation × BTM attitude	-0.759	0.094	-0.803	0.057	-0.010	0.007	-0.104
	Level of urbanisation × Prestige attitude	-0.020	-0.538	0.628	-0.076	0.140	-0.006	-0.168
	Level of urbanisation × Train attitude	1.309	0.896	0.283	-0.001	0.098	-0.020	0.052
	Level of urbanisation × PT efficiency attitude	-0.344	-1.359	0.775	0.343**	-0.174	0.018	0.053
	Level of urbanisation × PT safety attitude	1.013	0.867	0.314	-0.080	-0.148	-0.004	0.063
	Level of urbanisation × General car attitude	-1.363	-1.126	-0.598	0.174	0.008	0.015	0.164
	Level of urbanisation × Costs of driving attitude	-0.871	-0.413	-0.633**	0.086	-0.011	0.010	0.091
	Level of urbanisation × Environmental scepticism	0.590	0.343	0.113	0.017	-0.020	-0.007	0.143
	Level of urbanisation × Status sensitive	0.016	-0.632	0.437	0.092	-0.072	-0.005	0.195
	Level of urbanisation × Accessibility attitude	1.204**	0.999**	0.205	-0.002	0.059	0.010	-0.068

* P <= 0.01
** P <= 0.05

The adjusted R-squared values in Table F.8 show similar model fits as the urbanity model. Again, the BTM, walking and other model have the lowest model fits. Compared to the urbanity model, the model fits for the total, car, BTM and other modes distances have slightly improved. The model fits for train, bicycle and walking distances have stayed roughly the same. For those dependent variables, no differences between the levels within the urban and non-urban regions are expected, as having six levels instead of two does not improve the variance explained by the set of independent variables.

Table F.8: Adjusted R-squared values for the MMR with level of urbanisation as moderator

Model	Total	Car	Train	BTM	Bicycle	Walking	Other
1	0.002	0.012	0.010	0.000	0.009	0.012	0.004
2	0.087	0.111	0.090	0.034	0.045	0.030	0.012
3	0.098	0.132	0.113	0.036	0.120	0.037	0.011
4	0.101	0.133	0.122	0.052	0.120	0.043	0.013

F.3. MODERATIONS BY URBANITY

Below, all effects significantly moderated by urbanity are discussed. For all effects, the differences between urban and non-urban areas are depicted with the help of figures containing the mean predicted average daily distance in total or by a specific mode. The mean predicted average daily distance is the distance a respondent is predicted to travel based on its personal characteristics, its answers on the attitude questionnaires and the urbanity of its residential location. Hence, the predicted daily distance follows from the MMR equation as discussed in Chapter 3. The formula does contain an intercept, 28 independent variables, being sociodemographics, attitudes and a built environment variable, and 27 interaction terms of those variables with the built environment variable. The MMR model predicts a coefficient for all terms plus one constant which represents the mean value given that all variables have a value of zero. To determine the predicted daily distance for a respondent, the model-determined coefficients are multiplied with the value of the independent variable they belong to. It is important to mention that this is not limited to just the significant variables. This does make sense, as significance does not tell anything about importance, but only about the accuracy of the determined coefficient. While there cannot be ruled out that the coefficient is a result of chance, it has a probability that it does not equal zero too. Further, removing variables would change the coefficients of other variables. Given the data, the calculated coefficients have the highest likelihood, and hence are all used to predict the daily distance covered by a respondent for all modes and in total.

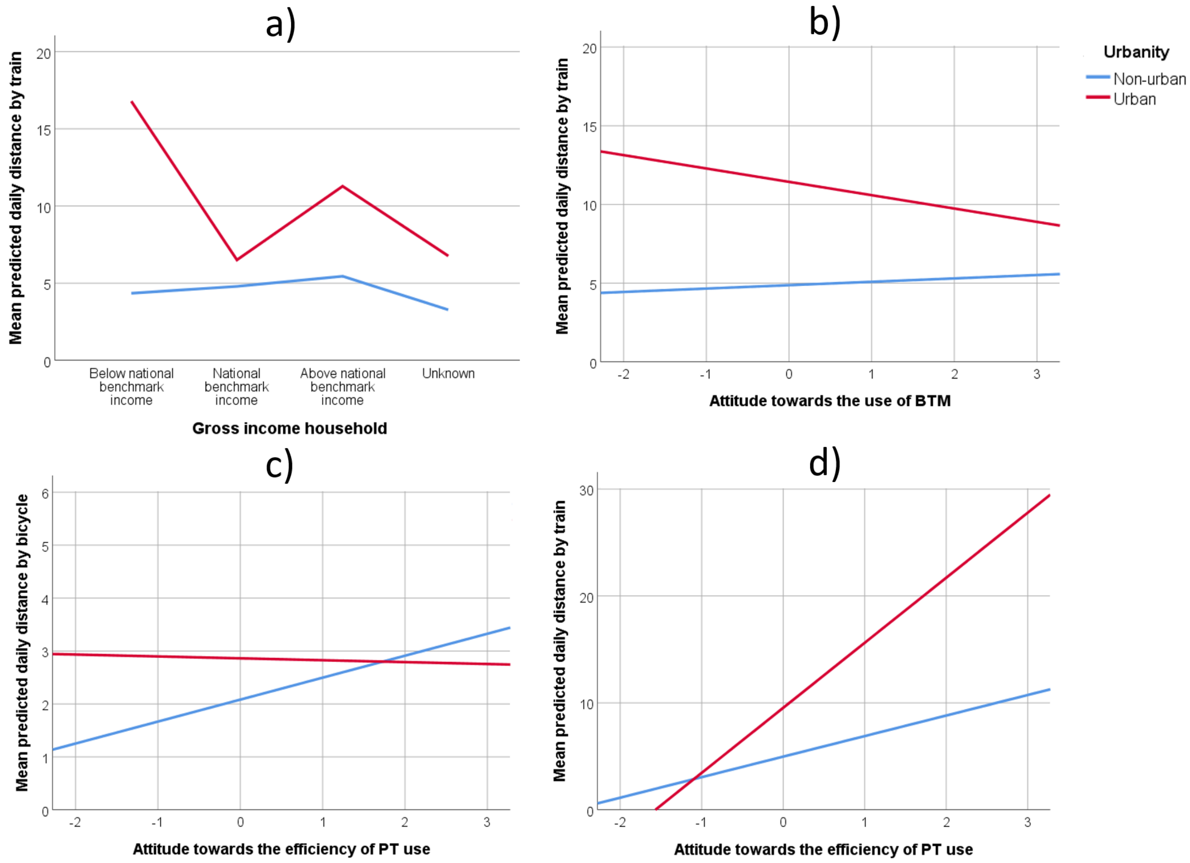

Figure F.1: Effects significantly moderated by urbanity

BENCHMARK INCOME ON TRAIN KILOMETRES

The benchmark income dummy has two significant interactions with the level of urbanisation, one on distance travelled with train and one on walked distance. The latter is discussed in the main text. The effect of national benchmark dummy on train distance is moderated by urbanity (see Figure F.1.A). Compared to the reference category of a household income below the national benchmark, urban inhabitants belonging to the national benchmark category travel significantly fewer kilometres with the train. On the other hand, people living in non-urban areas travel slightly longer distances as their household income increases. A possible explanation could be related to the share of people with a non-Dutch ethnicity. Urban areas tend to have higher shares of non-Dutch inhabitants than non-urban areas. Also, people with a non-Dutch ethnicity on average have lower incomes than people with a Dutch ethnicity and travel more with public transport than Dutch people (Harms, 2006). Combining the higher share of non-Dutch people in urban areas, the higher share of non-Dutch people in lower income categories and their higher use of PT could be a possible explanation of the strong decreasing effect of higher income in urban areas. That the number of train kilometres travelled increases from the benchmark category to the above benchmark category in both urban and non-urban areas could be related to the fact that higher income categories in general have a higher level of education, from which is known that it leads to the use of environmental friendly travel modes more often (Clark & Scott, 2013). However, in countries with higher levels of development and schooling quality the highest education level has more effect on household income than the lower levels of education (Akgüç, 2011). That would correspond with the increase both urban and non-urban inhabitants show when going from the benchmark income category to the above benchmark income category.

ATTITUDE TOWARDS THE USE OF BTM ON TRAIN DISTANCE

The level of urbanisation has an interaction with the effect of attitude towards the use of BTM on train distance. For inhabitants of non-urban areas, the distance travelled by train increases with increasing attitude towards the use of BTM. For inhabitants of urban areas, the distance covered by train decreases when the attitude of BTM increases, indicated by the red line in Figure F.1.B. A possible explanation for this difference could be that when non-urban inhabitants have a positive attitude towards BTM, it is likely that they also have a positive attitude towards the use of trains, and hence the use of that mode increases. In urban areas, where more possibilities are available, BTM and train might compete each other on certain locations. For that reason, it does make sense that the use of train decreases when an alternative is liked more. As the attitude is mean-centred, the unstandardised coefficient of -4.002 indicates that the daily distance travelled with train decreases with 4 kilometres from the constant when the attitude increases with 1 unit compared to the mean attitude for inhabitants of urban areas.

PT EFFICIENCY ATTITUDE ON TRAIN AND CYCLING DISTANCE

Another significant interaction of level of urbanisation with one of the mode-use attitudes is with the PT efficiency attitude on daily distance travelled by train and bicycle. For inhabitants in urban areas, the PT efficiency attitude has almost no influence on the distance by bicycle, indicated by the almost horizontal, but lightly declining, line in Figure F.1.C. This indicates that the PT efficiency attitude use has not a lot of influence on the daily distance travelled by bicycle. For inhabitants of non-urban areas, a positive relationship can be observed between attitude towards the importance of efficiency of PT use and the cycled distances. This is not an immediately clear relationship. A possible explanation could be that the attitude towards efficiency is an average of statements for train and BTM related to flexibility and time saving of the modes. Bicycles are very flexible in use, hence people that value flexibility of PT might also value the flexibility of bicycles. A possible explanation for the difference between urban and non-urban inhabitants could be related to the differences in overall PT and bicycle usage. In urban areas, both PT and bicycle use are higher than they are in non-urban areas (see descriptive statistics in Chapter 4). Due to lesser presence of PT in non-urban areas, it is less often a feasible alternative to using a car.

The effect of attitude towards the efficiency of PT use on train kilometres as indicated by Figure F.1.D shows an increase of daily distance travelled by train with an increase of the attitude score. The steeper slope of urban areas might result from the higher presence of train stations in urban areas, increasing the possibility one travels by train if he thinks it is an efficient way of travelling.

F.4. MODERATIONS BY LEVEL OF URBANISATION

The most interesting effects that are significantly moderated by the level of urbanisation are discussed in the main text. In this appendix, the somewhat less interesting moderated effects are shown, and possible explanations for the moderation are briefly discussed. The figures show the mean predicted value of a dependent variable on the y-axis. This value is based on the values one has on all independent variables multiplied with the corresponding coefficients as determined by the MMR analysis.

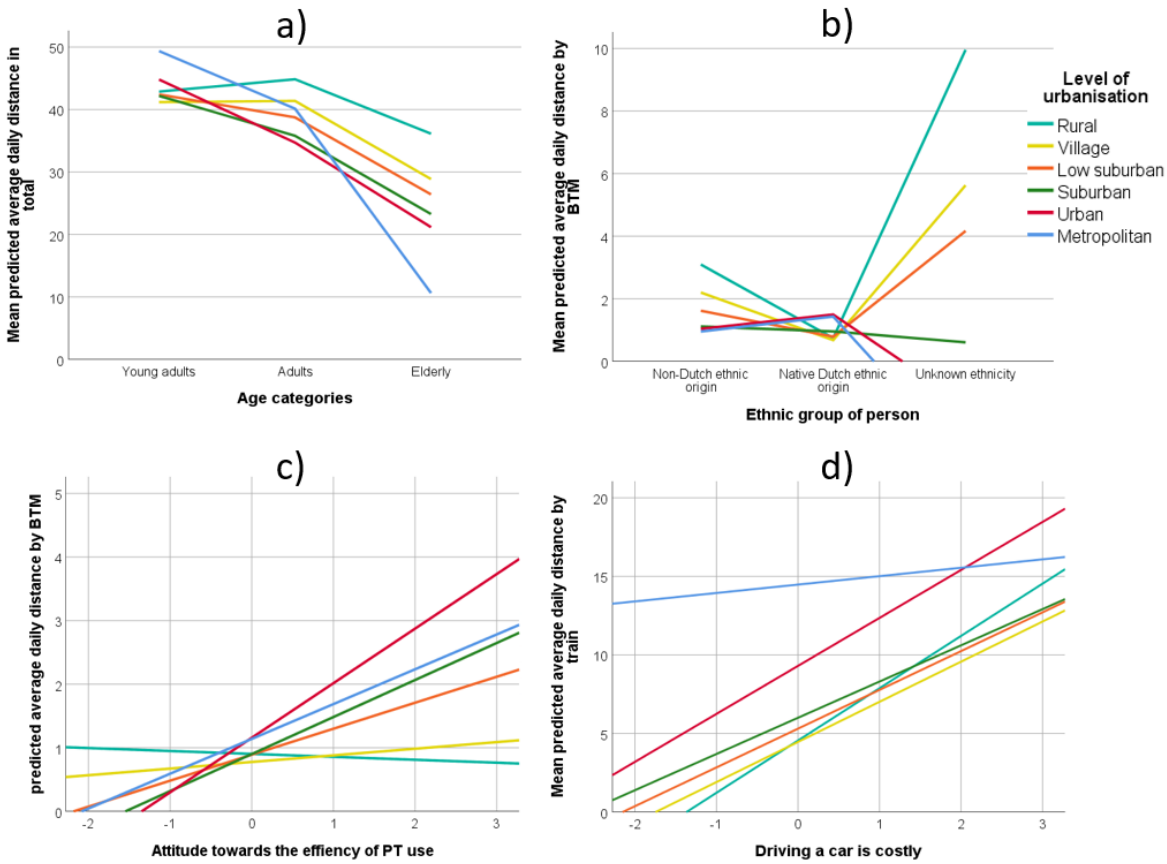

Figure F.2: Effects significantly moderated by level of urbanisation

AGE ON TOTAL DISTANCE

The level of urbanisation moderates the effect of age on average total daily distance travelled via the adult dummy. The general observable relationship between age and total distance travelled is that as age increases, the total average daily distance travelled decreases as depicted in Figure F.2.A. This is less applicable to villages, and not at all for rural areas. Villages show a very small increase, and rural areas show quite some increase in total distance travelled when comparing adults with young adults. For metropolitan and urban areas, the average daily distance travelled in total decreases when someone is an adult, compared to being a young adult. The decline is the largest for the two highest levels of urbanisation. The middle levels, being suburban and low suburban, show smaller declines. In general, there can be concluded that the difference between adults and young adults ranges from slightly positive for rural areas to strongly negative for metropolitan areas. The levels in between show a gradual gradient, with a tipping point from positive to negative between village and low-suburban.

ETHNICITY ON BTM DISTANCE

The level of urbanisation moderates the effect of ethnicity on daily distance travelled by BTM. More specifically, there is a significant difference between the reference category of non-Dutch ethnicity and the Dutch ethnicity category for certain levels of urbanisation. The different effects are visualised in Figure F.2.B. The effects for urban and metropolitan areas are almost similar, both show a decrease in distance travelled by BTM. The rural, village and low suburban levels show a decline in distance travelled by BTM when comparing the mean distance of Dutch people with those of a non-Dutch ethnicity. This significant moderation effect did not follow from the MMR analysis with urbanity as moderator, indicating that there is no clear difference between the urban and non-urban levels. That is probably caused by the suburban effect, which is located in between the two highest and three lowest levels. It does show a minor decline, but not as strong as the three lowest levels of urbanisation have.

In general, people with a non-Dutch ethnicity use public transport more often, which is mainly a result of significant differences between non-Dutch and Dutch women (Harms, 2006). For them, PT is often a substitution for cycling, as bicycle ownership is way lower for non-Dutch people compared to Dutch people. As it is a substitution for cycling, it can be expected that it mainly are short trips. Dutch people will more often use the bicycle for those trips. So when they use PT, it is likely to be for relative longer distances. That could also be a reason for the larger increase in metropolitan areas. Dutch people living in urban areas are likely to cycle more and mainly short distances, as lots of activities can be reached within cycling distances. When using BTM, and to lesser extent train, it is likely that the destination is not within (an individual's) acceptable cycling distance, so a relative long distance will be covered with PT.

The unknown ethnicity category does also show different effects for the different levels of urbanisation. However, it does have a very small sample size and does also not carry any information, as the respondents could be either Dutch or non-Dutch and also have various reasons for not telling their ethnicity. Therefore, it is not useful nor interesting to interpret the results.

PT efficiency attitude on BTM distance

The effect of attitude towards the efficiency of PT use on the distance travelled by BTM as shown in Figure F.2.C is clear, the more someone think that the use of PT is efficient, the more kilometres he will travel by BTM. Not only is the effect clear, it also makes sense. After all, when someone things PT is not an efficient way of transportation, it is unlikely that he will consider it as a feasible alternative and hence not use it.

The positive effect between PT efficiency attitude and BTM kilometres is especially large for metropolitan areas. Roughly speaking, the higher the level of urbanisation, the higher the slope of the effect is. Probably this is related to the higher possibilities of actual using BTM in more urbanised areas. When someone living in a metropolitan area has a positive attitude towards the efficiency of PT, he can translate that attitude in the actual use due to the high offer of BTM. In less urbanised areas there are less possibilities of BTM, possibly leading to situations where someone has a positive attitude towards the efficiency of PT, but does not have the possibility to actually use it. While the most levels show effects that are expected and do make sense, this is not the case for the rural level. Whereas the other levels show an increase, rural inhabitants travel less with BTM when their attitude towards the efficiency of PT increases. It is also remarkable that for low attitudes, the rural and village levels have a relative high number of daily kilometres travelled by BTM. This possibly indicates that the efficiency of PT is not of major importance when choosing to use it in the rural and village levels of urbanisation. That could make sense in a way that in general PT is not that efficient in those levels, given that the PT network is not dense and hence relative long access and egress distance have to be made to reach a BTM stop. In those cases, using PT is likely to be a choice that is made based on other reasons, like not having a car available to use.

Cost of driving attitude on train distance

Another significant moderation effect is one between level of urbanisation and the costs of driving attitude on train kilometres. The cost of driving attitude indicates whether a respondent thinks that using a car is costly. The higher, the more sceptic he is due to the, in the eyes of the respondent, high costs. The general effect is that as the scepticism towards the costs of driving a car increases, the number of average train kilometres increases too. As can be seen in Figure F.2.D, this applies to all six levels of urbanisation. The main difference is that the slope of the metropolitan level is way smaller than the slopes of the other levels. Even the urban level, which often shows similarities with the metropolitan level, has a significant different slope.

This indicates that inhabitants of metropolitan areas are not sensitive to the costs of driving a car when considering travel modes. Apparently, they do not consider the costs of driving a car when choosing the mode of travel, or at least do not think as them as one of the main criteria. This can be a result of other negative aspects of having a car in metropolitan areas, like parking and the relative large time necessary to leave the city (centre). The reverse is also possible, that due to the good train infrastructure in metropolitan areas it does not really matter how expensive other alternatives are as it is not likely that they can compete with train.

F.5. MODERATIONS BY URBANITY AND LOU

Besides effects of explanatory variables on travel distance that are being moderated by urbanity or by LoU, there are also some effects that are moderated by both. For those effects, a clear distinction between urban and non-urban areas is visible in both the moderated effects by urbanity as by LoU. All significant moderations, with exclusion of those already discussed in the main text, are shown in Figure F.3.

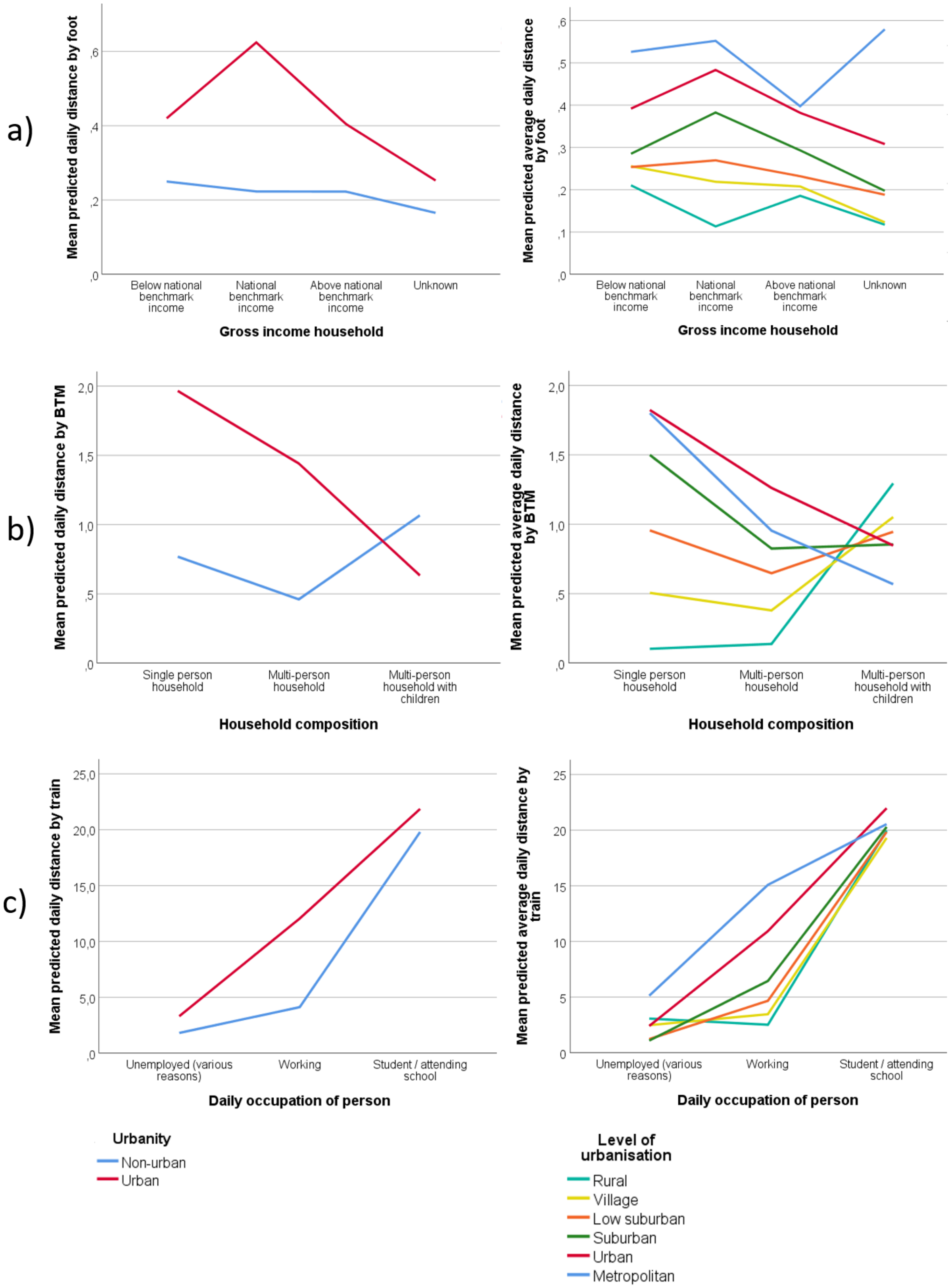

Figure F.3: Effects significantly moderated by urbanity and level of urbanisation

INCOME ON WALKING DISTANCE

The effect of having a benchmark income compared to having a below benchmark income has varying directions dependent on the urbanity and LoU. The average daily distance travelled by foot slightly decreases for people living in non-urban areas when they have a national benchmark income, albeit being a very minor decrease. People living in urban areas travel significant longer distances by foot when they earn the national benchmark income compared to a below benchmark income. Both effects are shown in Figure F.3.A. A distinction can be made between the two lowest levels of urbanisation and the four highest. In the rural and village levels of urbanisation people with an average income walk less then people having a below average income. For the other four levels of urbanisation, this is the other way around. For the low suburban level of urbanisation the increase is small, but as the level of urbanisation increases, so does the mean predicted average daily distance travelled by foot.

That people with an average income walk more in more urbanised areas might be a result of the level of education of those with an average income. It is likely that those with an average income have a higher level of education than people with a below average income. As discussed in the section about the effect of education on walking distance, the higher educated someone is, the longer the average daily distance covered by walking. This is especially the case in urbanised areas, as those have a lot of activities within walking distance. However, when looking at the above national benchmark income level, this theory does not hold, as average distance travelled by foot decreases compared to the national benchmark category.

HOUSEHOLD COMPOSITION ON BTM DISTANCE

Another significant interaction of urbanity is one with the multi-person household with children dummy from the household composition variable on the daily distance travelled by BTM. The mean predicted values for the daily distance travelled by BTM are shown in Figure F.3.B. For people living in urban areas, the mean distance travelled by BTM is lower in multi-person households with children than it is for single person households. For inhabitants of non-urban areas, a different relationship between household composition and distance travelled by BTM can be observed. There, multi-person households with children travel more than single person households.

Besides different effects when being moderated by urbanity, the effect of the multi-person hh with children is also moderated by LoU. Where in rural areas and villages persons belonging to a multi-person household with children travel longer distances with BTM than individuals belonging to a single person household, this is not the case for low suburban, suburban, urban and metropolitan areas. When interpreting the effects in Figure F.3.B, it is important to stress that the levels are dummy coded, and hence the moderation indicates a significant difference between the effect of various levels of urbanisation have when comparing multi-person households with children with the reference category of a single person household. Hence, to interpret the figure, one should look at the starting and ending point of the lines, as those indicate the mean predicted values of the relevant levels.

A possible explanation might be related to the costs of alternative modes, specifically the costs of having a car. Especially for single person households having a car might be too expensive, as in general single person households are young and they cannot share the costs with someone else. To travel, they have to use other modes. With increasing possibilities comes increasing use, so it does make sense that BTM use in the more urbanised areas is high and it is low in lesser urbanised areas for single person households. The declining effect of household composition on BTM distance does make sense for urban inhabitants when considering that BTM offers less flexibility compared to other modes, which is disadvantageous when travelling with children. For example, a car can be used to bring children to school and drive to work directly afterwards. Also, travelling with BTM with (young) children can be stressful due to aspects like checking in and reaching the vehicle in time. That the distance travelled by BTM increases for non-urban inhabitants could be caused by the higher share of students within multi-person households with children in non-urban areas (12.7%) compared to urban areas (7.4%). In general, students/ persons attending school travel more with PT, indicated by the positive coefficients the main effect of the student dummy has on train and BTM distance. Hence, the increase in BTM kilometres might be a result from students / persons attending school that are living with their parents. The varying means for single person households are likely to be mainly related to the possibilities to use BTM in varying levels of urbanisation.

DAILY OCCUPATION ON TRAIN DISTANCE

The job dummy has a significant positive coefficient on the daily distance travelled by train. Being unemployed (for various reasons) is the reference category of the dummy coding system for the daily occupation variable, hence the effect of having a job compared to being unemployed is significantly higher for urban areas than it is for non-urban areas. This effect can also be seen in Figure F.3.C. Where the urban level shows a strong increase, the non-urban level has a much smaller increase. The daily distance travelled by train does not vary that much for unemployed people, but when looking at the means for working people a large difference can be observed. Besides being moderated by urbanity, the effect of having a job is also moderated by the level of urbanisation. The slope from train kilometres travelled by unemployed to working increases with every increase in level of urbanisation. The small decline for inhabitants of rural areas is probably a result from the relative high daily distance travelled by train for unemployed people. As that category is a composition of various groups of unemployed people, such as retirees, people being unwanted unemployed and people being deliberately unemployed, it is difficult to say something about the reason why the distance travelled by train is high for this category in the rural and village levels of urbanisation.

On the one hand, it does make sense that the mean daily train kilometres are higher for working people in urbanised areas than the mean for people living in less-urbanised areas. After all, in urban and metropolitan areas there are more stations and higher frequencies, whereas there are limited or no options within close range for people living in less-urbanised areas. On the other hand, people with a job living in less-urbanised areas are likely to have to travel longer distances to reach their working place, whereas people living in urban and metropolitan areas are in close proximity of many jobs. Nevertheless, they still travel long distances by train. An explanation for this could be that people living in urban and metropolitan areas either travel short distances within the urban or metropolitan area, or travel long distances to other urban and metropolitan areas. Medium distances, which are covered a lot by inhabitants living in less-urbanised areas surrounding urban areas, do not offer urban inhabitants new activities as the 'supply' within their living area can only be matched or increased by other urban areas. Due to the dense train network in the Randstad, the main urbanised area in the Netherlands, it is possible to live in one city and work in another one. As connections to other main cities are often comparable in time with connections to smaller cities in the near proximity, it does make sense that urban inhabitants with a job travel quite long distances by train.

UNKNOWN ETHNICITY ON TRAIN

A last variable from which the effect on daily train distance is moderated by both urbanity and LoU is the dummy of unknown ethnicity. Since no information is known about these respondents, no meaningful interpretations can be drawn. Hence, the effect is not displayed in a figure, as it has no added value.