SUSTAINABLE URBAN AREAS

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Residential self-selection and travel

The relationship between travel-related attitudes, built environment characteristics and travel behaviour

Wendy Bohte

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Delft Centre for Sustainable Urban Areas

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Preface

The research theme of residential choice and daily travel choices is, quite literally, one that is 'close to home'. This tangibility was one of the aspects of my PhD projects that I valued the most. Everyone has to choose a place to live and this will always affect their daily travel choices in some way or another. This meant that it was not difficult to explain my research to other people, including the participants in my fieldwork, although concepts such as residential self-selection, travel-related attitudes, GPS and GIS techniques are less easy to grasp. Although residential and travel choices are relevant for everyone, my personal life made them especially so for me during my PhD years. Just as I started my research by relocating, I will also end my time as a PhD student with a move. Having had two children in the last two years, I almost decided to buy a car very recently. But contrary to the expectations of 'some' people, we still prefer to live without this 'status symbol'. Maybe if we ever live further from metro and tram services, we will (finally) change our attitudes towards car use? Another consequence of working on my PhD at this stage in life has been a severe shortage of time. I therefore am extra grateful for all the support that has been forthcoming from those around me.

First of all, I would like to thank my supervisors Professor Bert van Wee and Dr Kees Maat. When I first submitted my unsolicited application to the OTB Research Institute for the Built Environment, I could not possibly have imagined that they had written a research proposal that corresponded so closely with my interests. Kees was always willing to discuss my research with me – even when I needed to discuss my theoretical framework because I had got stuck for the umpteenth time. Our cooperation in the development of the GPS data collection method was also invaluable. The meetings with Bert were always inspirational. They made me consider alternative research directions and continue with renewed enthusiasm.

Many of my OTB colleagues have contributed a great deal to my PhD research and to the pleasure of working at OTB. In particular, I would like to thank the members of the Urban and Regional Development Section. I also thank my former roommates Henk-Jan van Mossel, Jan-Willem Smid, Paul Metzemakers and Evert Meijers for the pleasant atmosphere in our room. The expertise, opinions, humour and care of Evert, Henk-Jan, Eva Heinen and Janneke Toussaint were a great asset to me. Sylvia Jansen and the people of the OTB's GIS-t Section were very helpful in the development of my data collection methods. I owe a debt of gratitude to Wilko Quak who developed the GIS part of the GPS data collection method and was always willing to make adjustments to the system even at short notice. Student Sam de Bree assisted me very ably with logistical aspects of the fieldwork and the helpdesk.

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Of course I could not have done without the thousands of respondents who took the time to answer my rather long questionnaire and my particular appreciation goes to the efforts of the 1,400 respondents who participated in the GPS fieldwork. The stories of those that I talked to on the phone made my research come to life for me. There were interesting and sometimes sad stories, or funny inquiries like: 'what will you do with the GPS data that shows I was driving at over 200 km per hour?'

The support of my friends and family has been very important to me, particularly that of my mother Betsy Bohte, who was also a great help with the practical execution of the fieldwork, my father Herman Bohte and my parents-in-law Stef and Heleen Schoots. Francien Berndsen and my sister Kristel Bohte, thank you for assisting me as the 'paranymphs' (acolytes) at the defence of my PhD thesis. Martijn, your patience – and sometimes your impatience, your interest in my work, the extra time you put into managing our household and designing our new house – I could never have finished my PhD without all of this. Thank you so much. Zanna and Bram, with your beaming faces, you helped me to put everything in perspective.

1 Introduction

1.1 Background

> *'I think that cars today are almost the exact equivalent of the great Gothic cathedrals […] and consumed in image if not in usage by a whole population which appropriates them as a purely magical object'.*

This famous quote by Roland Gérard Barthes (1957) about the Citroen DS accompanied the announcement of the VATHORST GRAND PARADE of cars that took place in Vathorst, a recently constructed residential area in Amersfoort, the Netherlands (2005). The parade represented what designer Neeltje ten Westenend found to be the binding element of households in this residential area: their love of cars (Ten Westenend, 2005).

There is no doubt that residential areas, travel behaviour and travel attitudes are related, but in what way? Travel behaviour research shows that the characteristics of the built environment in residential areas influence peoples' daily travel behaviour; however, the extent of this influence is subject to debate. An important issue in this debate concerns the notion of a causal link between the characteristics of the built environment, travel behaviour and travel-related attitudes. For while households will adjust their travel behaviour to the characteristics of the built environment, they may also search for residential locations that comply with their travel-related attitudes. In other words, they may self-select their residential location on the basis of the travel-related characteristics of the built environment, such as distances to facilities, motorways and railway stations. As a result, if residential self-selection is ignored, the causal effect of the built environment on travel behaviour may be overestimated.

Most national governments of Western countries aim to influence the travel patterns of households – at least to some degree – through the spatial planning of residential areas. Over time and between countries, the main aims of spatial policies have varied, from reducing congestion, reducing travel times, reducing environmental pollution, increasing liveability to preserving rural landscapes. Today, maintaining and improving accessibility for economic reasons, the depletion of fossil fuels and the reduction of carbon dioxide emissions to limit climate change are the major reasons for influencing travel behaviour (e.g. Hilbers *et al.*, 2006; OECD, 2007; TRB, 2003; Van den Brink and Van Wee, 2001). In addition, health professionals have recently called on spatial planners to develop residential areas that promote walking and cycling (e.g. Frumkin *et al.*, 2004; NICE, 2008).

Nonetheless, in most countries the extent to which policies are put into practice is limited. Over the last few decades, the Netherlands has probably had the most far-reaching mobility aims in its spatial planning policies. In the 1970s the *Third National Policy Document on Spatial Planning* aimed at reduc-

ing car mobility. Policies aimed to increase the use of slow modes and public transport through undertaking new developments in existing urban areas, providing high-quality public transport in the newly developed areas and mixed land use (housing, work and recreation) at the urban regional level. New employment locations were to be situated near railway stations. In 1973 the national government prohibited large-scale out-of-town retail developments to protect city centres and prevent an increase in car use (Evers, 2002). Spatial policy aiming at urban concentration was intensified in the following two decades, with the introduction of the compact city policy. *The Fourth Report on Spatial Planning Extra* (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 1991) resulted in the development of so-called VINEX locations. These are large new residential areas situated within or adjacent to medium to large-sized cities, aiming to provide good accessibility by public transport and bicycle. Living, working and personal care was to take place at the level of the urban region to reduce mobility and protect rural areas (Snellen and Hilbers, 2007).

Schwanen *et al.* (2004) evaluated the effect of Dutch spatial planning and found indications that the compact city policy of the 1980s and 1990s had decreased travel distances and car shares. Dutch retail planning seemed particularly successful. Compared to other countries car use for shopping is relatively low. Snellen and Hilbers (2007) described the effect of the Dutch VINEX policy from the 1990s as being fairly successful. VINEX developments in the infill areas of the older parts of cities, the proximity of facilities, the urban centre and the quality of public transport all reduce mobility. In VINEX developments adjacent to existing urban areas the distance to daily facilities and the lower land-use mix have negatively influenced the number of kilometres travelled, while proximity to urban centres has had a positive effect. However, the socio-demographic characteristics of the residents of these locations can also be associated with higher levels of mobility. An example of spatial planning that missed its mark can be found in Nieuwland, a residential area and VINEX location in Amersfoort (and one of the case studies presented in Chapters 4 and 5). Nieuwland was developed and promoted as an environmentally friendly residential area, using environmentally friendly building materials for example, but also had limited parking spaces. However, it attracted car-oriented households, with an average car ownership rate of 1.4. Consequently, the availability of 1.25 parking spaces per house was not nearly sufficient (visitors must also be added to the 1.4 cars per household) and resulted in an 'environmentally friendly' residential area with cars everywhere, including the green spaces (Gemeente Amersfoort, 2005).

Recently, the *National Spatial Strategy* (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 2004) and the *Mobility Policy Document* (Ministerie van Verkeer en Waterstaat, 2004) shifted spatial policy aims from reducing car mobility to facilitating car travel. Mobility is no longer interpret-

ed as a problem but as a necessity. Reliable, fast and safe mobility is seen as a prerequisite for a well-functioning society and economy. The use of public transportation and slow modes and the reduction of car kilometres are still promoted, but the focus is now on strengthening urban networks by concentrating housing and employment developments near public transport and motorway nodes (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 2004; Ministerie van Verkeer en Waterstaat, 2008; Priemus, 2007).

In the United States, New Urbanism, Smart Growth and related movements have introduced strong ideas on neighbourhood design, which also address how such design can positively affect travel behaviour. However, their principles are only put into practice at a very local level. New Urbanism is an urban design movement which arose in the United States in the early 1980s. The movement advocates the idea that neighbourhoods should have a diverse population and mixed use, that their design should be pedestrian, transit and car-friendly and that their architecture should celebrate local history, climate, ecology and building practice. One of their 'principles' states that most dwellings should be located within a five-minute walk of a neighbourhood centre (Congress for the New Urbanism, 2001). Related to New Urbanism, but with somewhat more emphasis placed on promoting public health, is Smart Growth Development, which started in the mid-1990s and to which several US non-profit and government organisations are committed (Bullard, 2007). Handy (2005) reviewed studies evaluating Smart Growth policies and found that research can confirm, to a limited extent, propositions made by proponents of Smart Growth. She concluded that new highway capacity will influence where growth occurs and might also increase travel a little, light rail transit will only stimulate higher densities under certain circumstances and New Urbanism makes it easier, for those who wish, to drive less.

It can be concluded that although the idea underlying these policies and principles is that spatial planning can influence travel behaviour, evaluations provide only limited evidence. Moreover, the extent of the effect of the built environment on travel behaviour is heavily debated by travel behaviour researchers and the evidence is not always consistent. Many studies have found significant links between the built environment and travel behaviour (e.g. Newman and Kenworthy, 1999; Ewing, 1995; Frank and Pivo, 1995; Cervero and Kockelman, 1997; Næss and Sandberg, 1996; Stead, 2001), while others conclude that there are only small effects (e.g. Boarnet and Sarmiento, 1998; Maat and Timmermans, 2009a; Snellen *et al*., 2001).

Various factors which only contribute to the misinterpretation of the link between the built environment and travel behaviour have been identified. These usually arise from analyses that are performed at too general a level or in which the complexity of travel behaviour is not adequately taken into account. Several studies present evidence that suggests that analyses of more specific travel behaviour better address the influence of the built

environment; for example, the influence of distance on travel mode choice differs depending on the trip purpose (e.g. Cervero and Duncan, 2003; Handy and Clifton, 2001; Schwanen *et al*., 2004). In addition, Iacono *et al*. (2008) and Scheiner (2009) have shown that studies which use small distance categories when examining the effect of distances on mode choice reveal effects of distances that were overlooked by other studies.

Research on the relationship between the built environment and travel behaviour is complicated by three important issues. First, because of the derived nature of travel behaviour, research should preferably also include activity patterns. The activity-based approach to travel demand emphasises that travel behaviour is derived from participation in various activities and focuses on activity and travel patterns during the day or over even longer periods (e.g. Arentze and Timmermans, 2004; Bhat and Koppelman, 1999; Pendyala and Goulias, 2002). Second, studies on car ownership show that it is influenced by the characteristics of the built environment and therefore car ownership mediates the relationship between the built environment and travel behaviour (Maat and Timmermans, 2009b; Simma and Axhausen, 2003; Van Acker *et al*., 2010). Third, and the subject of this dissertation, is the role of residential self-selection, and therefore the causal link between the built environment, travel behaviour and travel-related attitudes. Taking into account the indirect influence that travel-related attitudes have on travel behaviour, through their role in residential choice, is critical for determining the influence of the built environment on travel behaviour (e.g. Bagley and Mokhtarian, 2002; Handy, 1996; Boarnet and Crane 2001; Krizek, 2003; Mokhtarian and Cao, 2008; Van Wee, 2009).

With the new paradigm of an activity-based approach to study travel behaviour and the inclusion of factors that mediate the relationship between the built environment and travel behaviour, the use of new methods of analysis such as structural equation modelling have emerged. At the same time, data collection methods have also been further developed. This dissertation contributes to the improvement of data collection methods in two areas relevant to the analysis of the role of residential self-selection. First, in order to collect more detailed and reliable travel behaviour data, a method has been developed using recent improvements in the use of the Global Positioning System (GPS), such as better reception of satellite signals by GPS devices. This has led to the development of a method that combines GPS logs, GIS technology and an interactive web-based validation application. As discussed in the next section, the introduction of psychological theories also contributes to the further development of methods to measure attitudes in the field of travel behaviour research.

Residential self-selection

Several studies on residential choice have found that households deliberately consider the characteristics of the built environment when choosing their

residential location, although several attributes concerning housing and the neighbourhood are of similar or greater importance than many others in residential choice (Chatman, 2009; Filion *et al*., 1999; Van Wee *et al*., 2002; Molin and Timmermans, 2003). Thus, at least to some extent, households self-select towards a residential neighbourhood that supports their travel preferences, and therefore the success or failure of spatial planning that aims to influence travel behaviour will depend on whether this self-selection is properly taken into account. If spatial planners do not allow for the fact that households self-select concerning their travel preferences, households may have to adjust their travel behaviour by using non-preferred modes, travelling further, more or less frequently, or visiting non-preferred activity locations. Thus, whether and how people adjust their travel behaviour will determine whether or not self-selection will have a positive (e.g. less congestion, more sustainable) or negative impact.

In the last fifteen years it has become more common to take residential self-selection into account in travel behaviour research, with numerous studies focusing on its role. Cao *et al*. (2009) provided an extensive review of these studies, dividing them into nine methodological categories, thus demonstrating the wide variety of methodologies used. These categories are direct questioning, statistical control, instrumental variables, sample selection, propensity score, joint discrete models, structural equation models, mutually dependent discrete choice models and longitudinal designs (for a description of these methodologies see Mokhtarian and Cao, 2008). Almost every study finds at least some indication of the influence of residential self-selection on travel behaviour. However, as noted by Cao *et al*. (2009), very few studies provide conclusions on the relative effect of the built environment compared to the effect of residential self-selection. The studies that did compare the effects, generally found that the effect of the built environment was greater than the effect of self-selection. However, there is a methodological problem with these studies because most used cross-sectional data. Because both travel (and residential area) related attitudes as well as travel behaviour can change, and often do so particularly after residential moves, panel data research should be preferred in this area of study (Mokhtarian and Cao, 2008). Krizek (2003) used longitudinal data and found that when households relocate to a neighbourhood with different accessibility characteristics, their travel behaviour will change, but he recognises that because he did not include changes in preferences towards travel and residential location, the changes that he found in travel behaviour may also be partly attributed to changes in preferences.

In addition to the different methods of analysis, studies also differ concerning whether or not they explicitly include attitudes and, if so, which attitudes they include and how they are included. The results of self-selection studies, including the conclusion of Krizek (2003), indicate that studies that explicitly include attitudes do provide most insight into residential self-selection. All

peer-reviewed published studies in the overview by Cao *et al.* (2009) that at least give some indication of the relative effect of the built environment on travel behaviour compared to the effect of residential self-selection, explicitly include travel-related attitudes. However, to the best of my knowledge there are no longitudinal studies that include travel-related attitudes.

The diversity of measures and modelling of attitudes in self-selection studies implies that the results of these studies are hardly comparable, even if researchers are able to give some indication of the extent of the self-selection effect. It also indicates that there is no consensus on what methods are best for studying the role of attitudes in research into the effect of residential self-selection on travel behaviour. Moreover, there is very little discussion and evaluation of what attitudes should be included and how they should be measured. This thesis aims to fill this gap by focusing on two issues; firstly, in relation to determining the effect of residential self-selection on travel behaviour, the thesis examines the reverse influence of travel behaviour and the characteristics of the built environment on travel-related attitudes. Secondly, the importance of measuring attitudes and behaviour at the same level of aggregation is also acknowledged. Furthermore, the thesis also considers the importance of including underlying beliefs about the outcomes of travel mode use (e.g. the environmental damage caused by car use or the comfort of cycling) and the explanation of residential self-selection in terms of socio-demographic variables, lifestyle orientation (e.g. the importance attached to having a career) and attitudes towards housing and the neighbourhood.

1.2 Aim, research questions and approach of the study

This thesis aims to improve the understanding the role that attitudes play in residential self-selection and their impact on the influence of the built environment on travel behaviour. This leads to the following central research question: *To what extent does residential self-selection affect travel behaviour – and can this effect be identified by estimating the impact of travel-related attitudes on travel behaviour that is otherwise due to the characteristics of the built environment in the residential location?* More specifically, the following four research questions were formulated:

1. How can travel-related attitudes best be included in research into the role that residential self-selection plays in the relationship between the characteristics of the built environment and travel behaviour?
While social psychologists debate the measurement and role of attitudes in travel behaviour research, these discussions are far more limited in residential self-selection studies. In this thesis it is assumed that the measurement

and modelling of travel-related attitudes is of vital importance in identifying residential self-selection, and therefore the measurement and use of attitudes in travel behaviour research are extensively reviewed in Chapter 2. Decisions on how to measure and model attitudes in the empirical part of the thesis (Chapters 4 and Chapter 5) were made on the basis of this review.

2. How can GPS technologies be implemented to improve the reliability, efficiency and spatial and temporal detail of the measurement of travel behaviour?
An important sub-aim of this PhD project was to develop and use a data collection method that enables the collection of more accurate and more detailed travel behaviour data than is possible with conventional methods. Better measurement of such data is relevant for travel behaviour research in general, and not only for research focusing on the importance of attitudes and residential self-selection in relation to travel behaviour. This resulted in the development of a method that combines GPS logs, GIS technology and an interactive web-based validation application. The method is described and evaluated in Chapter 3. The use of this method made it possible to collect data over several days (namely a week) and with a lower burden on the respondents than would have been the case with existing methods.

3. To what extent does residential self-selection influence the relationship between characteristics of the built environment and travel behaviour?
Although all of the relevant studies, with a few exceptions, conclude that residential self-selection influences the relationship between the built environment and travel behaviour, the extent of this influence is little known. Therefore, an empirical study was performed to test the role of travel-related attitudes and residential self-selection. The analyses are presented in Chapters 4 and 5 and are limited to self-selection relating to the distance to activity locations and its effect on travel mode choice and total kilometres travelled. As mentioned above, detailed analyses of the influence of distance are scarce, but could be relevant for spatial planning that aims to influence mode choice. The analyses are also limited to homeowners because of restrictions in the Dutch rental market. It is expected that self-selection will be more significant among homeowners and therefore easier to assess.

4. To what extent is residential self-selection explained by socio-demographic characteristics, lifestyle orientation, attitudes towards housing and the neighbourhood in residential choice, and beliefs that underlie travel-related attitudes?
To be able to take advantage of residential self-selection mechanisms in spatial planning, knowledge is required concerning the kind of person who will self-select and concerning those who will adjust their travel behaviour in situations in which they are or are not able to self-select and in what way they will adjust their behaviour. Therefore, Chapter 5 includes analyses that ex-

plain the role of residential self-selection in terms of socio-demographic characteristics, lifestyle orientation, attitudes towards housing and the neighbourhood in residential choice and beliefs that underlie travel-related attitudes. It is assumed that lifestyle orientation issues, such as the importance of having a career or the importance of having children, add further to the explanation based on socio-demographic variables. Furthermore, it is assumed that some households have a combination of attitudes about housing, the neighbourhood and travel that are more easily satisfied by the housing market than others. Finally, this thesis analyses beliefs about the outcomes of travel mode use, because it is assumed that these beliefs and their importance can vary depending on aspects related to the trips taken, for example the distance involved or the trip purpose.

Case study area

To disentangle the interaction between travel-related attitudes, the built environment and travel behaviour the appropriate measurement of these factors is vital. Therefore, extensive attention is paid to data collection. The data were collected in three municipalities that are centrally located in the Netherlands: Amersfoort (137,000 inhabitants), Veenendaal (61,000 inhabitants) and Zeewolde (19,000 inhabitants) (see Figure 1.1). Most previous empirical research on residential self-selection and mode choice originates from the United States. However, because of differences in the spatial and cultural settings it is assumed that residential self-selection mechanisms in countries such as the Netherlands will differ significantly from the US. In particular, the Netherlands is less car-oriented with a much larger and higher quality infrastructure for walking and cycling, as well as shorter distances for daily shopping.

To ensure that a wide variety of built environment characteristics were included in the study, the sample was drawn from ten districts which covered a broad range of urban forms, varying from the historical city centre of Amersfoort to suburban residential areas of the new town of Zeewolde, and from car-friendly to bicycle and public transportation-friendly districts. The districts chosen all have a high percentage of owner-occupied houses and the sample selection was limited to homeowners because renters have a very limited choice set.

Data

The data collection took place in two stages. First, in the second half of 2005 an internet questionnaire was conducted. This approach was chosen primarily because it offers automatic routing options, as the survey was very complex. The questionnaire included items on attitudes towards travel and housing, travel behaviour, residential choice and socio-demographic data. As will be further discussed in Chapter 2, when attitudes are measured there must be a balance between the extensiveness of the measurements and therefore

Figure 1.1 Study area

Districts in study area

1 Nieuwland
2 Vathorst
3 Kattenbroek
4 Schothorst-Noord
5 Centrum
6 Leusderkwartier and Bergkwartier
7 Horsterveld
8 Zeewolde-Zuid
9 Dragonder-Noord
10 Dichtersbuurt and Schepenbuurt

railway station
highway
railway

their reliability, the length of the questionnaire and therefore the response rate, and the willingness of respondents to answer personal questions. To limit the length of the nonetheless lengthy survey, several attitudinal variables were measured with one direct question, while the use of multiple items would have been preferred.

The second survey took place in the first half of 2007 using a newly developed method that combines GPS logs, GIS technology and an interactive web-based validation application. GPS was used to collect data for an entire week on the travel behaviour of 1,200 of the respondents who had earlier participated in the internet survey. See Chapter 4 for an extensive description of this fieldwork (and Bohte *et al*., 2008).

Several digital spatial data were derived from geographical databases and further prepared with the use of geographical information systems (GIS). Road distances from the respondents' homes to several activity locations were calculated, as well as a so-called 'shopping basket' that contains the shortest route to a bakery, pharmacy and supermarket and the return home.

1.3 Outline

This thesis comprises a collection of four papers that have either been published or have been submitted to peer-reviewed journals. Consequently, there is some overlap of the individual chapters concerning the literature reviews and data description.

Chapter 2, published in *Transport Reviews*, reviews theories and empirical research on residential self-selection and travel behaviour that explicitly include attitudes. Based on this review, the conditions under which travel-related attitudes will most likely contribute to determining the influence of residential self-selection on the relationship between the built environment and travel behaviour are discussed.

Chapter 3, published in *Transportation Research Part C*, presents the GPS-based data collection method that was developed. The chapter starts with an overview of literature on GPS-based travel-behaviour data collection methods, followed by the description and explanation of the specific method developed for the empirical research of this thesis. The method is evaluated by comparing the results of the GPS survey in this thesis with paper diary data from the Dutch Travel Survey. Following this analysis, Chapter 4 discusses the results of an evaluation survey held among the participants of the GPS survey.

In Chapter 4 (submitted for publication), the indirect residential self-selection effect of attitudes towards travel mode use and the importance of distances to activity locations on travel behaviour are tested by estimating structural equation models. Two models explain the total kilometres travelled and two models explain car trip share. By estimating models with and without the

'reverse' influence of behaviour on attitudes, the effect of accounting for this reverse influence is presented. In addition, the importance of including attitudes and behaviour at compatible levels of aggregation is tested.

Subsequently, Chapter 5 (submitted for publication) empirically tests the assumption that the influence of beliefs concerning travel mode use on travel mode choice and residential self-selection related to the distance to activity locations (e.g. the distance to shops and railway stations) vary depending on trip distances and activity location types. Furthermore, the influence of changes in socio-demographic characteristics and lifestyle orientation on residential self-selection are analysed.

Chapter 6 summarises the findings of this thesis by explicitly answering the research questions, and concludes with recommendations for policy and further research that can be derived from this thesis.

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2 Measuring attitudes in research on residential self-selection and travel behaviour

A review of theories and empirical research

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Abstract
Empirical studies that include travel-related attitudes to identify the role of residential self-selection in the relationship between the built environment and travel behaviour display a wide variety in the type of attitudes that they include, the relationships between the variables that they analyse and ways they measure attitude. This paper discusses what theories on attitudes and behaviour can contribute to examining the role of self-selection and reviews those studies on residential self-selection and travel behaviour that explicitly include attitudes. Although several studies state that residential self-selection is accounted for by the inclusion of attitudes, the complexity of the inclusion and the measurement of attitudes often leads to an underestimation of the role of residential self-selection. Because of their relevance to the reliability of results, the options for measuring travel-related attitudes are also discussed. When attitudes are included in questionnaires, it is essential to consider reliability, efficiency, response and the number of variables.

2.1 Introduction

Since the development of spatial policies that aim to influence travel behaviour, such as New Urbanism in the United States and the Compact City Policy in Europe, housing and transport researchers have become increasingly interested in determining the influence of the built environment on travel behaviour. Many studies have evaluated this influence by analysing the effect of land-uses such as compact development, mixed land-use and street design on the travel patterns of households. The majority of these studies have concluded that there is indeed a link between the characteristics of residential locations and travel behaviour, to some degree at least. However, the complexity of the relationship between the built environment and travel behaviour means that there is still considerable disagreement on the extent of the assumed effects (see e.g. Ewing and Cervero, 2001; Dieleman *et al.*, 2002; Bhat and Guo, 2007).

Residential self-selection significantly contributes to this complexity and ignoring residential self-selection leads to an overestimation of the impact of the built environment. Households may not only align their travel behaviour

to the possibilities and constraints of their residential location, but also self-select themselves by choosing to live in residential locations that correspond with their travel-related attitudes. For example, residents who prefer driving over using public transport may choose remote and spacious neighbourhoods, while households with a preference for public transport may opt for more urban residential locations within walking or cycling distance of a railway station. This is evidenced by several studies on residential choice which, using different research methods, have indicated that travel-related attitudes and preferences do indeed influence residential choice (e.g. Molin and Timmermans, 2003; Schwanen and Mokhtarian, 2007). The inclusion of attitudinal variables like preferences to account for residential self-selection in models that analyse the relation between the built environment and travel behaviour is in particular of importance if they add to the explanation of variation in travel behaviour by individual characteristics like social-demographic characteristics. These individual characteristics are more straightforward to measure than attitudinal variables and tend to be included more often (for further elaboration, see Mokhtarian and Cao, 2008; Van Wee, 2009).

A better understanding of the role of residential self-selection could lead to more tailor-made spatial planning, taking into account both residential and travel attitudes. As stated by Næss (2009), if households were able to self-select this would not mean the built environment did not influence travel behaviour. On the contrary, the built environment enables households to self-select. If it were known which combination of housing, neighbourhood and travel-related attributes households would prefer in a new house, spatial planners could provide such a combination. If the aim were to increase the sustainability of travel behaviour, spatial planning could provide households that have sustainable travel-related attitudes with houses that combine their housing, neighbourhood and travel preferences. It is possible to persuade households that prefer less sustainable travel modes – such as the car – to more sustainable ones – such as the bicycle – into more sustainable travel behaviour by building houses that correspond to their housing and neighbourhood preferences, and also by providing excellent cycling and public transportation infrastructure, including accommodating polluting travel behaviour – such as car driving – to a lesser extent.

In this paper, residential self-selection concerning travel behaviour refers to how households choose a residential location that conforms to their travel-related attitudes. An increasing number of studies are currently being carried out with the aim of determining the impact of residential self-selection. Mokhtarian and Cao (2008) have conducted an extensive evaluation of the most frequently used methodologies for analysing residential self-selection concerning travel behaviour. These methodologies vary from direct questioning to longitudinal research. Some include the measurement of attitudes, while other studies refer only indirectly to attitudes. In this paper, we add to

the review by Mokhtarian and Cao (2008) by further exploring the inclusion and measurement of attitudes in studies that have included attitudes directly.

Because of its general applicability, we will use the following frequently used definition of attitudes 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". These evaluations include affective evaluations (e.g. I like riding a bicycle), cognitive evaluations (e.g. riding a bicycle is environmentally friendly) as well as behavioural responses (e.g. riding a bicycle or signing a petition in favour of bicycle infrastructure).

Most empirical studies on the role of residential self-selection have measured current travel-related attitudes rather than attitudes at the time of residential choice to account for residential self-selection; therefore this review will discuss the whole interaction between travel-related attitudes, built environment characteristics and travel behaviour, and not just the influence of travel-related attitudes at the time of residential choice.

The main reason for using current attitudes in empirical studies is that these are the only attitudes available from the datasets used. Measuring attitudes at the time of residential choice is very complicated and retrospective questioning on the attitudes that individuals held at the time of making the residential choice is not a reliable method. Moreover, it usually is impossible to identify the exact role of travel-related attitudes in residential choice because of the complexity of such decisions – with each housing alternative consisting of other combinations of attributes and attribute levels, it is impossible to identify the exact role of travel-related attitudes. According to Lindberg *et al.* (1988), different dimensions of housing attributes may not be evaluated independently of one another and therefore the evaluation of housing attributes in isolation from one another does not seem reasonable.

Furthermore, the interaction between attitudes, the built environment and travel behaviour is an ongoing and complex process. Residential choice often coincides with changes in travel-related attitudes or induces them. For many households, residential choices are made during lifecycle transitions, such as starting a family, or at other important junctures such as changing jobs. These events can also influence travel-related attitudes. Households may also anticipate such changes in the future, causing a temporal mismatch, but self-selection in time. Additionally, although travel possibilities may not have matched the travel attitudes at the time of moving into the new residential area, residents can become accustomed to the travel possibilities in their area, and come to appreciate these possibilities and leave behind old travel habits and preferences.

Thus the mechanism of residential self-selection involves several issues that complicate the inclusion of attitudes into analysis models such as indirect relationships and causality in different directions. In this paper we will widen the residential self-selection debate by considering the specificity of attitudes, travel behaviour and built environment characteristics that are

included in analyses of self-selection. We will argue that dissimilarities in the specificity of studies may hinder the comparison of attitudes and behaviour, and this may in turn affect the accuracy of findings on whether residential self-selection has taken place and whether there is a significant relationship between the built environment, attitudes and travel. More general travel-related attitudes (e.g. attitudes towards cycling) may explain more specific travel behaviour (e.g. cycling to work). However, particularly if the aim is to unravel how the built environment can influence travel behaviour, the inclusion of specific travel-related attitudes may be necessary.

The main aim of this paper is to discuss how attitudes can be included in empirical research aimed at unravelling the residential self-selection issue. This paper is therefore structured as follows. Section 2.2 will discuss which factors and relationships are of importance in such models by discussing relevant elements from social psychological attitude-behaviour models. Subsequently, in Section 2.3, we will review which factors and relationships have been analysed in specific empirical studies. Finally, in Section 2.4, we will discuss the measurement of attitudes in order to identify residential self-selection. Attitudes are much less easy to measure than socio-demographic characteristics of individuals such as age, gender and educational level. Several factors can contribute to measuring attitudes more reliably and efficiently, but these cannot always be taken into consideration in empirical self-selection studies. We will therefore discuss the advantages and disadvantages of different methods of measurement that can be considered.

2.2 The inclusion of attitudes in travel behaviour models

The interest in the psychological construct of 'attitude' among travel behaviour researchers has varied over time. During the 1970s, attitudes emerged in several travel behaviour theories and studies, while recently attitudes have appeared increasingly in empirical studies. This section aims to identify which theoretical considerations could be relevant to residential self-selection studies using attitudes. Firstly, we will discuss the concept of 'attitude', and secondly we will briefly describe the history of the inclusion of attitudes in travel behaviour research. We will then discuss how attitudes can be included in travel behaviour models that include residential self-selection by evaluating the relevance of elements of social psychological theory.

2.2.1 The definition of attitude

The concept of attitudes originates from social psychology. Within social psychology various definitions of 'attitude' exist. Some definitions assume that

attitudes are learned, whereas others assume that they may, in part, have a biological basis. This paper will use the broad definition by Eagley and Chaiken (1993, p. 1) that an attitude 'is a psychological tendency that is expressed by evaluating a particular entity with some degree of favour or disfavour'. In their definition 'evaluating' refers to affective responses (e.g. I like riding a bicycle) as well as cognitive and behavioural responses. Cognitive responses are often referred to as beliefs. They refer to the probability that a particular object or relationship exists (e.g. riding a bicycle is environmentally friendly). Behavioural, conative or action responses refer to overt actions on the part of people that are related to the attitude object (e.g. riding a bicycle or signing a petition in favour of bicycle infrastructure) (Eagley and Chaiken, 1993). The target at which an attitude is directed can be either an object (e.g. attitude towards cars) or behaviour (e.g. towards driving a car). An attitude can concern a particular object (e.g. my car) or behaviour (visiting a shop this morning) or a range of objects (cars in general) or behaviours (shopping in general) (Eagley and Chaiken, 1993).

The specificity of travel-related attitudes that are included in residential self-selection studies varies from very general (e.g. attitude towards driving a car) to very specific (e.g. attitude towards taking the bus to get to the campus next time (Bamberg *et al.*; 2003)) and these attitudes refer to different components of travel behaviour: travel modes, trip characteristics (e.g. trip costs, routes, distances, times, quality of infrastructure) and destination characteristics (e.g. quality of services, opening hours).

2.2.2 Attitudes in travel behaviour research

Ajzen's (1991) Theory of Planned Behaviour (TPB) is probably the most frequently used social psychological theory on the effect of attitudes on travel behaviour (e.g. Bamberg *et al.*, 2003; Gardner and Abraham, 2008). The TPB is based on expectancy value-theory. According to expectancy-value theory, expected values are determined by cognitive evaluation or subjective probability that an attitude object possesses the attribute (e.g. riding a bicycle is environmentally friendly) multiplied by the affective evaluation of the attribute (using an environmentally friendly travel mode is good). It is assumed that the behaviour for which the expectancy-value product is the highest will be chosen (Eagley and Chaiken, 1993; Gärling and Garvill, 1993).

In the TPB behaviour is influenced by three types of beliefs: (1) the likely outcomes of the behaviour and the evaluations of these outcomes determine the attitude towards the behaviour; (2) the normative expectations of others and the motivation to comply with these expectations determine the subjective norm; and (3) the presence of factors that may facilitate or constrain the behaviour determine the perceived behavioural control. Attitudes, subjective norms, and perceived behaviour do not directly influence behaviour but influ-

ence behaviour through intention. In addition, behaviour is directly influenced by the extent to which a person has the necessary skills, resources and other prerequisites (actual behaviour control) (Ajzen, 1991).

Many travel behaviour studies and theoretical models are broadly based on the TPB, but involve additional factors and/or modified or different relationships between the various factors. Habit is one of the most significant factors that was added and several studies have demonstrated the role played by habits in travel behaviour (Verplanken, 1997; Gardner and Abraham, 2008). The TPB has also been criticised for neglecting the roles of 'affect' and 'desire' (Conner, 2000; Perugini and Bagozzi, 2004; Perugini and Dijst *et al*., 2008). The model of goal-directed behaviour (MGB) by Perugini and Bagozzi (2001, 2004) adds 'anticipated behaviour', 'past behaviour' and 'desire' to the TPB. Several travel behaviour studies have shown the value of this model and its additions to the TPB (e.g. Carrus *et al*., 2008; Dijst *et al*., 2008).

Another model that is frequently used in social psychological travel behaviour research is the Norm Activation Model by Schwartz (Schwartz and Howard, 1981). This was developed to explain moral behaviour, and can be applied to analyses of environmentally friendly travel behaviour which involves small individual costs (in terms of money, time or effort) (Steg and Buijs, 2004).

Since the late 1960s, travel behaviour research outside the field of social psychology has been predominantly based on micro-economic utility-maximisation theory. This approach treats travel alternatives as bundles of attribute levels; the total utility of an alternative is therefore determined by the utility an individual derives from its attribute levels. Similar to the conventional expectancy-value model it is assumed that individuals always prefer the alternative that delivers the highest utility or satisfaction. However, the utilities that an individual derives from the attributes of an alternative are not measured directly but deduced from actual behaviour ('revealed preferences'), the characteristics of the alternatives (e.g. speed, cost, comfort in the case of mode choice), personal characteristics (e.g. gender, age and income) and the decision context, which can include land-use characteristics (Ben-Akiva and Lerman, 1985). Affective evaluations are not directly included in models but rather placed within the random error term and are thus part of the unexplained variance. In any case, neither cognitive evaluations nor perceptions of attribute levels are included. Therefore the conventional micro-economic approach to individuals is sometimes described as an optimizing 'black box' (Morikawa and Sasaki, 1998).

However, although conventional utility theory does not include attitudes, researchers have repeatedly aimed to incorporate them. In the 1970s, the role of attitudes was discussed extensively among travel behaviour researchers (e.g. Hensher and Stopher, 1979; Stopher *et al*., 1981). For example, in the theoretical model by Golob *et al*. (1979) travel choices stem from a combina-

tion of the decision-maker's perception of the existence of constraints and his attitudes. The perception of the existence of constraints and attitudes is determined by the characteristics of the decision-maker and characteristics of alternatives. Moreover, attitudes and perceptions do not only influence travel choices, but are also influenced by the travel choices themselves. Similarly, Chapin (1978) argued that the propensity to engage in an activity and the opportunity to engage in an activity together determine which activities will be chosen. The 'propensity' element determines which activities are likely to fall within a person's realm of concerns and thus defines the scope of choice. It is the motivational basis for the activity, conditioned by person-specific constraints. The propensity itself is derived from motivations, attitudes, roles and person characteristics. The 'opportunity' element refers to the availability of a physical place or facility suited to the activity and to the congeniality of the surroundings for engaging in that activity. It depends on the perceived availability as well as on the perceived quality of facilities and services.

In Cullen's (1978) model, daily experiences (including travel experiences) influence longer-term life choices such as job and housing choices through attitudes. Long-term decisions determine the social and spatial context in which short-term decisions are made. In particular, negative experiences of daily routine activities can lead to a revision of people's attitudes towards the daily routines, leading to long-term life choice decisions that will alter the social and/or spatial context.

In the 1990s, there was apparent renewed interest in revealing the contents of the 'black box' of the micro-economic approach. Ben-Akiva *et al.* (1999) propose a framework in which they distinguish three psychological factors: perceptions, attitudes and preferences. They define perceptions as the individual's beliefs or estimation of the attributes of the alternatives (e.g. safety, convenience, reliability and environmental friendliness). In their view, attitudes reflect the needs, values, tastes and capabilities of individuals (e.g. 'the importance of reliability' and 'preferences for a specific mode'). Together attitudes and perceptions determine an individual's preference for an alternative or the utility s/he derives from an alternative.

2.2.3 Relevant factors and relations from social-psychological theories

The aim of this subsection is to identify which constructs and relationships from social–psychological attitude-behaviour theory are of importance in analysing the role of travel-related attitudes in the relationship between the built environment and travel behaviour. As explained in the introduction, we are interested in the influence of attitudes at the time of residential choice as well as current attitudes.

Perception – Most theoretical attitude-behaviour models, including the model by Ben-Akiva *et al.* described in Section 2.1, include perceptions or cognitive beliefs concerning attributes (or outcomes) of behaviour (or alternatives) and evaluate these beliefs. In these models, individuals do not base their (residential and travel) choices on the actual attribute levels of alternatives, but on their perception of these attribute levels. In most models, including the TPB, and the models developed by Golob (1979) and Chapin (1978) (see Subsection 2.2.2), perceptions also influence the relationship between constraints (or the availability of facilities and services and/or behavioural control) and actual behaviour. The inclusion of the perception of (the level of) travel-related attributes of the built environment in residential self-selection models is necessary when these differ significantly from the actual attributes of the built environment.

Direction of causality – An important issue in social psychology is the direction of causality in the link between attitudes and behaviour, which is also highly relevant to the self-selection issue. According to the widely recognized cognitive dissonance theory by Festinger (1957), people are inclined to reduce any dissonance between their attitudes and their behaviour either by adjusting their behaviour or by adjusting their attitudes. The effect of attitudes on behaviour is usually stronger than the effect of behaviour on attitudes, but the majority of research that has assessed both behaviour and attitudes at two or more points in time provides evidence that behaviour also influences attitudes (Eagly and Chaiken, 1993). Golob *et al.* (1979) addressed this issue as early as 1978, when they stated that travellers adjust their attitudes to bring them into line with their mode choice, thereby reducing cognitive dissonance. Moreover, it can be expected that particularly in the period after a residential move which includes a change of travel options, households rethink their travel behaviour which may lead to changes in their travel-related attitudes. Their perceptions of new possibilities will not be formed at once but may take some time to develop. Furthermore, the characteristics of the built environment can change over time. This means that if attitudes currently match (or do not match) the travel opportunities offered by the built environment characteristics of a household's location, it cannot be assumed the same was true at the moment of residential choice.

Habits – Triandis (1977) first introduced 'habit' into attitude-behaviour theory. In his theory of interpersonal behaviour, he defined habit as "situation-specific sequences that are or have become automatic, so that they occur without self-instruction". Together, habits, behavioural control and intentions determine behaviour (Triandis, 1980, p. 204). The significant role of habits in travel behaviour implies recognising habits is also of importance in residential self-selection analyses. Travel habits that were developed at a previous resi-

dential location may (temporarily) be continued at the new location, meaning that new travel opportunities are not recognized. After a residential move, new habits can develop that affect the influence of travel-related attitudes on travel behaviour.

The specificity of attitude and behaviour – An important issue in attitude-behaviour studies is the specificity with which attitudes and behaviour are measured. Research often fails to identify a link between attitudes and behaviour because of a mismatch between aggregation levels – for example, very general attitudes are related to specific behaviours (Eagley and Chaiken, 1993). Ajzen and Fishbein (1977) distinguished four elements of behaviour: action (e.g. driving), target (a car), context (in the city) and time (Saturday morning), and argued that the compatibility of the degree of specificity or generality of the attitudes and behaviours analysed should concern all four of these elements. In residential self-selection analyses, the specificity of travel-related attitudes and travel behaviour can vary from general (a positive cycling attitude; a built environment that is cycle-friendly) to very specific (if someone likes to take the bus to the swimming pool on Saturday mornings, the availability of a good bus connection on Saturday morning to the swimming pool indicates self-selection). The built environment could be placed under the 'context' category of Ajzen and Fishbein's argumentation, while in trips with a specific purpose (e.g arriving at the swimming pool), this purpose could belong to the 'target' category.

Ajzen and Fishbein's argument also relates to residential self-selection analyses. Some people may always want to travel by car, but for others mode choice depends on the distance to a location, the activity at the location, the time of day, travel companions, and so on. If travel-related attitudes depend on the context of the travel behaviour concerned, residential self-selection can best be identified if this context is also incorporated into the travel-related attitudes that are measured.

Furthermore, it is debateable to what extent self-selection concerning travel-related attitudes takes place at a more aggregated level. Do people self-select to a cycle-friendly neighbourhood or do they self-select to a location that enables them to cycle to work? Moreover, the travel-related attributes of a residential location that determine whether or not residents are self-selected tend to be very location-specific and an average level of these attributes for a whole neighbourhood cannot be used to determine whether residential-self-selection has taken place and residents are able to travel according their attitudes.

Whether more general built environment measures can be used depends on the differentiation within and between spatial entities. The aggregation of scores may lead to little differentiation between entities, while larger differentiations between the entities become invisible. Many suburban neighbour-

hoods in the USA can be classified as car-oriented and as lacking in good public transportation, cycling and pedestrian infrastructure, while Western European neighbourhoods generally have some level of infrastructure for cyclists, pedestrians and/or public transport, although this is not always equally distributed within the neighbourhoods. Due in particular to the lower distance thresholds of walking and cycling, the distances between people's homes and possible destinations need to be measured more specifically when it comes to walking and cycling distances. For example, if a neighbourhood has one shopping centre, only some households will live within walking distance of it.

The quality of public transportation is even more time- and location-specific. If the station is within easy walking distance, but the frequency is low, the public transport connection is useless. Moreover, each combination of origins and destinations has its own accessibility by public transportation. The need to analyse residential self-selection, the built environment and travel behaviour at a specific level decreases when there is less variety in the travel-related attitudes and travel-related attributes within and between the spatial entities.

It can thus be argued that when seeking to identify residential self-selection, travel-related attitudes, travel behaviour and built environment characteristics must all preferably be measured at the same level of specificity. Due to data limitations, cost or the time available, this may not always be possible. Whether travel-related attitudes need to be very specific also depends on the research question. Often more general attitudes will be sufficient for explaining more specific travel behaviour. However, if people evaluate travel modes differently when different trip lengths and/or trip destinations are involved, this knowledge could be used to identify adjustments that need to be made to the built environment to lead to changes in travel behaviour.

Household characteristics – It can be debated whether or not households characteristics and lifestyle directly influence behaviour or only influence behaviour through attitudes. Do households with children want to live near a playground because they have children or, because they would like their children to play in a playground? In this example, the latter scenario seems more plausible. However, household characteristics (such as income, basic needs that have to be fulfilled and handicaps) also constrain people in their travel and residential choice. These constraints will influence behaviour directly. Particularly in residential self-selection analyses that use current travel-related attitudes, the fact that residential moves often coincide with other important life decisions, such as having children or changing jobs, must be taken into account. These other life decisions may also change household's travel-related attitudes.

Intention and desire – The importance of factors that intervene the relationship between attitudes and behaviour, such as 'intention' in the TBP and 'inten-

tion' and 'desire' in the MGB in residential choice models, could be expected to depend on the aggregation level of travel-related attitudes and behaviour in the model. Although, in theory, the TPB and therefore also the construct of 'intention' can also be used to predict aggregated behaviour to the authors' perception, intention mainly seems to be included and successful in the prediction of more specific behaviour. In general, studies on residential self-selection and travel behaviour focus on more general travel behaviour. This is because the main interest usually lies in revealing the effect of the built environment more on the general travel behaviour of individuals or households rather than its influence on a single trip. Desires are less linked to specific behaviour, a final goal or outcome and refer to longer time frames in comparison to intentions (Carrus *et al.*, 2008).

Subjective and moral norms – The need to include subjective and moral norms will depend on which travel behaviour is analysed. Both have proven relevant in explaining more specific travel behaviour. However, again, the authors are not aware of their significance in studies on more aggregated travel behaviour.

2.3 Attitudes, built environment characteristics and travel behaviour in empirical studies on residential self-selection

Studies on the influence of the built environment on travel behaviour which address residential self-selection by including attitudinal variables date predominantly from the last few years, with the exception of a few older ones. The number of such studies is increasing, but remains limited and the number of empirical datasets used is particularly limited. The datasets available display a wide variation in the type of attitudes measured. Table 2.1 presents an overview of studies on residential self-selection which include attitudes.

This section reviews if and how these studies address the issues and factors that were identified in Section 2.4 as relevant for residential self-selection analyses: perception, the direction of causality, habits, specificity of attitudes and behaviour and household characteristics. Besides, we evaluate how the studies deal with the indirect relationship of travel-related attitudes on travel behaviour through residential choice. Advantages and disadvantages of direct measurement of attitudes and indirect measurement of attitudes by measuring the evaluation of attributes will be discussed in the section on the measurement of attitudes, i.e. Section 2.4.

Because the analytical methodologies chosen largely determine what type of relationships can be analysed, the studies are categorized according the methodologies used. We adopt the categorization used by Mokhtarian and

Table 2.1 Overview of residential self-selection studies that include attitudes

Study & dataset	Methodology	TB variables	Spatial variables
Kitamura *et al.* (1997) SF Bay Area, 1993 Response: 11%	Multiple regression analyses	Trip frequency, transit trip frequency, transit trip share, non-motorised trip frequency, non-motorised trip share, car trip share	Neighborhood characteristics, e.g. distances to nearest bus stop and grocery store, backyard, existence of sidewalks, BART access, mixed land use, high density Perceptions of neighbourhood quality, e.g. no reason to move, streets pleasant for walking, good local transit service
Bagley & Mokhtarian (2002) SF Bay Area, 1993 Response: 11%	SEM	Vehicle miles, transit miles, walk/bike miles	Commute distance and suburban & traditional factor (FA 18 perceived and actual neighborhood characteristics e.g. home size, distance to nearest grocery store, average speed limit, grid street system, population density)
Van Wee *et al.* (2002) Utrecht, NL, 2001 Response:51%	Multiple regression analyses	Car trip frequency, distance by car, bicycle trip frequency, distance by bicycle, PT trip frequency, distance by PT	Commute distance, distance to railway station, distance to social recreation destinations
Schwanen & Mokhtarian (2005a) SF Bay Area, 1998 Response: 25%	Tobit models	Distance travelled overall, distance travelled by mode	Neighborhood type: suburban or urban Neighborhood type dissonance (score pro-high density factor vs neighborhood type)
Schwanen & Mokhtarian (2005b) SF Bay Area, 1998 Response: 25%	Multinomial logit analysis	Commute mode choice	See Schwanen & Mokhtarian (2005)
Næss (2005) Copenhagen, 2001 Response: 33%	Multiple regression analyses	Km on weekdays, % of km by foot or bike on weekdays	Distance to downtown, distance to the closest second order centre and closest railway station, density of inhabitants and workplaces at the residential location
Næss (2006) Copenhagen, 2001 Response: 33%	Multiple regression analysis	Commuting distance	See Næss (2005)

Attitudinal variables	Attitude measures	Results
Pro-environment, pro-transit/ridesharing, suburbanite, automotive mobility, time pressure, urban villager, TCM, workaholic	Attitudes: FA 39 statements, e.g. 'environmental protection costs too much', 'driving allows me freedom' and 'too much valuable agricultural land is consumed to supply housing'	Socio-economics & neighborhood characteristics → travel behaviour, but attitudes had a stronger influence on travel behaviour
Pro-alternatives, pro-drive alone, pro-environment, pro-growth, pro-pricing, time-satisfied, work-driven, pro-high density, pro-transit and pro-driving Lifestyle factors: adventurer, culture lover, hobbyist, homebody, nest-builder, outdoor enthusiast, relaxer	Attitudes: see Kitamura *et al.* (1997) Lifestyle: FA of over 100 types of activities and interests, e.g. gardening, attend theater, hunting	Attitudes and lifestyle → travel behaviour, neighbourhood characteristics had little impact on travel behaviour
Preferred travel mode	Direct measurement: 'To which category do you belong?' (preference for car/bicycle/PT/other)	Travel mode preferences → residential choice, especially regarding public transportation Travel mode preferences & residential location → travel behaviour
Attitudes toward land use and travel: travel dislike, pro-environmental policy, commute benefit, travel freedom, travel stress and pro-high density Travel liking by mode and purpose Lifestyle factors: status seeker, frustration, workaholic, family/community oriented Personality factors: adventure seeker, organizer, loner, calm Neighborhood type dissonance (score pro-high density factor vs neighborhood type)	Attitudes: FA 32 statements, e.g. 'Getting there is half the fun' 'I limit my auto travel to help improve congestion and air quality', 'Having shops and services within walking distance from my home is important to me' Travel liking: ratings Life style: FA 18 statements e.g. 'like moving at high speeds', 'I am generally satisfied with my life' (Redmond, 2000) Personality: FA 17 words/phrases	Neighbourhood type dissonance → distance traveled, but neighbourhood type appears to have a stronger influence
See Schwanen & Mokhatrian (2005), but without travel liking variables and neighborhood type dissonance	See Schwanen & Mokhtarian (2005)	Neighbourhood type dissonance → travel behaviour, but neighbourhood type also → travel behaviour, especially in the suburbs
Attitudes towards transport factor (high value = car-oriented attitude) and attitudes towards environmental issues factor	The environmental and transport attitudes are based on 7 statements each, the statements are not described	Attitudes & residential location both → travel behaviour
See Næss (2005)	See Næss (2005)	Attitudes & residential location both → travel behaviour

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Continueing table 2.1 Overview of residential self-selection studies that include attitudes

Study & dataset	Methodology	TB variables	Spatial variables
Khattak & Rodriguez (2005) North Carolina Response: 25%	Binary logit model, multiple regression analyses	Number of cars, external trips, walking trips, trip distances, trip duration	Conventional neighbourhood vs. neo-traditional neighbourhood
Handy *et al.* (2005) Northern Calif., 2003 Response: 25%	Quasi-longitudinal, multiple regression analyses, order probit model	Difference in frequencies of current use of modes and use of modes one year ago or before residential move	Accessibility, e.g. business types, eat-out places, theatres within 400 m, groceries, pharmacies within 1600 m Perception of neighbourhood characteristics: accessibility, physical activity options, safety, socializing, attractiveness and outd oor spaciousness
Cao *et al.* (2006a) Austin, 1995 Response: 23%	Negative binomial regression analyses	Pedestrian shopping trips, strolling trips	Neighbourhood characteristics, e.g. distance to commercial areas, sidewalks availability Perception of neighbourhood characteristics, e.g. safety, traffic, people, stores, walk advantage
Cao *et al.* (2007) Northern Calif., 2003 Response: 25%	Quasi-longitudinal, SEM	Driving, walking, car ownership	See Handy *et al.* (2005)
Scheiner & Holz-Rau (2007) Cologne, 2002/2003 Response: 27%	SEM	Modal share, vehicle kilometres travelled	Residential location type: density of supply, quality of public transportation, density and mixed land use
Frank *et al.*(2007) Atlanta, 2001/2002 Response: 30%	Logistic regression analyses, cross tabs	Physical activity, driving	Walkability index (commercial building floor area to land area ratio, land use mix, net residential density & intersection density)

Attitudinal variables	Attitude measures	Results
Eight attitudes towards residential spaces and the environment e.g. 'Environmental protection is an important issue', 'I can be comfortable living in close proximity to my neighbors' and 'Having shops and services close by is important to me'	One statement each	Attitudes → residential location type Attitudes & residential location type → travel behaviour
Attitudinal factors: pro-travel, pro-transit, pro-bike/walk, travel minimizing, safety of car, car dependent Preferred neighbourhoods characteristics: accessibility, physical activity options, safety, socializing, attractiveness and outdoor spaciousness	Attitudes: FA 32 statements e.g. 'I prefer to bike rather than drive whenever possible', 'I often use the telephone or the Internet to avoid having to travel somewhere', 'Getting to work without a car is a hassle' Preferred neighbourhoods characteristics: FA of impo rtance of same 34 characteristics	Attitudes, neighborhood characteristics & preferred neighbourhood characteristics → travel behaviour
Importance of stores within walking distance	Importance rating	Attitudes & neighbourhood characteristics → travel behaviour
See Handy *et al.* (2005)	See Handy *et al.* (2005)	Preferred neighbourhood characteristics & attitudes → neighbourhood characteristics → travel behaviour Neighbourhood characteristics, preferred neighbourhood characteristics & attitudes → travel behaviour
Lifestyle factor out-of-home self-realisation Location attitudes: accessibility of the city centre, importance retail/service, proximity to public transportation	Lifestyle includes out-of-home leisure preferences and self-realisation values, the authors do not describe the measurement of these preferences and values Location attitudes: importance rating	Attitudes & residential location → travel behaviour Lifestyle → attitudes Lifestyle → attitudes, residential location → travel behaviour
Non-motorized selection-factor, neighborhood preference factor	Non-motorized selection-factor: FA of importance-rating of 10 items, e.g. 'ease of walking', 'low transportation costs', 'near to public transit' Neighborhood preference factor: FA results in seven trade-offs between aspects of travel convenience and neighborhood design, e.g. walkability versus commercial-residential land use separation, commute distance versus residential density	Attitudes & residential location → travel behaviour

Cao (2008), but limit ourselves to those methodologies and studies which explicitly include attitudes. For an overview of empirical studies that include all the methodologies relevant for analysing the role of residential self-selection in travel behaviour we refer to Cao *et al.* (2009).

2.3.1 Direct questioning

A straightforward method of uncovering residential self-selection is simply to ask whether preferences for certain travel behaviour aspects have influenced a household's residential choice. A disadvantage of this use of preferences is that underlying attitudes remain unknown. How positive or negative alternatives are evaluated is not known, just that one alternative is more positively evaluated than the other. Furthermore, because trade-offs between different characteristics of housing alternatives are not all made consciously and residential choice may have taken place many years ago, respondents' answers may not be very reliable.

Van Wee *et al.* (2002) analysed the role of preferences for modes in residential choice and its consequences on actual travel behaviour. In the survey, the respondents were asked which travel mode they preferred and were subsequently asked whether the choice of their current residential location was related to this preference. It was found there was indeed a relationship between travel mode preferences and choice of residential locations. Particularly those who preferred public transportation had taken the accessibility of public transportation services into account when making their residential choices. Multivariate regression models showed that mode preferences added to the explanation of travel behaviour by personal, household and land-use variables.

2.3.2 Statistical control

The majority of the studies described in Table 2.1 used multiple regression analyses with a form of travel behaviour variable as the dependent variable and attitudes and the built environment variables among the explanatory variables. The results only give an indication of the existence of residential self-selection, namely a comparison of the association of attitudes and travel behaviour with the association between the characteristics of the built environment and travel behaviour. In these studies, in which attitudes are included for explaining variation in travel behaviour, it is generally assumed that residential self-selection probably took place. When it is shown that the built environment adds to the explanation, it is assumed the built environment influences travel behaviour. Different directions of causality can not be identified. The existence of indirect relationships between attitudes and travel behaviour can be assumed if models with and without attitudes are compared.

If, in the second model, attitudes contribute to explaining variance, while the explanatory power of the built environment characteristics diminishes, it can be assumed that attitudes influence travel behaviour through residential self-selection.

Probably the most extensive and most often cited of the earlier studies on the built environment, attitudes and travel behaviour is the study by Kitamura *et al.* (1997). They used a very extensive dataset collected in a survey in the San Francisco Bay Area. Their results show that attitudes (e.g. 'pro-environment', 'suburbanite' and 'time pressure') contribute to the explanatory power of regression models that explain the number of trips, transit trips and non-motorized trips and the share of auto, transit and non-motorized trips. The attitude factors were the most significant in the model for the share of auto trips. Here they added to the explanatory power of socio-economic factors and neighbourhood descriptors of 'parking space available', 'distance to nearest bus stop' and 'distance to nearest park'. The pro-environment factor, the pro-transit factor and the automotive mobility factor in particular show a large association with the share of auto trips. Most evidence of the role of residential self-selection can be gained from their comparison of a model with and without attitudes. The impact of 'distance to nearest bus stop' and 'distance to nearest park' on the share of car trips decreases when attitudes are added to the regression model. Because attitudes were more strongly associated with travel behaviour than neighbourhood characteristics, Kitamura *et al.* suggest that land-use policies may not change travel behaviour unless attitudes are also changed.

Næss's (2005) regression analysis, which explains total travel on weekdays, shows a positive attitude towards car use, distance to the city centre, to a second order centre and to a railway station are all positively correlated to the number of kilometres travelled. The density variable and the index of attitudes towards environmental issues are not significant, with a 0.15 significance level. In his model on the influence of the proportion of distance travelled by foot or by bicycle on weekdays, a positive attitude towards car use, distance to the city centre, to a second order centre and to a railway station are negatively correlated to the proportion travelled by bicycle or foot, while the density variable is positively correlated. The index of attitudes towards environmental issues was again not significant, at a 0.15 significance level. Næss concludes that in addition to socio-economic characteristics and attitudes, residential location also influences travel behaviour. The multiple regression analysis to explain commuting distance in Næss's (2006) study has similar results, with again a significant influence of attitudes towards car use and no significant influence of attitudes towards environmental issues. The results thus show a significant relationship between attitudes towards car use and travel behaviour. However, the conclusions on the role of residential self-selection could have been made more precise if cycling and walking attitudes

had been explicitly included in the models that explain the proportion travelled by bicycle and foot.

In the study by Cao, Handy, *et al.* (2006) the specificity of the variables included are compatible. They measured the importance of stores within walking distance, miles to the nearest store and the frequency of walks to a store and strolling trips. The results of the analysis show that individuals who rate 'stores within walking distance' as important in their decision to live in their current neighbourhood also stroll more frequently and walk more often to the stores. Although the respondents seem to have self-selected themselves, neighbourhood characteristics also add to the explanation of both frequencies. It is noticeable that the four neighbourhood characteristics that are associated with strolling frequencies are all perceived characteristics, while the objectively measured characteristics were not significant.

Research on residential self-selection now also appears in the medical field. During the last few years, determining the influence of the built environment on travel behaviour has gained the interest of policy-makers concerned with health issues and, specifically, obesity (Transportation Research Board, 2005; Van Lenthe *et al.*, 2005). Frank *et al.* (2007) examined whether spatial structure or neighbourhood and travel preferences could account for levels of physical activity, driving and obesity. They first estimated two regression models that included a 'walkability' variable as a built-environment variable and one of two attitudinal variables: a 'non-motorized' variable or a neighbourhood preference variable. The total number of trips, and the numbers of discretionary and non-discretionary trips all showed a positive correlation with walkability and the 'non-motorized' variable in the first model, and with walkability and neighbourhood preference in the second model. A crosstab shows that residential self-selection had possibly played a role: the percentage of people who walked and who lived in a walkable neighbourhood and also preferred to live in one was larger than the percentage of people who walked and were mismatched. Frank *et al.* conclude that their results indicate that respondents had self-selected themselves.

2.3.3 Comparison of consonant and dissonant residents

The regression analyses described in the previous subsection only indicate whether there is a correlation between attitudes and travel behaviour, and built environment and travel behaviour. Because self-selected and mismatched respondents were not separated, the effect of self-selection on travel behaviour could not be clearly identified. For this reason, some regression studies split up respondents into consonant and dissonant residents. As discussed in the previous section, consonant respondents have not necessarily self-selected themselves, since their attitudes or the characteristics of the built environment may have changed since their residential choice, but

among the consonant respondents many would be self-selected. Moreover, it may be just as interesting to know the association of consonance as the influence of (conscious) self-selection at the time of residential choice.

Schwanen and Mokhtarian (2005a) investigated the extent to which dissonance between the physical structure of the neighbourhood and land-use preferences near the residential location affect the distance travelled overall and by mode. For their analyses, the responses of the respondents to the following four attitude statements were used to calculate a pro-density score: 'Living in a multiple family unit would not give me enough privacy' (factor loading: -0.617), 'I like living in a neighbourhood where there is a lot going on' (0.486), 'Having shops and services within walking distance from my home is important to me' (0.401), 'I like to have a large yard at my home'(-0.323). Urban residents with a low pro-density score and suburban residents with a high pro-density score were described as 'mismatched'. Their analyses show that neighbourhood dissonance has a significant impact on distances travelled in general and by mode. Travel attitudes such as preferences for various modes, factors such as 'travel freedom' and some personality and lifestyle factors also showed significant associations with the distances travelled. Schwanen and Mokhtarian (2005b) used the same dataset to examine the effect of neighbourhood characteristics and preferences towards neighbourhoods on commute mode choice. Again they concluded that both residential self-selection and neighbourhood structure influence travel behaviour.

In both studies, because dissonance was measured at a very general level, namely concerning living in a suburban or urban area, and only one of the indicators of the pro-density score referred directly to travel behaviour, these results cannot be used to analyse residential self-selection concerning some specific aspects of travel behaviour. People who are categorized as dissonant in these studies may still be consonant as far as their travel preferences are concerned.

2.3.4 Instrumental variable models

Another method of including endogenous variables in a travel behaviour equation that includes residential self-selection is using instrumental variables. In instrumental variable models, the endogenous X is a function of relevant instrumental variables. In contrast to the statistical control method, the objective is to find variables that maximally explain X and are only minimally correlated with the error term (for further explanation see Mokhtarian and Cao, 2008).

Khattak and Rodriguez (2005) compared travel behaviour in a conventional neighbourhood to that in a neo-traditional neighbourhood to investigate whether residents in neo-traditional neighbourhoods substituted walking for driving trips or made more trips. Eight attitudes towards residen-

tial spaces and the environment were used as instrumental values to measure the choice for either a conventional neighbourhood or a neo-traditional neighbourhood. The logit model constructed to show the explanatory value of attitudes regarding residential choice shows that respondents from the two neighbourhoods differed in their attitudes towards residential spaces and the environment, indicating that people had self-selected. The predicted probability of residing in the neo-traditional neighbourhood was used to control for self-selection in the regression analyses that explained the number of trips by car, external and walking trips, trip distances and duration. After controlling for self-selection and some other factors, their findings indicated that neighbourhood design also influenced travel behaviour. Households in neo-traditional neighbourhoods made fewer trips by car, fewer external trips and walk much more. Their travel distances were also significantly lower. Trip duration was similar in the two neighbourhoods. Khattak and Rodriguez note that the attitudes they measured did not prove conclusively that self-selection had occurred since they were collected after households had moved, meaning that people may already have adjusted their attitudes to justify their decisions in order to reduce cognitive dissonance. Respondents may also have become accustomed to some neighbourhood characteristics and grown to like them. Moreover, Cao, Mokhtarian *et al.* (2006) used results from other studies (Cao, Mokhtarian *et al*., 2006; Handy *et al*., 2006) to argue that some of the attitudes they used to predict the probability of residing in the neo-traditional neighbourhood may be significantly correlated with the error term in the second phase models, meaning that one of the criteria for the inclusion of instrumental variables had been violated.

2.3.5 Structural Equation Models

Structural Equation Modelling (SEM) is a very useful analysis technique for research on residential self-selection because it integrates path analysis and factor analysis. This means that indirect relations like the influence of attitudes on travel behaviour through residential choice can be analysed. When attitudes are measured by multiple statements, confirmatory factor analysis can be included in the models (see Section 2.4). SEM also allows the measurement of causality between two variables in both directions. Nonetheless, the number of residential self-selection studies that have used SEM is limited.

To our knowledge, the first study on residential self-selection that included attitudes in an Structural Equation Model was carried out by Bagley and Mokhtarian (2002). Bagley and Mokhtarian used the same dataset as Kitamura *et al.* (1997, see Subsection 2.3.2). The structural equation model they constructed and that was identified included a traditional and a suburban factor as built environment variables, the attitudinal factors 'pro-high-density', 'pro-driving' and 'pro-transit', average number of miles travelled daily by per-

sonal vehicle, transit and walk/bicycle and commute distance as endogenous variables. Demographic, lifestyle and additional attitudinal variables were included as exogenous variables. To measure lifestyle, their questionnaire listed more than 100 types of activities and interests. The respondents had to indicate which subjects they had read about in the past month, how they had spent the past weekend and the activities they had participated in during the past year. The results of their analyses showed that, of all the explanatory variables, attitudinal and lifestyle variables had the greatest impact on travel demand, both direct and indirect, and that residential location type had little impact on travel behaviour. They found only one significant effect of residential location on travel demand: a positive correlation between suburban location and transit miles. Bagley and Mokhtarian used the possibility of SEM to test the influence of behaviour on attitudes. Their findings included one that the number of vehicle miles driven influenced pro-driving attitude.

Scheiner and Holz-Rau (2007) used data collected in the Cologne region to analyse the relationships between life situation, lifestyle, residential location type (density of supply, quality of public transportation, and density and mixed land-use) location attitudes (accessibility of the city centre, importance of retail/service and proximity to public transportation) and travel behaviour with the aid of several Structural Equation Models. Scheiner and Holz-Rau constructed separate Structural Equation Models for the share of car trips, share of non-motorized modes, share of public transportation trips and vehicle kilometres travelled. Each model only included the residential location attribute and the location attitude that was assumed to be most relevant for explaining the variable concerned (e.g. importance and quality of public transportation in the case of share of car trips). They found that 'life situation' had a stronger influence on travel mode than 'lifestyle', but that 'lifestyle' influenced location attitudes and decisions which in turn influence travel mode choice. Some of the models showed that the influence of location attitudes on travel behaviour was equal to or even stronger than the effects of location attributes on travel behaviour, thus indicating that self-selection had a significant effect.

2.3.6 Longitudinal analyses

As stated by Mokhtarian and Cao (2008), the collection of attitudinal data before and after a residential move is the only method of actually measuring whether attitudes have changed after a move and have possibly been adjusted in line with the spatial structure of the new residential location. To be able to determine the exact influence of travel-related attitudes on the choice of residential location, and therefore on the degree of self-selection, it is important that these changes in attitudes are accounted for (see cognitive dissonance theory Subsection 2.2.1). Asking respondents retrospectively about

their past behaviour is unreliable: people do not remember everything and their memories may diverge from actual behaviour. Remembering past attitudes will even be harder.

To the authors' knowledge, at the time of writing (summer 2008) no study on residential self-selection and travel behaviour has been carried out that includes longitudinal attitudinal data. Such an approach would be expensive, and it would cost a great deal of effort to maintain a survey panel over an extended period and existing panel travel surveys do not include relevant attitudinal questions. Krizek (2003) used longitudinal data to study residential self-selection, but without including attitudinal variables. His results suggest that when households relocate to a neighbourhood with different accessibility, their travel behaviour will change, but he recognises that because he did not include changes in preferences towards travel and residential location, the changes in travel behaviour he found could also be (partly) attributed to changes in preferences.

Handy *et al*. (2005) and Cao *et al*. (2007) used a hybrid solution by using quasi-longitudinal data to compare neighbourhood characteristics and travel behaviour before and after a move. Both studies used data from a survey held in 2003 in Northern California. The survey included travel-related attitudes and the respondents were asked to indicate how far their current travel behaviour differed from their behaviour before they moved if they had moved within the past year, or from their behaviour one year previously if they had not moved within the past year. Perceptions of the characteristics of the neighbourhoods were also measured. GIS data were also used to measure objective measures of accessibility.

The regression analysis carried out by Handy *et al*. (2005) to explain vehicle miles driven, travel-attitudes, neighbourhood characteristics and preferences, and socio-demographic variables, suggests that differences between the travel behaviour of residents in traditional neighbourhoods and residents in suburban neighbourhoods are more a function of travel-related preferences than of neighbourhood characteristics. However, their quasi-longitudinal analysis shows that neighbourhood characteristics influence travel behaviour. In this analysis, accessibility is the most important factor for explaining changes in driving. Some other spatial factors, such as the number of grocery stores within 1,600 metres, were also significant, as well as the car dependency attitude and the pro-bike/walk attitude.

The result of the SEM by Cao *et al*. (2007) shows that neighbourhood preferences and travel-related attitudes indirectly influence travel behaviour through residential choice and also directly influence car ownership, driving behaviour, and walking behaviour. Several changes in the built environment also significantly influence travel behaviour. In particular, increased accessibility proved to be the most important factor in explaining the reduction in driving.

2.3.7 Discussion

All the studies reviewed indicate that residential self-selection concerning travel behaviour takes place to some degree. However, the following summary, of how the issues identified in Section 2.4 are dealt with, shows variations in the degree to which the studies actually measure the role of residential self-selection.

Indirect relationships – Because the indirect influence of attitudes through residential choice on travel behaviour is the central issue in the question of residential self-selection, analysis methodologies should allow for indirect relationships to be measured. The majority of the studies reviewed did not use an analytical methodology that allowed for the analysis of the indirect relationship between attitudes and travel behaviour through residential choice. As argued by Mokhtarian and Cao (2008), the collection of longitudinal data and the use of SEM would be the best to meet all the methodological requirements for the analysis of the influence of residential self-selection on travel behaviour. However, no attitudinal longitudinal analyses have been conducted to date. Cross-sectional analyses that only include current attitudes do give some indication of the role of self-selection if indirect relation are analysed. Kitamura *et al.* (1997) found evidence of the indirect influence of attitudes by comparing a regression model with and without attitudes and Bagley and Mokhtarian (2002) did find indirect relationships through the use of SEM.

Perception – The studies that included perceptions of the characteristics of the built environment all find at least some evidence that perceptions influence travel behaviour in addition to actual characteristics. Additionally, in the study by Cao, Handy, *et al.* (2006) objectively measured characteristics were not significant, while perceived characteristics were.

The direction of causality – The influence of travel behaviour on attitudes has only been measured by Bagley and Mokhtarian (2002). They did find that attitudes were influenced by behaviour. Furthermore, none of the studies measured attitudes at different moments in time, although Khattak and Rodriguez (2005) do address the fact that the attitudes they measured did not prove conclusively that self-selection had occurred, because their data were collected after households had moved.

Habits – Habits were not addressed in either of the studies. Because of the strong evidence of the role of habits in travel behaviour, it can be argued that their role in the relationship between attitudes, the built environment and travel behaviour demands further investigation. If people do not leave behind the habits they developed at a previous residential location, this may mean

that travel behaviour does not conform with people's attitudes or with the built environment. It can also be assumed that travel-related attitudes are less accessible if people have strong travel habits, and measuring these travel-related attitudes will therefore be less reliable. The identification of habits can be used in policies that aim at encouraging more sustainable behaviour by making people more aware of their travel habits and providing them with information on more sustainable travel alternatives.

Specificity of attitudes, behaviour and built environment characteristics – The review of empirical studies shows that the majority of the studies link attitudes towards the different travel modes to travel behaviour with broadly comparable specificity, such as modal share or kilometres travelled by mode. The study by Cao, Handy, *et al.* (2006) measured more specific attitudes and travel behaviour. Nonetheless, several of the studies also include attitudes and behaviour of different specificity by including attitudes that concern a more specific component of behaviour or by linking more general attitudes to more specific behaviour. As shown by the results of these studies, these attitudes do contribute to the explanation of travel behaviour, but nonetheless, it can be debated to what degree they account for self-selection.

Moreover, we argue that to best determine whether travel-related attitudes correspond to the characteristics of the built environment and thus whether residential self-selection has taken place, the specificity of built environment measures needs to accord with the specificity of attitude measures. The aggregation level of built environment measures often differs from the degree of aggregation of attitudes and behaviour. In several of the studies, built environment characteristics are measured at a more specific scale. For example, the study by Kitamura *et al.* (1997) includes distance to the nearest bus stop as built environment characteristic and a pro-transit/ridesharing attitude. Distance to the nearest bus stop is only one of the factors that determines whether a residential location has good public transportation. Someone who lives close to a bus stop may have self-selected themselves to live near that bus stop, but not necessary to high quality public transportation. However, Kitamura *et al.* did include other public transportation variables like BART access; several detailed characteristics can be used to construct a more general view of the quality of public transportation.

Household characteristics – The studies that include lifestyle and socio-demographic variables show that these variables influence travel behaviour. Most studies do not analyse whether demographic variables and lifestyle influence behaviour directly or indirectly through attitudes, as is assumed in the TPB. The results of the study by Scheiner and Holz-Rau (2007) show lifestyle influences attitudes. Because household composition, career or orientation towards leisure influence people's attitudes towards travel behaviour, new life

choices after residential moves must be taken into account for when longitudinal data are used and current travel-related attitudes are compared with travel-related attitudes at the time of residential choice.

While this section has focused on the position of attitudes in analyses of residential self-selection and travel behaviour, the following section addresses another critical issue concerning the use of attitudes in these studies, namely the measurement of attitudes.

2.4 Measurement methods in studies on residential self-selection and travel behaviour

The reliability of residential self-selection studies which include attitudes is largely determined by the choice of attitude measures. Attitudes are not directly observable and their measurement is therefore always indirect and not completely verifiable. This implies that measures of attitudes should be well-considered and explained. This section presents the relevant options for measuring travel-related attitudes and discusses how attitudes are measured in studies on residential self-selection and travel behaviour.

Within psychology, various methods to measure attitudes exist. Travel behaviour research usually uses psychometric techniques to measure attitudes. In psychometric methods, respondents respond to a number of items which are all designed to measure an underlying attribute. Which psychometric method is most suitable depends on the type of attitude that is being measured. Among those studies on residential self-selection and travel behaviour that included attitudes, there is a large variation in how attitudes were measured (see Table 2.1, column 6). The inclusion of attitudes in the field of travel behaviour is still in a developing stage and different methods are explored. Therefore there seems to be no consensus on which measures are the most efficient and reliable. In addition, the amount of available attitudinal data is limited because most available datasets do not include attitudinal data.

2.4.1 Single item-measures

Single items that are measured using one statement or question can be good indicators for well-formed attitudes towards familiar objects. Many successful studies of attitudes have assessed attitudes informally using one or two rating scales (Eagley and Chaiken, 1993). However, when attitude objects are multidimensional, a single item can be ambiguous and can also include subtleties of meaning that may unintentionally influence the respondents' answers (Ajzen, 2002).

In the studies we have reviewed, single-item measurement is not used

often. Cao, Handy *et al.* (2006) and Scheiner and Holz-Rau (2007) measured the importance of proximity to specific destinations with one importance rating for each destination, and Schwanen and Mokhtarian (2005a) measured 'travel liking' in general and per purpose and mode separately with one question each. Van Wee *et al.* (2002) examined how residential self-selection can be studied by asking people directly which travel mode they prefer and whether the current choice of residential location was related to this preference. In a study on car use, Steg (2005) measured attitudes towards car use by asking respondents to indicate to what extent their family, friends or colleagues would consider them a 'car lover'. The aim of asking what others thought was to prevent socially desirable responses. The five response categories ranged from 'a true car lover' to 'someone who hates cars and driving'.

An advantage of single-item measures is that either the length of the questionnaire can be limited, which will positively influence the response rate, or more other variables can be measured. The survey that was used by Van Wee *et al.* was kept short, which was probably the main reason for the high response rate (51%) compared to the other studies (see Table 2.1, column 1).

2.4.2 Evaluative semantic differential

In social psychology, the most frequently used multi-item direct measure of attitude is the evaluative semantic differential by Osgood *et al.* (1957). Respondents are asked to rate an attitude object on a set of bipolar adjective scales. These adjectives are very general (e.g. good/bad, useful/useless). The total attitude score is calculated by summing or averaging the individual bipolar scales. Because the scales are not constructed for particular attitude objects, they are generally applicable which allows the comparison of attitudes across different attitude objects (Eagly and Chaiken, 1993). None of the residential self-selection studies we reviewed used this measurement method, but in social psychology evaluative semantic differentials are often used because of their ease of construction (Ajzen, 2006). For example, in a study based on the TPB, Bamberg *et al.* (2003) assessed attitudes towards travel modes using two statements, one being: 'For me, to take the bus (use my car/bicycle/walk) to get to the campus next time would overall be good-bad'.

2.4.3 Likert scaling

Travel behaviour research, including most of the studies on residential self-selection described, often uses Likert-type scaling. Likert's method is a multi-item attitude measurement that infers a common underlying attitude from a broad range of items/evaluations. Inferred evaluations generally show less correlation with actual behaviour than do direct measures, but inferred evaluations are particularly useful when the interest lies in the factors behind a

positive or negative evaluation and when the object has many different dimensions (Ajzen, 2002). Knowledge on why one travel mode is evaluated better than another can be used to adjust infrastructure or services in order to make a particular travel mode more attractive.

Likert's method measures attitudes by summating the rating of items. Respondents have to indicate their degree of agreement with different items that represent either a favourable or unfavourable attitude toward the object (usually by means of a five-point scale: strongly agree, agree, undecided, disagree, strongly disagree). The scores of all items are summed to obtain an attitude score of the respondent. If Likert's method is followed correctly, an initial pool of items that were chosen intuitively must be pilot tested on a group of respondents to eliminate ambiguous and non-discriminating items (Eagly and Chaiken, 1993).

Particularly if respondents have to evaluate a list of attributes and do not have to provide relevant attributes themselves, this can lead to an overvaluation of non-salient and unimportant beliefs. Several empirical studies have proven the significance of the importance and salience of beliefs in attitude-behaviour modelling (Van der Pligt and De Vries, 1998). Not everyone evaluates the same attributes of alternatives and even when the same attributes are evaluated the importance attached to the evaluation of an attribute may vary. For example, two individuals may both believe that cycling to work is healthy and therefore good. However, they may still differ in how important they think it is to be healthy, and therefore differ in how important it is for them to find a residential location within cycling distance from work.

Although the majority of the residential self-selection-studies reviewed use Likert-type scaling, most of these studies do not follow Likert methods in the summation of the ratings of items. The study by Næss (2005) is the only one of the reviewed studies that constructed attitudinal variables by simply summing the evaluations of multiple statements. Næss constructed environmental and transport attitudes by summing seven statements for both factors. However, the description of the variables does not include which statements were used and how they were used, so the value of these measures cannot be evaluated.

While evaluative semantic differentials mainly measure cognitive evaluations, Likert scaling has the advantage that it more easily allows the inclusion of affective and behavioural evaluations. For example, the study by Handy *et al*. included the behaviour statement 'I often use the telephone or the Internet to avoid having to travel somewhere' and the statement 'I like moving at high speeds' in the study by Schwanen and Mokhtarian (2005a) measures an affective evaluation.

2.4.4 Measures of attribute importance

An option for measuring attitudes indirectly that acknowledges the differences in the importance that people attach to attributes is multiplying the ex-

pected consequences of attributes by the importance people attach to these consequences. The residential self-selection studies we reviewed did not measures attitudes by combining performance and importance ratings, but several of the studies did include measures of importance.

An example of such measure from the field of social psychology can be found in the PhD study by Anable (2002). She measured attitudes towards the use of the various travel modes on a day trip for leisure by having respondents rate 22 characteristics of using those modes (e.g. excitement, control, energising, scenery, value for money). Firstly, she used five-point scales to measure the importance attached to each characteristic when travelling ('While you are on your journey on a day/afternoon out for leisure, how important or unimportant are the following?' 'convenience', 'being safe', 'having privacy', etc.), and secondly she asked them to rate each mode for each characteristic ('If I made a journey on a day/afternoon out for leisure (by car, bus, bicycle etc.) it would be... convenient,' 'dangerous', 'private', etc.). She subsequently determined the total score per mode by deducting the importance score of each characteristic from the performance score and then dividing this outcome by the importance score, and totalled the scores of all the aspects of each mode. She chose to use this deficiency score instead of simply multiplying the importance score with the performance score because this indicates the extent to which the evaluation of a mode on an attribute satisfies the importance attached to this attribute. Anable argues that when the performance score is higher than the importance score, the over-performance can be ignored by setting the deficiency score to zero because this extra satisfaction will not be 'consumed'. She also recognises that when a mode satisfies those attributes that are most important, this is not reflected in the score because the score is expressed as a proportion of importance.

It can be assumed that when it concerns travel mode choice people are able to indicate at least some differentiation in the importance they attach to different attributes. However, following Fishbein and Ajzen (1975) it can be questioned whether subjective estimates of perceived importance resemble empirically derived weights. In their often cited review, Nisbett and Wilson (1977) presented a large amount of empirical evidence of people's limited ability of introspection concerning judgemental processes.

2.4.5 Factor analysis

Another method of inferring attitudinal factors from multiple indicators is the use of factor analysis. In factor analysis, it is assumed that indicators are measured on an interval scale, but ordinal indicators, such as those measured with Likert-type statements, may be used if the ordinal categories are not expected to seriously distort the underlying metric scaling (Kim and Mueller, 1978). Factor analysis can either be exploratory or confirmative. Explorato-

ry factor analysis (EFA) is most appropriate when the number of factors and their mutual associations are not clearly known in advance. EFA combines indicators that are associated with each other into one factor. Confirmatory factor analysis can be used to test whether measured (indicator) variables load as predicted on an expected number of factors (Floyd and Widaman, 1995).

The majority of the residential self-selection studies we reviewed used Principal Component Analysis (PCA), the most widely used EFA, to construct attitudinal factors from multiple Likert-type statements. The number of factors identified in a PCA is arbitrary. In SPSS, the default setting is that all factors have an eigen-value less than '1'. The eigen-value for a given factor measures the variance in all the variables which is accounted for by that factor. Other considerations can include whether the addition of one more factor leads to a significant decrease in the eigen-value and the number of factors in comparison to the number of variables. To be able to use the identified factors in following analyses, their scale can be determined by summing all items that belong to a factor by using the factor score coefficients of all items that load high on a factor or by using the factor scores of all items that load on a factor.

Although PCA is the most often used form of EFA and in practice both methods are used for similar purposes, it is subject of discussion whether common factor analysis, the second form of EFA, is more appropriate for identifying latent constructs. While PCA aims to explain all variance in a dataset, common factor analysis, only explains the common variance of all items, without explaining their unique variance. Therefore several researchers argue that PCA is most appropriate for data reduction and common factor analysis is most appropriate for identifying latent variables that explain the covariance among the different items (Floyd and Widaman, 1995; Fabrigar *et al.* (1999).

Furthermore, it is noticeable that in the residential self-selection studies we reviewed, the factor analyses that were performed are hardly explained. Some studies present the loadings of the items on the factors, but the criteria used to determine the number of factors are not explained.

When a number of diverse statements are gathered into one factor, the naming of the factors is crucial for the interpretation of the results of those analyses that use the factor as input. The meaning of a latent attitudinal factor is determined by the meaning of its indicators. Additionally, if underlying indicators/items/statements are unclear or ignored in further analyses, an important added value of inferred measurements – namely the identification of underlying factors – disappears.

Factor names in the residential self-selection studies often sound very attractive (e.g. 'urban villager', 'out of home self-realisation'), but the name of the attitudinal factor constructed does not always seem to cover the content of the statements that it is based on. For example, the attitudinal factor 'pro-alternatives' in the study by Bagley and Mokhtarian (2002) consists of such diverse statements as 'shops and services within walking distance of home

important' and 'should provide incentives to use electric/clean-fuel vehicles'. Frank *et al*. (2007) used ten items to assess the reasons for moving as input for a PCA. On the basis of the results, they constructed a 'non-motorized' factor existing of the items 'importance of ease of walking', 'importance of low transportation costs' and 'importance of nearness to public transit'. It seems questionable whether statements that measure such diverse items at these can be seen as belonging to one attitude domain and therefore placed into one factor. When it is very difficult to find a factor name that covers everything, using a more neutral name may be considered (e.g. travel attitude 1), and then clearly linking this to a table showing all included items.

Travel behaviour studies carried out by social psychologists often use CFA. A standard CFA model with a single factor needs at least three indicators to be identified. A model with two or more factors needs at least two indicators per factor, but a minimum of three indicators per factor is recommended (Kline, 2005). An example of using CFA for measuring is the measurement of the meaning of car use by Steg (2005). She used 3x5 statements by Dittmar (1992) to measure the instrumental (e.g. 'I only have a car to travel from A to B'), symbolic (e.g. 'My car shows who and what I am') and affective meaning (e.g. 'I feel free and independent if I drive') of car use. Cronbach's alphas were calculated to determine the internal consistency reliability. Both Cronbach's alphas of the instrumental and affective factor were sufficient – respectively .68 and .70 – while the symbolic factor score was less convincing with .60 after two items were dropped.

2.4.6 Discussion

When an attitude measure is chosen, several consequences have to be considered and traded off: the validity and reliability of the measure, the value of addressing the multiple underlying dimensions of an attitude and the length of the survey in relation to the response. Combining measures which conform to social psychological standards with all the variables relevant for analysing residential self-selection will often lead to questionnaires that are too lengthy for many respondents to fill in thoroughly. Given the need for trade-off, explanations and justifications of the measures chosen might reasonably be expected from the reviewed studies. However, it is noticeable that in the studies reviewed, scant explanation is given to the choice of measurement methods.

One of the trade-offs is between single-item or multi-item measures. Single-item measures are sometimes sufficient, but may also miss some important nuances of an attitude. None of the reviewed residential self-selection studies used direct multi-item measures. These can render the direct measurement of an attitude more reliable.

The majority of the studies used indirect multi-item measures. An advantage of indirect measures is that underlying aspects are taken into account.

It depends on the goal of the measurement which methods is most appropriate. If the goal is to identify unknown latent constructs underlying residential or travel decisions, EFA is appropriate. If predefined attitudes are to be included in a model (e.g. attitude towards driving a car) CFA can be used to confirm the relationship between items that are expected to measure the same attitudinal factor. CFA can be incorporated into SEM, which is recommended for the analysis of residential self-selection (see Subsection 2.3.5). The use of confirmatory factor analysis requires extensive preparation and testing beforehand in order to ensure that attitude factors are based on at least three statements with reasonable factor loadings.

If underlying evaluations of attributes are of interest, factor analysis is less appropriate, because evaluations of different attributes may not be correlated. For example it can be expected that 'cycling is healthy' is not correlated with 'cycling is cheap'. The evaluation of underlying attributes can be addressed by measures that multiply the expected consequences of attributes by the importance people attach to these consequences. Such measures were never used in the residential self-selection studies. The measurement of attitudes towards the different travel modes by Anable (2002) seems very useful, because people accord varying levels of importance to different travel attributes (e.g. environmental pollution and trip time differs). Such measures may be more reliable than measures that just sum the evaluations of attributes. However, many studies have shown that subjective importance measures do not resemble empirically derived weights of attribute evaluations.

The fact that attitudes are not directly observable makes it difficult to validate attitude measures. Indicators may not measure the intended latent attitudinal factor, but also respond to distortions and tendencies that may adversely affect the validity of a measure. For example, some respondents tend to answer 'yes' or agree with items, others may intentionally distort answers when they think questions are too personal (Eagley and Chaiken, 1993). One option is to compare the results of different measures, but this requires a greater number of questions and the same measurement failures may still occur.

2.5 Conclusion

Several empirical studies have analysed the influence of residential self-selection on the relation between the built environment and travel behaviour by including attitudinal variables in their analyses. The majority of the results of these studies indicate that residential self-selection affects residential choice. However, whether residential self-selection is actually explained will depend on the specification of these attitudes. The aim of this paper was to discuss

how the inclusion of attitudes can contribute to the residential self-selection debate by reviewing and analysing empirical studies that explicitly include attitudes. Although the number of these studies is still limited, they clearly indicate the value of including attitudes. However, in general these studies also have several limitations as a result of the availability of attitudinal data, the methodologies that were used and the attitude measures that were chosen.

From our review of relevant social psychological and travel behaviour theories and the review of residential self-selection studies, we are able to make five recommendations.

Firstly, we support the conclusion of Mokhtarian and Cao (2008) that it would be preferable to use longitudinal data which allows changes in time to be analysed, combined with the use of SEM which allows the analyses of indirect relations and causality in both directions. Many of the studies reviewed use multiple regression methods with attitudes and the characteristics of the built environment as explanatory variables, and do not measure indirect influences between variables and causality in two directions. None of the studies has used longitudinal attitudinal data. Those quasi-longitudinal studies that have been conducted have not included past attitudes.

Secondly, we stress the importance of the specificity of the measurement of travel-related attitudes, travel behaviour and the characteristics of the built environment for the identification of residential self-selection. If people's travel-related attitudes are different when it concerns different travel contexts such as different trip lengths and different destination types, residential self-selection can best be identified if travel-related attitudes are measured within the same context. Additionally, the use of aggregated built environment measures may blur relevant differentiations within an area. Particularly when it concerns accessibility by foot, bicycle or public transport, exact distances and the location-specific quality of infrastructure and services have to be considered when identifying residential self-selection. Because measuring more specific attitudes and built environments characteristics is often complicated and costly, the challenge for future research is to distinguish between analyses that need specific measures and analyses that allow for some relaxation in the specificity of attitudes and/or built environment measures.

Thirdly, measuring attitudes is very complicated. No simple suggestion concerning the most appropriate measure for identifying residential self-selection can be given, and further exploration is needed. The items chosen to measure attitudes should be efficient and contribute to the reliability of the measure. The studies we reviewed use predominantly indirect multi-item measures. Because they measure how respondents evaluate the attributes of an attitude object, they can be used for identifying underlying aspects. However, when, as in many of the studies that used EFA to construct attitudinal factors, diverse items were put together into one factor and barely referred to in further analyses, this reduces the benefits of using multi-item measures

instead of single-item measures. Because the studies we reviewed did not use these measures, we did not evaluate social psychological measures that used direct multi-item measures, which do not measure the underlying attributes of an attitude object but use several items to evaluate the general behaviour or object the attitude is targeted at. Such measures could increase the reliability of the measurement, but do not improve the insight gained into underlying factors.

Fourthly, the review of theories and studies suggests that it is useful to include perceptions and habits. The built environment both constrains and facilitates travel behaviour, but perceptions of these constraints and facilities may differ from the actual situation. If people do not know that a certain bus line exists, for example, they will not self-select themselves to it. Habits were not included in any of the empirical studies, but other travel behaviour studies suggest that further investigation of their value seems to be appropriate. If the habits that were developed at previous residential locations are continued, habits will significantly contribute to the explanation of travel behaviour by attitudes and the built environment. Strong habits also imply that travel-related attitudes are less accessible, and that this should be acknowledged when these attitudes are measured. Spatial policy can use the identification of habits to encourage more sustainable behaviour by making people aware of their travel habits and providing them with information on more sustainable travel alternatives.

Finally, attitudes in residential self-selection studies cannot be included without a trade-off between the extensiveness of attitude measures, the number of attitudes and other variables included in a questionnaire and the length and complexity of the questionnaire. Because trade-offs are necessary, the choices that are made should be well explained and justified. This review of the studies carried out hitherto shows that many underlying variables such as lifestyle and more general attitudes contribute to explaining residential self-selection, but when the aim is to identify residential self-selection, it is possible that they should be left out in favour of measuring the relevant travel-related attitudes. The length of questionnaires should be limited to encourage respondents to finish the questionnaire and give properly considered answers to the questions. Progress could be made by standardising the definitions and measures of attitudes that are used. At the moment, the type of attitudes included and the measurement of attitudes differ enormously between residential self-selection studies. Building on previous work can sharpen definitions and measures, and standardisation is required to be able to compare the outcomes of different studies.

It can be concluded that research on the role of residential self-selection is promising and further development of this research will improve the understanding of residential self-selection. This will be of great benefit for any spatial policy which aims to encourage more sustainable travel behaviour. When

constructing new neighbourhoods or modifying existing neighbourhoods, spatial planners could provide households that have sustainable travel-related attitudes with houses that combine their housing, neighbourhood and travel preferences. What is more, households that evaluate less sustainable travel modes slightly more favourably than more sustainable ones may be induced into more sustainable travel behaviour by building houses that fulfil their housing and neighbourhood preferences, and that facilitate the use of more sustainable travel modes. On the other hand, if it is known that people evaluate car use more positively than any other transport mode, it can be questioned whether investment in public transport or walking and cycling facilities will lead to the desired results. Because travel-related attitudes and the existing quality of infrastructure for the different transport modes are strongly related, neighbourhoods that have almost no public transportation, walking or cycling infrastructure will not only attract car-oriented households, but will also reinforce this orientation towards cars. This would suggest that changing travel behaviour and attitudes by changing spatial structure will be nearly impossible.

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3 Deriving and validating trip purposes and travel modes for multi-day GPS-based travel surveys

A large-scale application in the Netherlands

Wendy Bohte and Kees Maat (2009), Transportation Research Part C 17, pp. 285-297

Abstract
In the past few decades, travel patterns have become more complex and policy makers demand more detailed information. As a result, conventional data collection methods seem no longer adequate to satisfy all data needs. Travel researchers around the world are currently experimenting with different Global Positioning System (GPS)-based data collection methods. An overview of the literature shows the potential of these methods, especially when algorithms that include spatial data are used to derive trip characteristics from the GPS logs. This article presents an innovative method that combines GPS logs, Geographic Information System (GIS) technology and an interactive web-based validation application. In particular, this approach concentrates on the issue of deriving and validating trip purposes and travel modes, as well as allowing for reliable multi-day data collection. In 2007, this method was used in practice in a large-scale study conducted in the Netherlands. In total, 1,104 respondents successfully participated in the one-week survey. The project demonstrated that GPS-based methods now provide reliable multi-day data. In comparison with data from the Dutch Travel Survey, travel mode and trip purpose shares were almost equal while more trips per tour were recorded, which indicates the ability of collecting trips that are missed by paper diary methods.

3.1 Introduction

Travel patterns of individuals are becoming increasingly varied in time and space. This is due to a range of factors, including spatial fragmentation, part-time working, working from home, specialisation in the workforce, automation, a rise in the number of double-income families, growing diversity in household compositions and a trend towards more cars per household. As a result of this increased complexity of travel behaviour, current travel behaviour research increasingly focuses on trip chaining, complete daily and weekly activity patterns, interrelationships within households and the relationship between spatial structure on a detailed level and travel behaviour (e.g. Boar-

net and Sarmiento, 1998; Golob, 2000; Krizek, 2003; Maat and Timmermans, 2006). Single aspects of travel behaviour are no longer treated as stand alone behaviour, but as being part of complex travel and activity patterns.

Because of this shift to a more integral approach, it has become essential to use data collection methods that are able to obtain detailed travel behaviour characteristics of all trips that an individual or even a household makes during a day and preferably during several days. Current travel behaviour research combines data on the location of origins and destinations, trip purpose, trip length, trip duration, departure and arrival times and travel modes in its analyses. Besides, even more specific data such as exact routes, activities and the people who accompany respondents during their trips are being used. Moreover, the availability of detailed GIS data enables researchers to perform analyses on the effect of spatial structure on travel behaviour at a very detailed level, provided that the travel behaviour of individuals is also measured at a detailed level and the locations visited are geocoded. It is now increasingly accepted that data collection methods based on the Global Positioning System (GPS) may potentially replace traditional methods such as activity diaries because they better match present data requirements.

Traditionally, travel behaviour data are collected through paper or phone recall surveys. People are asked to describe their travel behaviour on an average day or to reconstruct their travel behaviour on one or more previous days. It has been shown that data collected using these methods deviate systematically from actual behaviour. Respondents underreport small trips as well as trips that do not end or start at home. Moreover, car drivers underestimate their travel time, while people who travel with public transportation overestimate the time spent on travelling (Ettema *et al.*, 1996; Stopher, 1992).

In order to avoid these disadvantages, the use of paper travel diaries became popular during the late 1990s (e.g. Maat *et al.*, 2004; Stopher and Wilmot, 2000). In a paper travel diary, people are asked to record travel times, trip origins and destinations, travel modes and other different travel details during the day for several consecutive days. However, because of the burden of taking these detailed notes all days, the chances of non-response are relatively high. People are also inclined to postpone filling in their diaries, which will lead to less accurate time and location data. Respondents may even forget whole trips. An important drawback of the paper diary method is the difficulties that the respondents seem to have with determining the exact locations of the places they visited. Due to the burden on the respondents as well as the decrease in the quality of the recorded data, paper diaries are used for capturing only a couple of days of travel behaviour (Schönfelder *et al.*, 2002; Schlich and Axhausen, 2003). Analyses of two-day travel diaries from a Dutch research project show that respondents were less accurate during the second day of the fieldwork (Arentze *et al.*, 2001). GPS-based data collection methods are potentially more accurate and less of a burden on respondents compared

to paper diary methods, while exact location coordinates of trip destinations and travel times can be recorded. Moreover, additional characteristics such as exact routes can be recorded.

The Global Positioning System is a satellite-based positioning system. When a GPS device receives signals from at least three satellites, the position of the device can be determined, accurate to within approximately 10 m. A GPS data logger saves its location on the earth in location coordinates. In addition to location coordinates, GPS data loggers record the times at which they were situated at these locations. As a consequence, the accuracy of the data depends much less on the respondents' memory and the effort they are willing to make in retrieving addresses and taking notes when compared with paper diary methods.

These improvements in accuracy are confirmed by various studies comparing travel behaviour data recorded using GPS data loggers, data recorded by respondents in paper diaries and data obtained by means of telephone surveys. In telephone surveys and paper diaries, the number of kilometres travelled and the number of trips is underreported. Short trips in particular tend to be overlooked. The times and locations measured with GPS data loggers were also found to be more accurate (Forest and Pearson, 2005; Ohmori *et al*., 2005; Steer Davies Gleave and Geostats, 2003; Wolf, *et al*., 2003). Especially when GPS data are placed in a GIS application for further interpretation, the possibilities for use of GPS data are promising (Chung and Shalaby, 2005; Schönfelder *et al*., 2002; Tsui and Shalaby, 2006; Wolf *et al*., 2001).

The lower burden on the respondent reduces the rate of non-response, which means that data can be collected over a longer period than just a few days. Furthermore, data collection by means of GPS yields an advantage in terms of data processing. The data are available immediately in digital format, thereby avoiding the need for time-consuming data entry. Not only does avoiding the need for data entry result in considerable cost savings, but it also eliminates the possibility of data entry errors.

To date, data collection by means of handheld GPS data loggers has only been applied in a few, largely experimental studies. The majority of GPS-based studies have been conducted in the USA, whereby GPS devices have been placed in cars. However, since the attention in many travel behaviour studies is not only on car trips, and since in many countries other modes have a considerable mode share, travel behaviour data should be collected for all different modes. With the introduction of light-weight handheld GPS devices with increasingly better reception and battery life, there has recently been a sharp increase in the use of handheld GPS data loggers for measuring trips by all travel modes (Kochan *et al*., 2006; Steer Davies Gleave and GeoStats, 2003). Nevertheless, the number of GPS studies that include the registration of travel modes and trip purposes, which are beyond the experimental stage, is still limited because, in contrast to travel times and distances, these travel charac-

teristics cannot be derived directly from GPS logs and ask for a more complex derivation method.

This paper contributes to the improvement of GPS-based travel surveys by introducing a combined method of GPS, GIS and web-based user interaction, which has been applied in large-scale fieldwork in the Netherlands. With more than 1,000 participants this is the first time, as far as we know, a GPS-based method has been employed that measures travel modes as well as trip purposes and the location coordinates of trip destinations on such a large-scale.

The method we developed consists of an interpretation and a validation process. To obtain travel modes and trip purposes, either further questioning of the respondents or extensive data interpretation with some additional information from the respondents is needed. To reduce the burden on the respondents as much as possible, the latter option was chosen. In the interpretation process, GIS data (e.g. railways and shops), characteristics of the respondents (e.g. home address), and the data from the logs of the GPS data loggers that respondents carry are combined in rule-based algorithms. The travel behaviour data that result from this interpretation round can be corrected and added to by the respondents in a validation application. The link between both processes is interactive: when new individual characteristics (e.g. the address of a friend's house) are entered by the respondents, they will be used for further interpretation of the data. In particular, our approach concentrates on the issue of deriving and validating trip purposes and travel modes, as well as allowing for reliable multi-day data collection.

The remainder of this paper is structured as follows. Section 3.2 gives an overview of the advantages and drawbacks of current GPS-based data collection methods that are suitable for measuring travel modes and/or trip purposes. Section 3.3 describes the GPS-based method that we developed, and Section 3.4 evaluates the value of our method by presenting results of the fieldwork we recently undertook. The results are compared with results from the Dutch National Travel Survey 2006 (see http://www.rws-avv.nl/mon) that used paper diaries. The paper ends with conclusions (Section 3.5) about the use of GPS-based methods for the collection of travel behaviour data and a discussion about future possibilities.

3.2 Literature review of GPS-based methods for the collection of travel behaviour data

Travel researchers around the world are currently experimenting with different GPS-based data collection methods. This section reviews literature on GPS-based data collection methods. The review is focused on methods that can be used for deriving travel modes and trip purposes from GPS logs and

their value for the method we developed and that will be described in the next section. Because of the complexity of deriving these two characteristics, one of the main aims in developing our method was to improve the accuracy and ease of deriving them. Travel behaviour characteristics such as travel times and distances can be derived almost directly from GPS logs because a GPS data logger records exact positions and exact times. However, for deriving travel modes and trip purposes additional data such as GIS data, and respondent characteristics and smart algorithms are needed. Due to the fact that deriving travel modes and trip purposes is relatively complicated, different research projects to date have explored and experimented with possibilities for deriving these characteristics, but they all leave room for improvement.

Moreover, because travel modes and trip purposes can never be derived from GPS logs and also other data gaps may occur (e.g. those caused by respondents forgetting their device or from losses of satellite reception), possibilities for validation and completion of the derived data by the respondents have been discussed and evaluated. A simple, straightforward method for collecting the data that cannot be derived from the GPS logs alone is to ask the respondents directly. Different options can be found in the literature, including asking respondents to enter data in a GPS-enabled mobile phone (Ohmori *et al.*, 2005) or in a PDA with GPS (Kochan *et al.*, 2006), or to keep a paper diary in addition to carrying a GPS device.

However, these methods do not solve all the drawbacks of paper diary methods. People have to remember and take the time to make notes or enter information in a PDA or mobile phone frequently. Since another important aim of our method is to be able to lower the burden on the respondents and to improve the accuracy of the data collection in comparison with paper diary methods, our review only discusses validation methods that ask respondents for validation afterwards and only after first deriving as much information as possible without intervention of the respondents.

3.2.1 Deriving travel modes

Different methods have been developed and tested, which derive travel modes as reliably as possible by combining the x and y coordinates and timestamps in the GPS logs without respondent involvement. Of course, average speed and maximum speed can be determined from the location and time data in the GPS logs. However, none of the travel modes can be distinguished with full certainty without additional information. For example, a train and a car trip may deliver the same average and maximum speed as can occur with a car trip in a jammed city and a cycling trip. To be able to distinguish between different modes with the same speed, methods have been developed that combine GPS data with GIS maps.

In the method that is described by Tsui and Shalaby (2006) the time at

which an activity has taken place is deduced from the logs, and the travel mode used is deduced by taking the average and maximum speed and the rate of acceleration observed during the trip. By comparing GPS logs with public transport routes, it can be determined whether a person has travelled by bus or by tram. Missing or poorly recorded sections of the route are then completed where possible using public transport route information. Trips made by metro are identified by examining whether the recording of the previous trip ended in the vicinity of a metro station and the beginning of the following trip started near a metro station. The method was tested on the GPS logs of nine volunteers from Toronto. The travel modes used were correctly determined in more than 90% of cases. The method achieved slightly better results than a method that did not include the use of GIS.

Chung and Shalaby (2005) compiled algorithms that include GPS data and GIS sources. To test their method, a student was asked to repeat 60 trips exactly from the Toronto 'Transportation Tomorrow Survey' whilst carrying a GPS data logger. The accuracy with which the travel modes could be determined was found to be 92%. In total, 79% of the trips made were correctly identified by combining the GPS data with the GIS data, whereby the missing information was primarily attributable to missing GPS data.

Stopher *et al.* (2008) described a method that uses a probability matrix for determining travel mode. Trip characteristics such as the average speed, the maximum speed and the speed recorded most often and bicycle ownership define whether a trip is assigned as on foot, by bicycle or by motorised vehicle. Subsequently, street and public transportation maps are used in GIS for specifying the type of the motorised vehicles.

3.2.2 Deriving trip purposes

For deriving trip purposes from GPS logs, the use of GIS is indispensable. A few studies describe possibilities for deriving trip purposes by combining GPS logs with GIS data. It is noticeable that at the moment, studies that present empirical results of map-matching methods usually only focus on car trips.

An early car-based study is an American pilot conducted by Wolf *et al.* (2001), where GPS data loggers were placed in the cars of 13 respondents. The research showed that trip purpose could be accurately derived from GPS data and an extensive GIS land use database.

An important precondition for such methods is the availability of detailed GIS data. Wolf *et al.* (2004) used the data from the Swedish study conducted by Rätt Fart in order to evaluate the use of GIS data collection by means of GPS. In this study, 186 cars were provided with a GPS device for at least 30 days. Trips ending within 200 m from the home location were assigned with the trip purpose 'home'. Other trip purposes were derived by matching the GPS-data with available points of interest and land-use polygons. The results were

compared with the 2000 and 2001 Swedish national travel survey to determine the most probable trip purpose by matching socio-demographic and trip and activity data. The researchers found the results promising, but argued that refinement of the methodology and especially the availability of more GIS data are needed.

An option that does not often seem to be discussed in the literature is the use of individual characteristics (household composition, possession of travel modes, home and work addresses) as input for algorithms that derive trip characteristics from GPS logs. In the method that was described by Stopher *et al.* (2008), the address of the respondent's workplace or school, the two most frequently used grocery stores and occupation are collected beforehand and used to derive trip characteristics.

3.2.3 Validating

Studies using a method that uses algorithms and GIS to derive travel modes and trip purposes still need to approach respondents to add missing information and validate the derived data if their aim is to collect travel behaviour as accurately as possible, because not all travel modes and trip purposes can be derived without interference from the respondents. Some trip purposes like homes of friends and family cannot be derived from GIS data, and the division of trips by algorithms may also need some adjustments when short stops were missed or wrongly allocated (e.g. in case of traffic jams). Moreover, when batteries run out or respondents forget their device, missing trips have to be added. Finally, bad satellite reception can cause errors in the data (www.cmtinc.com, 2000).

Different possibilities exist for asking respondents for additional information. In a study conducted by Bachu *et al.* (2001), 16 cars from 10 households were equipped with a GPS data logger for 2-3 days. After all the trips recorded by car had been processed into GIS maps, the respondents were asked, by means of face-to-face interviews, to add to the data on the maps by providing details on the purpose of their trips and the number of people that were in the car.

The use of an Internet recall survey is more complicated, but does offer useful opportunities for further processing of the data during the validation by the respondents. Among others, the Internet is a medium that enables us to present derived data in interactive maps and tables. As far as we know, no system has yet been designed that works almost perfectly and has been used in a large-scale fieldwork. However, when a working system is developed, the processing of GPS data into trip characteristics should be rather quick and cheap, because no manual data entry is needed. Stopher and Collins (2005) conducted a pilot study in which they researched how data collection using GPS data loggers in cars can be improved by adding to the data by means of

an Internet recall survey. They created maps depicting routes, origins and destinations per respondent for each day. The respondents were able to indicate missed trips and destinations on the map, which were then processed together. Despite the fact that the Internet application presented various technical problems, the development time of the application was very long and only six households continued to use the applications throughout the study, the researchers hailed the results of the test as promising.

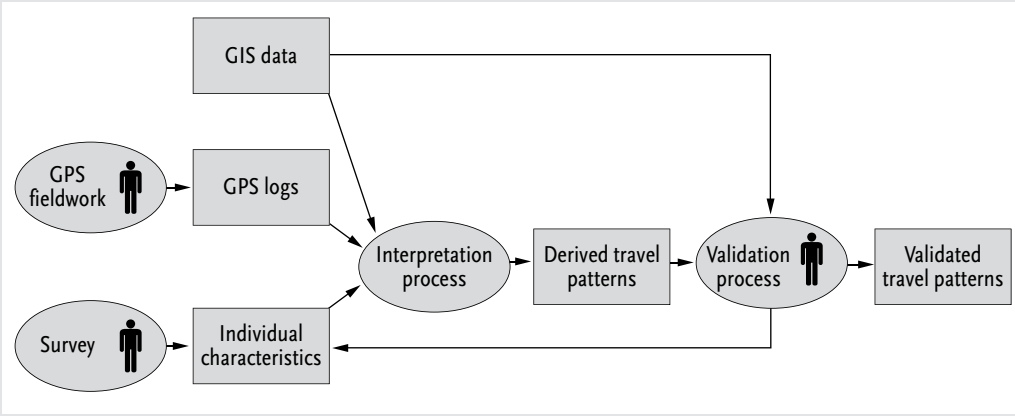
Doherty *et al.* (2006) anticipated that respondents cannot handle interactive maps, and therefore methods that require the interpretation of maps, such as that introduced by Stopher and Collins (2005), are not very user friendly. In the method that Doherty *et al.* theoretically described GPS logs are first split into trips, then activities and missing sections are determined via algorithms and subsequently start and end times, travel modes used and activity locations are determined with the use of GIS. The results are then presented to the respondents in tables in an Internet questionnaire. The respondents are asked to check the details and to add information relating to the number of travelling companions, amongst other things. It is possible to view the trips on a map in the application should respondents wish to do so, but any adaptations to the data by the respondents are made in the tables. Although their method has undergone little testing, Doherty *et al.* have high expectations for this method and envision various possibilities for improvement, including the introduction of 'learning rules' whereby, when travel behaviour is measured over several days, information from previous days can be used to accurately deduce even more trip characteristics in the following days.

Hato (2006) described a method that uses GPS- and Internet-equipped mobile phones. They collected additional information by asking the respondents to indicate the start and the arrival of trips, travel modes and destinations during the day. Afterwards they were asked to check this information and to add additional characteristics in a web-based diary. For reminding and confirmation, maps were provided that depicted the routes that were taken. To test the validity, the method was used in three waves of the Matsuyama Probe Person survey by 100, 311 and 378 respondents. The results indicated that this method reduces the omission of trips and path and time measurement errors.

3.3 Architecture of the GPS-based system

This section describes the architecture of the GPS-based system we developed and have used for a large-scale fieldwork. The aim of our system is to be able to measure travel modes, trip purposes, location coordinates of trip destinations and trip distances, times and duration as accurately as possible and with minimal burden on the respondents. We used the experience and results

Figure 3.1 Architecture of the GPS-based system



of the studies described in the previous section. In comparison to these studies, we devoted additional attention to options for validation by the respondents when we developed our system and we will follow Stopher and Collins (2005) in their use of interactive maps. We realise that the system we present here is just a stage in an ongoing development process.

The GPS-based system consists of two main processes: an interpretation and a validation process (Figure 3.1). During the interpretation process, a collection of scripts that include various rule-based algorithms runs on top of a spatial Database Management System (DBMS) to combine and interpret three different data sources: GPS logs created by providing respondents with GPS devices for one or more days, individual characteristics of the respondents collected by a survey and GIS data (locations of services, railways, etc.). The DBMS that was used is PostgreSQL/PostGIS, a commonly used system (see http://postgis.refractions.net).

When trip characteristics are reconstructed as much as possible, they are forwarded to the validation process. The main part of the validation process consists of a web application that gets its data from the spatial database. In the user interface of the web application, the derived data are presented to the respondents in maps and tables. They are asked to use this validation application to correct and add to the derived trip characteristics. The link with the interpretation process is interactive. When the input of the respondents delivers new individual information such as the addresses of friends and family or when new trips are added, this information is reused for further interpretations.

3.3.1 The interpretation process

During the interpretation process, characteristics of the trips made by the respondents are derived from the raw data in the GPS logs as much as possible. In addition to the GPS logs, two other sources are used as input, namely the GIS data and the individual characteristics of the respondents. Various rule-based algorithms are used to combine these three sources. Table 3.1 chronologically

Table 3.1 Rules used in the interpretation process

1 Removing unreliable trackpoints and the division into trips	
1a	IF distance between trackpoint and previous trackpoint < 10 metres THEN remove trackpoint*
1b	IF duration between trackpoint and previous trackpoint ≥ '00:03:00' THEN split track*
1c	IF speed_trackpoint > 200 km/h THEN remove trackpoint
1d	IF adjacent trips are within same shopping centre polygon THEN merge trips
1e	IF speed_trackpoint < 5 km/h AND duration between trackpoint and previous trackpoint > '00:01:00' THEN trackpoint = trackpoint_garbage IF 3 x nr trackpoints_garbage within trip > nr trackpoints within trip THEN remove trip
1f	IF $\sqrt{((\text{trip xmax- trip xmin})^2 + (\text{trip ymax- trip ymin})^2)}$ / triplength < 0.3 THEN remove trip
1g	IF nr trackpoints within trip < 4 THEN remove trip
2 Set the category of a trip	
2a	IF distance between trip end and POI < 50 metres THEN set category = category POI ('shopping', 'recreation', 'culture', 'medical', 'kids' or 'railwaystation')
2b	IF endpoint trip is within railway station polygon THEN set category = 'railwaystation'
2c	IF endpoint trip is within shopping centre polygon THEN set category = 'shop'
2d	IF distance between home respondent and endpoint trip < 100 metres THEN set category = 'home'
2e	IF distance between work respondent and endpoint trip < 100 metres THEN set category = 'work'
2f	ELSE set category = 'unknown'
2g	IF distance between trip end and trip end with known category < 50 metres AND category trip = 'unknown' THEN set category = known category
3 Set the modality of a trip	
3a	IF average trip_speed < 10 km/h AND max trip_speed < 14 km/h THEN set modality = 'foot'
3b	ELSE IF average trip_speed < 25 km/h AND max trip_speed < 45 km/h THEN set modality = 'bicycle'
3c	ELSE IF average trip_speed < 200 km/h AND THEN set modality = 'car'
3d	IF trackpoint is within railarea** THEN trackpoint = railpoint IF nr trackpoints within trip ≥ 20 AND max trip_speed > 20 km/h AND 2 x nr railpoints within trip > nr trackpoints within trip THEN set modality = 'train' AND set category = 'railwaystation'
4 Merge and add train trips	
4a	IF modality adjacent trips = 'train' THEN merge trips
4b	IF distance between endpoint previous trip and railway station < 200 metres AND general direction of previous trip is towards the station AND distance between startpoint next trip and railway station < 1500 metres AND general direction of next trip is away from the station AND modality previous trip OR modality next trip = 'bike' OR modality previous trip OR modality next trip = 'foot' AND duration trip > '00:03:00' AND triplength > 5000 metres THEN create new trip AND set modality = 'train' AND set category = 'railwaystation'

* Rules executed with the use of GPSbabel (OPEN source ware, see http://www.gpsbabel.org) before data are placed into the PostgreSQL/PostGIS-database.

** Railarea = line element of 100 metres width following rail tracks.

describes the rules that are used as well as the parameters that were chosen.

Developing the rules and parameters was an ongoing process on the basis of the literature and our own logic. We started developing rules, applied them on the next wave of tracks and presented them to the respondents for validation. On the basis of the returned data, we further improved the rules. This process was repeated for all waves, time and again improving the system. Finally, we tested the final developed rules on the whole dataset. It goes without saying that this is basically a never-ending process.

Our aim was to be able to present workable and recognizable data to the

respondents for validation. In the near future further testing with varying parameters and the large dataset that was collected will lead to more fine tuning of all rules, and therefore also of our system. The series of operations that take place during the interpretation is further explained in the following sections.

Removing unreliable trackpoints and the division into trips

First, it is determined which data are reliable, and the GPS log is split into trips. A GPS log consists of a series of points, the so-called 'trackpoints'. Every trackpoint is described in the log on the basis of x and y coordinates and the time at which the GPS data logger was at these coordinates. The speed of the device at the time of logging is also recorded.

To ensure that no activity is recorded when the device was inside a building, the log is filtered to accomplish that two adjacent points are always more than 10 m apart (1a). Subsequently, the log is divided into actual trips made. Which parts in the log must be considered for separate trips is deduced from the respondent's 'rest' periods and the loss of satellite reception in buildings. When the GPS logs indicate that someone remained in a certain location for at least 3 min, the location in question is classed as the destination of the previous trip (1b). Wolf *et al.* (2001) compared the use of different thresholds and found a 3-min threshold that resulted in the best prediction.

In the next step, trackpoints that were logged with an unrealistically high speed of over 200 km/h (1c) are removed from the log. When adjacent trips took place in the same shopping centre, these trips are merged into one shopping trip (1d). If each store visited would be seen as a separate trip, the result would be too chaotic for the respondents when they have to validate their trips. Then in the following step all trips that contain more than 33% unreliable trackpoints with a speed below 5 km/h and a time gap with the previous trackpoint of at least 1 minute, are being removed (1e). Multi-modal transport is split up into a number of trips, which means that railway stations and bus stops are included as separate trip purposes. If a respondent rides his bicycle to the train station, takes the train and then walks from his arrival station to work, this is classified as three trips in our model. Finally, all trips that exist of trackpoints within a very small area and trips with less than four trackpoints are being removed (1f and 1g).

When the log is split into separate trips, this automatically shows the times and locations at which trips were started and completed. After all, if it is known which trackpoint was the first to be placed in a location where someone remained for an extended period of time, it is also known what time the person arrived there and what the x and y coordinates are of the point in question. It is possible to deduce the departure time from the first trackpoint that is placed some distance from the location where the person remained for an extended period of time.

One of the shortcomings of the current generation of GPS devices is the fact that, after the device has been turned off or lost reception, it often takes a while (usually no more than 30 s) before a GPS device has found enough satellites and receives enough signals to be able to determine its location (this is also referred to as getting a 'fix'). This often means that the departure from a location is not logged. Therefore, it is assumed that the location that is the destination of a trip is also the starting point of the next trip.

Determining trip purposes

GIS data are used to allocate trip purposes. All the potential trip purposes are classified into 13 categories, such as 'home', 'work', 'friends/family' and 'cultural'. Locations of facilities are derived from GIS maps listing Points of Interest (POIs) such as the x and y coordinates of schools and other facilities. If a trip ends within a radius of 50 m from a known location, it is assumed that this is the location that is being visited (2a). If more than one POI lies within 50 m the closest POI will be allocated to the trip. A threshold of 50 m is rather low, but we chose to avoid wrongly assigned trip purposes as much as possible. Wrongly assigned trip purposes are more confusing and could be overseen by respondents in the validation application, while filling in 'unknown' trip purposes is made obligatory and less confusing. The list of POIs that is used at the moment is not very extensive, but in future applications better results could be achieved when a more complete list is used. Shopping centres and railway stations can be spread out over a large area, therefore they are not represented by points, but their whole shape has been drawn as a polygon in GIS maps (2b and 2c).

Because the home addresses of respondents are already known (after all, this is where the GPS data loggers were delivered), they can be entered into the database. The post codes of the work locations of the respondents are also translated into x and y coordinates. Because the work location will be visited frequently, the work address is asked for in the beforehand survey. If a respondent's trip ends within 100 m from his home or work address, it is assumed that he respectively went home or to work (2d and 2e). Since home and work locations are known to be often visited by the respondents it is safe to have trips ending within 100 instead of 50 m assigned to these two categories.

If it is not possible to filter out a possible trip purpose on the basis of the underlying GIS maps and the known data on the respondent, the trip purpose will be listed as 'unknown' until the respondent has provided the trip purpose within the internet application. Once a respondent has assigned a trip purpose to an unknown trip purpose, this trip purpose will be assigned to all following trips that end within 50 m of the same location (2g).

Determining travel modes

To determine the travel modes used to complete a trip, different data are

used. First, by calculating the average and maximum speed it can, in most cases, be determined whether the person walked, cycled or drove a car (see rules 3a, 3b and 3c for the parameters used). For determining the maximum speed of a trip, the speed of the trackpoints with the highest speed was neglected, and the speed recorded for the following trackpoint was used to avoid using trackpoints that were collected when satellite reception was not optimal, causing misplaced registration and wrong estimation of speeds.

To determine whether the trip was completed by train instead of by car, a link to GIS data is required, because the speeds of these travel modes may be very similar. By checking whether at least 50% of all trackpoints of a trip lie within 50 m of the centre of a rail track and whether the maximum speed was at least 20 km/h it is determined whether a trip is likely to have been made by rail and the respondent therefore probably took the train (3d). If adjacent trips are all train trips these trips are merged into one trip (4a). Moreover, due to bad reception of satellites within trains sometimes whole train trips can be missing. Therefore, the starting and ending points of a trip are compared against the locations of train stations via underlying GIS maps. When a set of rules apply, among which that a trip ends in the vicinity of a railway station and the next trip starts near another railway station, it is assumed that a train trip took place between the two trips (4b).

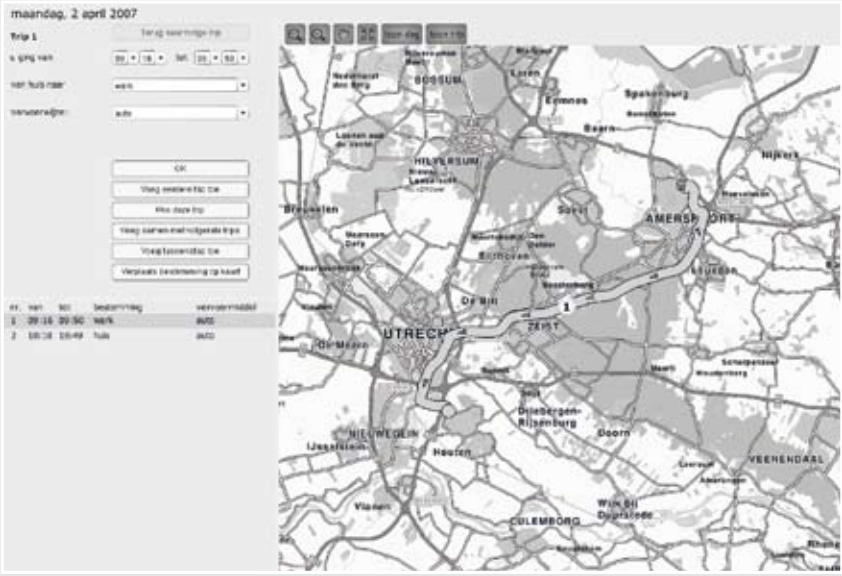
3.3.2 The validation process

After the data have been automatically interpreted, they are presented to the respondents in the web-based user interface of the web application. The respondents are asked to check their travel behaviour data and to make corrections and/or additions wherever necessary.

The decision to use the Internet was made for several reasons. Firstly, an important advantage of using the Internet for a recall survey is that, when entering information, the user interacts directly with the database and information provided can then immediately be used to better approximate the respondents' trips at a later time. In contrast to telephone surveys, respondents can answer the survey whenever they prefer. Another important advantage is the possibility of easily showing respondents their travel behaviour depicted on a 'zoomable' map and allowing them to move locations belonging to their trips on the map. An experiment by Stopher and Colins (2005) already showed that respondents were able to indicate missed trips and destinations on maps depicting the routes they had taken. Finally, exchanging the data via the Internet also eliminates the associated costs of delivery and data entry.

An important disadvantage could be the threat of generating a selective response. To be able to use the application, respondents have to have at least some experience with computer programs, and the computer and Internet connection they use cannot be too slow. These preconditions can lead

Figure 3.2 Screenshot of the user interface of the web application



to an under representation of older and lower-educated people. However, in the recent years, computer and Internet accessibility have grown enormously, and it can be expected that selectivity caused by a lack of computer skills, respondents without access to a computer, or respondents with no or slow Internet connections will decrease rapidly.

Interface

The interface of the validation application consists of a map and a table depicting all trips a respondent visited during a day as derived in the spatial database and a form that respondents can use to adjust the depicted trip characteristics (Figure 3.2). This interface was built by Demis (see http://www.demis.nl). During their validation, the respondents chronologically move through the days and all trips within a day of the fieldwork. When one day is validated, the next day will appear on the screen.

The map can be panned dynamically and zoomed in and out, with a changing level of detail while zooming. This is realized by using a map database with maps on six successive spatial scales. The maps, provided by Falk, also include street names and points of interest. The trips are also displayed as a table that lists, on every line, the originating location, the departure time, the travel mode used, the arrival time and the trip purpose. The trip purposes are listed by category (work, shops, etc.). The map and the table are linked dynamically. If a trip is selected in the table, this same trip is highlighted in the map and vice versa.

Adjusting trip times, travel modes and trip purposes

When the rules used in the interpretation process were not able to determine or wrongly determined the starting or ending times of a trip, or when

the travel mode used or the trip purpose could not be derived (correctly), respondents can adjust these trip characteristics by choosing another option from the dropdown menus. When the respondent amends any data, these amendments are passed on to the spatial database and are used for further real-time interpretation: the new data are used to better derive the trips of the respondent in the days after the day for which an adjustment was made. For instance, if on the first day a respondent indicates that he visited friends in a certain location, any visits to this location on subsequent days will be changed in the table from a trip to an 'unknown' location to a trip to a location in the 'friends/family' category. Needless to say, the respondent always has the option to change this category again at a later time.

Merging and splitting trips
When the GPS log is not correctly divided into trips, respondents can merge or split trips. A merge of one or more trips can be necessary when, for instance, someone spent a long time in one spot due to a traffic jam or loss of reception of satellite signals that caused a gap in the logging of a trip. A trip can be divided into two or more separate trips by clicking on the location of the stops on the map. For example, it can occur that someone stops for such a short period of time (e.g. for a quick dash into a shop) that the system did not recognize this stop as a 'destination'.

Moving the location of a trip destination and adding whole trips
Finally, respondents can change the location of the destination of a trip when the GPS data logger stopped logging before the end of a trip or even add a whole trip when the data logger was forgotten, the battery was not charged or the data logger did not acquire reception of satellites. A location of a trip destination can be moved by clicking on the dot on the map representing the location in question and dragging it to the right destination. A complete trip can be added by clicking on the origin of a trip and subsequently on the location of the trip destination. Because collecting route information is not one of the aims of this GPS-based method, respondents are not asked to draw their whole route.

3.4 A case study

The GPS-based data collection method we developed was applied for the collection of one-week travel behaviour patterns of over a thousand people. This data collection was part of a larger research project about the role of residential self-selection in the relationship between land-use and travel behaviour (Bohte *et al.*, 2007).

In this section, the results and evaluation of this case study are used for an evaluation of the method. The section starts with a description of the study

area, the respondent sample and the fieldwork organisation. Then, the interpretation process is evaluated by discussing the percentages of modes and trip purposes that had to be changed or added by the respondents because the interpretation model was not able to derive them correctly. Subsequently, some results (trip frequencies and trip chains) are compared to the data from the Dutch Travel Survey (DTS, 2006; the government's national survey, a one day paper recall survey). Finally, some results from the evaluation survey that was conducted with the respondents are presented.

3.4.1 Description of the case study

The fieldwork took place in the first half of 2007 among a sample of residents of Amersfoort (137,000 inhabitants), Veenendaal (61,000 inhabitants) and Zeewolde (19,000 inhabitants), three municipalities in the centre of the Netherlands. Because our research focuses on residential choice, and in the Netherlands most people who want to rent a house do not have many options as availability is low and distribution is (partly) regulated, we restricted our research to home owners.

The respondents were recruited from the respondents of an Internet survey held at the end of 2005. In total, 1200 respondents participated in the GPS fieldwork, 1104 of whom completed the entire project. People above 65 are underrepresented (4% of all respondents), but the age group of 50-65 years old was well represented (35%) and more men (57%) than women (43%) participated The selection of homeowners and probably also the larger interest of higher educated people in GPS-related issues have led to an overrepresentation of higher educated people.

The respondents carried a handheld GPS data logger for one-week. To measure travel behaviour in different weather situations and to limit the costs of the purchase of GPS data loggers, the fieldwork was executed in 15 waves. The device we used was an adjusted Amaryllo Trip Tracker (http://www.amaryllo.com) with a SiRFII chipset that was programmed to log a trackpoint every 6 s. Although at the time of the survey the next generation chipset SirFIII was already available, the main reason to choose the SirFII was the much smaller energy consumption. The battery of the device lasts approximately 16 h which was accomplished by disabling all unnecessary functions.

During the fieldwork, the respondents were guided as much as possible. They were instructed by the students who delivered the data loggers and collected them again after one- week. Besides the respondents received an instruction manual, they could phone or e-mail a helpdesk and read background information about the research on a website designed for the fieldwork. Moreover, they received post-it notes to put on their doors and key rings for reminding them to carry the device.

One day after the GPS data loggers had been collected, the GPS logs from

the data loggers were placed into the spatial DBMS to be combined with GIS data (location of shops, railway stations, railways, schools and cultural services) and data on individual characteristics (car ownership, home and work addresses) that were collected beforehand. On the same day, the respondents received an e-mail with a link to the user interface of the validation application, so that they could validate and add to the collected and derived data.

3.4.2 Corrections by the respondents

By determining what percentage of all travel modes and trip purposes had to be provided or changed by the respondents in the validation application, we can estimate the success of the interpretation process. Table 3.2 shows that in almost three-quarters of all cases, the travel mode proves to have been estimated correctly during the interpretation process. Car use is deduced correctly most often (75% of all trips), followed by cycling (72%) and walking (68%), respectively. An important reason for not accomplishing higher percentages is that the assignment of a mode is almost exclusively based on average and maximum speeds of trips. For example, driving slowly by car through a built-up area will lead to the assignment of bicycle as travel mode. Another reason is that quite a lot of trips were missed by the GPS data logger. These trips had to be completely reconstructed by the respondents. Due to failure of reception of satellite signals in the train, travelling by train was only detected correctly in one-third of all train trips. When a GPS data logger with a SirFIII set is used, reception within trains is much better. Moreover, at the moment more effective rules to repair missing train trips as well as rules for deriving trips made by bus, tram or metro are being developed. During the fieldwork, the spatial database did not (yet) contain rules to detect trips made by bus, tram or metro and trips made by less common modes like scooters. Therefore, whenever one of these modes was used the respondent always had to adjust the travel mode that was derived in the database.

Trips that end at home are most often given the correct trip purpose because the home location is already known (74% of all trips that end at home). Visits to shops are detected correctly in 35% of cases. This is a relatively low percentage because the list of shop locations that were available for interpretation was not entirely complete. Although the home address-

Table 3.2 Percentage of trip purposes and travel modes that were correctly derived in the spatial database

	Correctly derived trips	
	Percentage	**N**
Trip purpose		
Work	31%	6,199
Study	4%	190
Shop	35%	4,444
Social visit	11%	2,120
Recreation	19%	3,486
Home	74%	11,518
Other	29%	5,729
All purposes	**43%**	**33,686**
Travel mode		
Car	75%	18,017
Train	34%	747
Bus/tram/metro	0%	328
Bicycle	72%	8,653
Foot	68%	5,481
Other	7%	460
All modes	**70%**	**33,686**

Table 3.3 Average number of trips per travel mode per day and per trip purpose per day

	GPS-based method (1,104 respondents, 7,395 days)			DTS recall survey (40,208 respondents/days)		
	Mean	Share	SD	Mean *	Share *	SD*
Trip purpose						
Work	0.84	18%	1.57	0.60	16%	1.00
Study	0.03	1%	0.19	0.02	1%	0.15
Shop	0.60	13%	1.05	0.42	11%	0.71
Social visit	0.29	6%	0.70	0.26	7%	0.60
Recreation	0.47	10%	1.09	0.43	11%	0.81
Home	1.56	34%	1.23	1.61	42%	1.20
Other	0.77	17%	1.48	0.47	12%	1.03
Travel mode						
Car	2.44	54%	2.54	2.01	53%	2.07
Train	0.10	2%	0.48	0.09	2%	0.48
Bus/tram/metro	0.04	1%	0.36	0.09	2%	0.48
Bicycle	1.17	26%	1.90	0.81	21%	1.55
Foot	0.74	16%	1.31	0.75	20%	1.52
Other	0.06	1%	0.69	0.06	2%	0.40
Total number of trips	4.55	100%	3.24	3.80	100%	2.76

* Weighted to match age and education level of the GPS dataset.

es of friends and family were not known in advance, 11% of these visits are nonetheless already recognised in the database due to the 'learning' function, which remembers the locations that were visited earlier in the week.

3.4.3 Comparison of trip characteristics with the Dutch Travel Survey

By comparing trip characteristics from the final GPS dataset (after validation by the respondents) with data from the Dutch Travel Survey (DTS, 2006; the government's national survey, a one day paper recall survey), it can be estimated whether the GPS-based method delivered reasonable results. Table 3.3 shows that the trip purpose and mode shares in both data sets are quite similar, while the absolute numbers are higher in the GPS dataset. Nonetheless, the number of tours per day is almost equal in both dataset (GPS: 1.56 and DTS: 1.61). The main difference lies in the number of trips per tour. The respondents in the GPS sample have an average of 2.9 trips per tour, while the respondents from the DTS survey show an average of 2.3 trips per tour. The mean as well as the standard deviation of the frequency of trips to work and shopping trips and the frequency of trips by car and by bicycle is clearly higher in the GPS dataset. On one hand, it seems very plausible that the GPS method measures more trips than the traditional method. It can be expected that in a paper recall survey such as the DTS small stops within a tour such as picking up a child, a short visit to a shop on the way back from work or a walk during lunch time, may be forgotten. Other studies that compared the collection of travel behaviour data by phone or on paper with data collected with GPS did find a significant underreporting of trips in the phone/paper

Table 3.4 Burden reported by respondents (N=905)

	Very	Somewhat	No
Burden of carrying GPS device	1%	14%	85%
Burden of charging GPS device	5%	10%	86%
Burden of web application	22%	45%	33%

survey (Wolf *et al.*, 2003; Forest and Pearson, 2005; Hato, 2006).

On the other hand, we realize that the higher number of trips may be partly caused by trips that are incorrectly split up into more than one trip because the reception of satellite signals failed for a while and respondents did not merge these trip parts afterwards in the validation application. Further analyses of the GPS dataset are necessary to be able to determine what caused this relatively high number of trips per tour more accurately.

3.4.4 Results from the evaluation survey

After the respondents finished the validation of the week, they participated in the fieldwork, they were asked to complete an evaluation survey. They were asked about their experience of the week they carried the GPS device and about the use of the validation application.

Table 3.4 shows that only 1% of the respondents experienced a considerable nuisance to continuously carry the device, 14% found it somewhat of a nuisance and 85% did not mind at all. However, remembering to carry the device was considered a problem by a larger proportion of people (40%). A quarter of all respondents did in fact forget their device on one or more occasions. The vast majority of respondents (86%) did not consider the fact that the device had to be charged daily to be a problem. Moreover, in general the students who collected the devices received positive reactions from the respondents and very few respondents contacted the helpdesk with complains or questions.

Not surprisingly, because every first time use of a new computer program has its learning curve, many respondents reported that checking and updating their trips were fairly difficult. Nearly 25% indicated that they found following the program quite difficult, and 45% found it somewhat difficult. One of the reasons is that there are still many gaps in the GPS logs. This is especially the case for respondents who have a car with heat-resistant windscreens and respondents who frequently travel by train. People with little computer experience or who were using an older computer have a relatively high degree of difficulty with the application. Some respondents found it difficult to remember their trips in the initial days of the fieldwork when asked about them more than a week later. Nonetheless, a third of all respondents were able to get through the whole application in 15 min or less; two-thirds needed half an hour or less. Although Doherty *et al.* (2006, see Subsection 3.2.3) assumed that respondents have difficulties interpreting the maps, this was not backed up by the evaluation. Because of the frequent use of route planners on the Internet and in-car navigation systems, it is not unreasonable to expect that many people already have some experience with the use of digital maps.

3.5 Conclusion and discussion

This paper described a GPS-based data collection method for collecting travel behaviour of individuals which we have developed. We evaluated the system by applying this in a large-scale data collection effort. The main aim of the development of this method was to build a system that can be used for collecting travel times and distances, travel modes and trip purposes as accurately as possible and also with a low burden on the respondents. The experience and evaluation of the use of other GPS-based methods were used as a starting point for the development of our method. Compared to other methods, we had a stronger focus on validation by the respondents.

The GPS-based system consists of an interpretation and a validation process. Three data sources are combined in the interpretation process: GPS logs, individual characteristics of the respondents and GIS data. When in the interpretation process trip characteristics are reconstructed, they are forwarded to the validation process. In the user interface of the validation application, the derived data are presented to the respondents in maps and tables. Here, the respondents can correct and add to the derived trip characteristics. The link with the interpretation process is interactive, and new information delivered by the respondents is used for further interpretations.

The evaluation of the results of the case study shows that this method of data collection has a lot of potential. Because GPS data loggers can record exact location coordinates and time, the location coordinates of destinations can be determined with an accuracy that can never be approached by the traditional methods. Furthermore, because the method is able to derive a lot of trip data before the respondents go through the validation application and also adds extra information during the time they validate the data, the burden on the respondents was reasonably low. The data collected with the survey carried out beforehand proved to be very useful as input for the algorithms in the interpretation process. The participants did not consider carrying and charging the GPS device as a nuisance, and were enthusiastic about viewing their trips in the maps of the validation application. The majority of respondents were able to go through the validation application within a reasonably short period of time. Therefore, the result was that 7-day travel behaviour was collected from more than a thousand respondents. The comparison with data from the national travel survey showed that the GPS-based method was able to record a larger number of trips. This indicates that fewer trips were missed.

However, the evaluation also shows that the method has room for improvement. Firstly, the method is dependent on the quality of the GPS data loggers that are used. The data logger that was used in the case study presented has a relatively poor reception of satellite signals compared to GPS data loggers that are available at the moment (e.g. Stopher *et al*., 2008). The use of a better performing GPS data logger would certainly diminish the number of missing

trips and the number of gaps in the recorded trips. Especially, the device did not operate well inside trains at all, which meant that many train trips were missing. Moreover, battery life was not optimal. People had to remember to recharge their GPS data logger every night. Because a substantial part of the technical drawbacks such as battery life and size and weight of devices may be largely solved or at least improved within the next few years it is important that if possible, new research projects use state-of the-art GPS data loggers. Although the introduction of the European equivalent of GPS Galileo will double the number of satellites that can be used to determine location coordinates on earth, gaps in GPS logs caused by disruption of satellite reception will always remain since signals cannot pass through materials such as concrete and metal. However, major improvements could be made by the integration of GPS, mobile phones and the Internet. Although at the moment location positioning with the use of mobile phones is less accurate than with GPS, mobile phones have far better reception within buildings and vehicles. A combination with the Internet enables wireless and instant data transition and processing. At the moment, the main drawbacks of this method are the costs and the energy consumption of such devices. Asking respondents to recharge their mobile phone several times a day is too much of a burden.

Secondly, although the majority of the respondents needed 30 min or less to go through the whole week in the validation application, some did struggle a lot with it; especially people with very few computer skills, old computers and complicated travel behaviour. In addition, because of the bad reception of satellites inside trains, frequent train travellers had to add many trips, which could be a lot of work. An extension of the algorithms that are used during the interpretation to derive more data automatically would further lower the complexity of validating for the respondents. The large dataset that was collected and the availability of extensive digital spatial databases with infrastructure and location information offer a great opportunity for fine tuning of the algorithms. It is also expected that progress can be made by asking the right questions in a survey carried out beforehand. The survey that was part of the described fieldwork contained questions concerning car ownership, possession of vehicles and routine trips. These individual characteristics can be used to calculate the probability that a person uses a specific mode or visits a specific location. Implementation of such rules would probably have improved the completeness of the derived data. Moreover, algorithms could be constructed that compare trips of the same respondents on different days. Since a large part of travel behaviour is routine, gaps in one day can perhaps be repaired with information from other days, even in real-time when the respondents are using the validation application.

In summary, we can conclude that, at present, both GPS and GIS are starting to make a significant contribution to collecting data on travel behaviour of individuals. The system we developed solves some previous shortcomings,

and has proved to perform well. However, if the current (technological) developments continue, and methods for collecting the necessary additional information such as the method described in this paper are developed further, it is likely that data collection by means of paper diaries will disappear entirely in the near future and will be replaced by methods that collect data with the aid of GPS, GIS, the Internet and related technologies.

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4 Cause or effect? An analysis of the role of travel-related attitudes to identify residential self-selection concerning travel behaviour

Bohte, W. Maat, K. and Van Wee, B. Submitted.

Abstract
Many studies have found evidence to support the assumption that the built environment influences travel behaviour. Studies that include the role of residential self-selection show that this influence can be attributed partly to households selecting a residential location that suits their travel-related preferences. This paper adds to that literature by firstly studying the importance of including not only the impact of attitudes on residential choice and travel behaviour, but also the impact of the characteristics of the built environment and travel behaviour on attitudes (the reversed relationship), and secondly by studying the importance of synchronising the importance of the aggregation levels of attitudes and travel behaviour. Structural equation models show that if the 'reverse' influence of behaviour on attitudes is not accounted for, which is often the case, the role of residential self-selection is overestimated. At the same time, studies that do not include attitudes and behaviour at compatible levels of aggregation may underestimate residential self-selection.

4.1 Introduction

Numerous empirical studies have found that the characteristics of the built environment have a significant effect on travel behaviour (e.g. Ewing and Cervero, 2001), suggesting that well-situated residential locations and smart urban designs could reduce the environmental impact of transportation in urban areas, reduce congestion and enhance accessibility. However, recent evidence has suggested that this association cannot be attributed to the influence of the built environment on behaviour alone. The self-selection of households into residential locations that conform to their travel-related attitudes also plays a role. This phenomenon is referred to as 'residential self-selection' (Bohte *et al.*, 2009; Litman, 2010; Mokhtarian and Cao, 2008; Van Wee, 2009).

This paper presents a causal model that identifies the relationship between residential self-selection concerning the distances to activity locations and travel behaviour. Our analysis disentangles the influence of residential location and travel-related attitudes on the total number of kilometres travelled

and the share of trips that is travelled by car. Although several methods have been applied to understand residential self-selection (Mokhtarian and Cao, 2008; Bohte *et al*., 2009), some aspects have received scarce attention so far. This paper highlights two aspects.

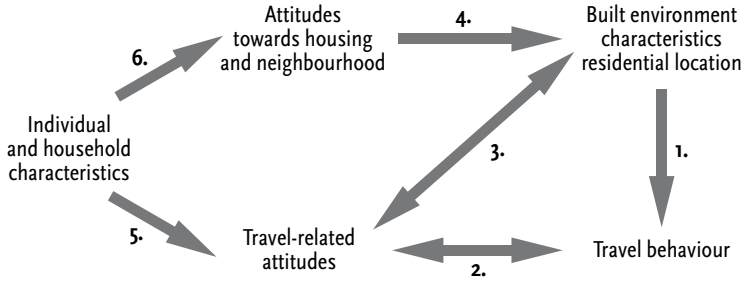
First, as argued by Chatman (2009), attitudes not only influence the choice of residential location and travel behaviour, but can themselves be influenced by the characteristics of the residential location and travel behaviour. For example, when individuals are presented with opportunities for new activities, or when they move house, this will result in adjusted travel patterns, and may, as a consequence, result in changes in attitude. In studies that do not measure causality in both directions, correlations between travel-related attitudes and travel behaviour may therefore not be uncovered. A few studies have explored the reverse influence of travel behaviour on attitudes and found supporting evidence (e.g. Tardiff, 1977; Reibstein *et al*., 1980, Tertoolen *et al*., 1998; Bagley and Mokhtarian, 2002).

Second, when travel-related attitudes, travel behaviour and residential choice are measured at different aggregation levels, this may mean that residential self-selection remains undetected. Ajzen and Fishbein (1977) distinguished four elements of behaviour: action (e.g. driving), target (a car), context (in the city) and time (Saturday morning), and argued that the compatibility of the attitudes and behaviours analysed should concern all four of these elements. Socio-psychological studies have shown that when studies conclude that attitudes and behaviour are not related, this is often caused by a mismatch of specificity between attitudes and behaviour (Eagley and Chaiken, 1993). In residential self-selection studies that include residential choices as well as travel choices, aggregation levels often do not match. Most studies model the outcome of residential choice in terms of the built environment (e.g. urban density or distance to a city centre), which refers to a single choice made in the past together with current travel behaviour over a longer period (e.g. kilometres travelled). The travel-related attitudes included usually only match one of the two behaviours (thus the importance of density in residential choice or travel liking) (Bohte *et al*. 2009).

An example of matching attitudes and behaviour is the residential self-selection study by Cao *et al*. (2006). They analysed the importance of stores within walking distance, choice of residential location (miles to the nearest store) and travel behaviour (frequency of walks to a store) and were able to identify the role of residential self-selection. If, for example, in the study by Cao *et al*. attitudes towards walking were measured instead of the more specific importance of stores at walking distance, residential self-selection could not have been identified, because people who like to walk may not want to walk to stores, or may not even want to visit stores.

Figure 4.1 summarises the assumed relationships that will be tested in this paper. Firstly, it is assumed that travel-related-attitudes and built envi-

Figure 4.1 Conceptual model of the influence of attitudes and residential self-selection on travel behaviour



ronment characteristics of the residential location influence travel behaviour (arrow 1 and 2). Secondly, travel-related-attitudes and attitudes towards housing and the neighborhood affect built environment characteristics of the residential location through the evaluation of housing alternatives when searching for a new home (arrow 3 and 4). It can thus be assumed that residential self-selection takes place and that people select themselves according to the built-environment characteristics of a new house that at least to some degree conform to their attitudes towards travel behaviour. Thirdly, and consequently, it is assumed that attitudes towards travel behaviour influence travel behaviour indirectly through residential choice (arrow 1 and 3). Fourthly, in line with Chatman's hypothesis, we test the reverse causality of residential choice and travel behaviour on travel-related attitudes (arrow 2 and 3). And finally it is assumed that individual and household characteristics influence travel-related attitudes and attitudes towards housing and the neighbourhood (arrow 5 and 6).

Since this conceptual model has a complex structure, including latent variables, direct and indirect effects and causality in both directions, structural equation modelling (SEM) in which path analysis and factor analysis can be combined, was used to test the assumed relationships.

While most studies on residential self-selection originate from the USA, the analyses in this paper use data collected in the Netherlands. Socio-demographic data, housing characteristics and the attitudinal data were collected through an internet survey. Travel behaviour was measured using a GPS-based data collection method with a newly developed method that combines the use of the Global Positioning System (GPS), a Geographic Information System (GIS) and web-based user interaction. This combination made it possible to measure detailed travel behaviour during a week, without undue effort for the respondents (Bohte and Maat, 2009).

This paper is organised as follows. Section 4.2 describes relevant previous studies on travel-related attitudes, residential self-selection and travel behaviour. Section 4.3 describes the research methodology, data collection and the data itself. Section 4.4 discusses the results of the structural equation analyses and the final section (4.5) presents the conclusions that can be drawn from these analyses.

4.2 Literature

Residential self-selection concerning travel behaviour can be defined as: 'the choice of a residential location with built environment characteristics that conforms to people's existing travel-related attitudes'. The role of residential self-selection is increasingly taken into account in studies on the influence of the built environment on travel. As already discussed in the introduction, travel-related attitudes play a central role in defining residential self-selection. However, most studies do not include attitudes explicitly, but assume that attitudes can be represented by social-demographic characteristics while the inclusion of attitudes is seen as only relevant for the study of decision-making behaviour (Morikawa and Sasaki, 1998). The majority of these studies found that residential self-selection influences travel behaviour, while the built environment also has an impact (Pinjari *et al.*, 2007; Pinjari *et al.*, 2009; Cervero, 2007; Krizek, 2003; Bhat and Eluru, 2009). On the other hand, others argue that the influence of residential self-selection is overestimated (Chatman, 2009).

Several residential self-selection studies that explicitly include attitudes have shown that attitudes do add to the explanation of travel behaviour by built environment characteristics and socio-demographic variables (e.g. Kitamura *et al.*, 1997; Schwanen and Mokhtarian, 2005; Næss, 2005, Khattak and Rodriguez, 2005; Frank *et al.*, 2007). However, as discussed by Bohte *et al.* (2009) because the defining, modelling and measurement of attitudinal variables varies considerably between studies, their results are hardly comparable. Attitudes can be defined very broadly, as in the popular definition of Eagley and Chaiken (1993, p. 1) who define an attitude as 'a psychological tendency that is expressed by evaluating a particular entity with some degree of favour or disfavour'. According to their definition, 'evaluating' refers to affective responses (e.g. I like riding a bicycle) as well as cognitive (e.g. riding a bicycle is environmentally friendly) and behavioural (e.g. riding a bicycle or signing a petition in favour of improved bicycle infrastructure) responses. Residential self-selection studies include affective, cognitive as well as behavioural responses. The aggregation level of attitudes in travel behaviour studies varies from very specific such as 'attitude towards taking the bus to get to the campus next time' in the study by Bamberg *et al.* (2003) to much more general such as travel preferences or attitudes towards public transportation. Moreover, as argued in the introduction, travel and residential behaviour are often not measured at the same level of aggregation, meaning that residential self-selection may have taken place without being identified. The overview of Mokhtarian and Cao (2008) shows that many different methods are used to model the relationship between travel-related attitudes, residential self-selection and travel behaviour. The analyses in the current paper are performed using structural equation modelling because it enables the inclusion of causality in both

directions and the measurement of indirect relationships and latent variables. Only a small number of studies on travel-related attitudes, residential self-selection and travel behaviour have previously used structural equation models. To be able to compare our results with the results of those studies, they are described more extensively below.

One of the first and the most cited studies on residential self-selection that included attitudes was carried out by Bagley and Mokhtarian (2002). The structural equation model they constructed included a traditional and a suburban factor, the attitudes 'pro-high-density', 'pro-driving' and 'pro-transit', the average number of miles travelled daily by personal vehicle, transit, and walking/bicycle and commute distance as endogenous variables. They found that attitudinal and lifestyle variables had the greatest influence on travel behaviour, both directly and indirectly. The pro-high density attitude was associated with living in traditional residential neighbourhoods, while the pro-driving and pro-transit attitudes were associated with living in suburban neighbourhoods. However, because residential location type had little influence on travel behaviour, these travel-related attitudes hardly influenced travel behaviour through residential location. Only one significant effect of residential location on travel demand was found: a positive correlation between suburban location and transit miles. Bagley and Mokhtarian used SEM to test the influence of behaviour on attitudes. They found that the number of vehicle miles driven influenced pro-driving attitudes.

In the structural equation model constructed by Cao *et al.* (2007) travel-related attitudes did have an indirect effect on travel behaviour through residential self-selection. Neighbourhood preferences and travel-related attitudes such as 'car dependent' and 'safety of car' influenced travel behaviour through residential choice, and also influenced driving and walking behaviour directly. At the same time, the built environment also significantly influences travel behaviour.

Scheiner and Holz-Rau (2007) used SEM to model separately the share of car trips, the share of non-motorised modes, the share of public transportation trips and the number of vehicle kilometres travelled. Each model included a residential location attribute (e.g. the quality of public transportation) and a matching location attitude (e.g. the importance of public transportation). In some of their models, the influence of location attitudes on travel behaviour was equal to or even stronger than the effect of location attributes on travel behaviour, thus indicating that self-selection had a significant effect. In particular, the importance of public transportation had a positive influence on the share of public transportation trips and non-motorised trips and negatively influenced the share of car trips, while also having an indirect influence on these trip shares through the quality of public transportation.

Scheiner (2009) constructed similar models to explain trip distances and found that location preferences showed no substantial direct or indirect influ-

ence on trip distances. He concluded that the results do not indicate that residential self-selection influences trip distances significantly. The importance of proximity to shopping was significantly directly related to the maintenance trip distance. Moreover, the models showed a strong connection between the importance of proximity to shopping facilities and shopping supply quality and between shopping supply quality and maintenance trip distance, indicating that residential self-selection influenced travel behaviour.

4.3 Methodology and data

4.3.1 Methodology

This study analyses the influence of residential self-selection concerning distances from the home to activity locations on travel kilometres and the share of trips made by car. Because previous studies have shown that including travel-related attitudes does add to the explanation of residential self-selection by socio-demographic variables, the models explicitly include attitudes.

The analyses included all the assumed relationships depicted in Figure 4.1. To test the impact of excluding causality in two directions as most self-selection studies do, we estimated two models for car trip share and two models for kilometres travelled. The two models for each dependent variable differ with respect to the inclusion (or exclusion) of an assumed influence of the built environment and travel behaviour on travel-related attitudes. We do acknowledge that as recommended in the final section, but not realisable in the current fieldwork, if it is assumed reversed causality exists, not only current attitudes, but also attitudes at the time of the residential choice need to be measured to identify the role of residential self-selection.

Structural regression modelling was chosen to analyse the assumed relationships, because it allows the analyses of indirect effects, as in path analysis, and a measurement model that includes underlying observed variables to measure latent variables such as attitudes, as in confirmatory factor analysis.

Because it is assumed that residential-self-selection can best be identified when attitudes and behaviour are measured at the same level of aggregation (see previous section), travel-related attitudes at two levels (the importance of distance to activity locations in residential choice and attitudes towards travel mode use) are included to match the different aggregation levels of the behaviour included (distance to activity locations, kilometres travelled and the share of trips made by car).

Maximum likelihood (ML) estimation was used to estimate the models. An important assumption of this method of estimation, which is popular in SEM, is that all endogenous variables should be continuous (Kline, 2005). The attitudinal variables in our models are measured with Likert-type scales

and thus measured at an ordinal level. However, several studies have shown that, depending on their distribution, they can be treated as continuous variables (e.g. Lubke and Muthén, 2004). The attitudinal variables in our analyses all show a normal distribution with skewnesses and kurtoses below 3.0 and above -3.0. It was therefore decided to include them as endogenous variables. The final models were constructed through model trimming. All non-significant relationships were fixed at zero and thus removed from the models.

4.3.2 Data collection

To include a wide variety of built environment characteristics, the sample was drawn from a broad range of urban forms, varying from urban to suburban, and including car-friendly, bicycle-friendly and public transportation-friendly areas. For this, the surveys were conducted among a sample of residents from Amersfoort (137,000 inhabitants), Veenendaal (61,000 inhabitants) and Zeewolde (19,000 inhabitants), three municipalities in the centre of the Netherlands. Amersfoort has a historical centre and includes many suburban residential areas and industrial estates; Veenendaal is known for its shopping facilities, bicycle-friendliness and green areas; Zeewolde is a new town built on reclaimed land, bordering the water front. Amersfoort is well connected to the national railway network and has, just like Veenendaal, three railway stations; the nearest railway station to Zeewolde is 13 kilometres away.

The sample was randomly drawn from the Civil Registries of the three municipalities and limited to homeowners because those living in rented property have a very limited choice set. The ten districts included in our fieldwork all have a high percentage of owner-occupied houses.

The data collection took place in two stages. First, in the second half of 2005 an internet questionnaire was conducted. The internet survey included questions to assess attitudes, travel behaviour, residential choice and socio-demographics. Second, travel behaviour itself was measured with the use of GPS. The participants in the GPS survey were recruited from the respondents of the internet survey participants. The GPS survey took place in the first half of 2007 with the use of a method that combines GPS logs, GIS technology and an interactive web-based validation application. This method was developed and used in order to obtain more accurate and detailed travel behaviour data than would have been possible with conventional methods. Unlike GPS-based models, conventional methods often underreport the number of trips and kilometres travelled (e.g. Steer Davies Gleave and Geostats, 2003; Wolf *et al.*, 2003). Because of the lower burden on the respondents data can be collected over the course of several days.

The respondents carried a handheld GPS data logger for one week. After the GPS data loggers had been retrieved, the GPS logs made by the data loggers were placed into a spatial Database Management System to be combined with

GIS data (location of shops, railway stations, railways, schools and cultural services) and data on the individual characteristics (car ownership, home and work addresses) from the internet survey. Various rule-based algorithms were run to derive trip distances, trip times, travel modes and travel times as accurately as possible. Subsequently, the respondents were asked to validate the data, and add to the collected and derived data in a web-based validation application. For a more detailed description of this data collection method, see Bohte and Maat (2009).

Our analyses only include respondents who took part in both surveys. We received 3,979 completed questionnaires from the 12,836 people who were approached to fill in the internet survey – a response rate of 31.0 percent. In total, 1,200 of these respondents participated in the GPS fieldwork, 1,104 of whom completed the entire project and the results from 936 respondents were usable. Both partners in a household were asked to participate, however because the analyses were performed at the individual level, one of the partners was randomly selected and therefore data on 736 respondents were used. Because of the low response rate of single persons, this selection did not lead to any underrepresentation of people with a partner.

4.3.3 Variables

The endogenous dependent variables of kilometres travelled and the percentage of trips made by car were derived from the results of the GPS-fieldwork. The other variables were measured using the internet survey. Table 4.1 gives an overview of all the variables included. Due to the selection of home owners, the majority of the participants had a medium or high level of education and a relatively high income, and many lived in single-family houses. The year of moving to that home, the number of rooms, and the type of housing were included in the analyses to control for the limited availability of houses with specific built-environment characteristics at the time of the residential move. For example, during periods when new developments were built close to a railway station it was easier to self-select to live near a railway station than in other years.

Socio-demographic variables, year of move, number of rooms, housing type are included as exogenous variables. Because of the dichotomous measurement of car availability, it could also only be included as exogenous variable, although in accordance with the results of the studies by Van Acker *et al.* (2010) and Simma and Axhausen (2003), it is assumed that attitudes and built-environment characteristics influence car availability.

In addition to the conceptual model, attitudes towards travel mode use and car availability were also directly related to the distances to activity locations (as part of residential choice), because it was assumed that attitudes towards travel mode use and car availability do not solely influence residential choice

Table 4.1 Descriptive statistics of the variables (N=736)

		%/Mean	SD
Individual characteristics			
Age		44.3	10.0
Gender (% male)		56.4	
Partner (% with partner)		92.5	
Child (% with child)		66.0	
Education:	% Low (primary and pre-vocational secondary)	6.4	
	% Medium (general secondary and pre-university)	34.6	
	% High (professional college and university)	59.0	
Income:	% < average income (< €15,000 net personal income)	31.7	
	% average income -2 x average income (€15,000-30,000)	56.2	
	% > 2 x average income (> €15,000-30,000)	12.1	
Paid work:	% no paid work	14.9	
	% part-time (< 35 hours)	36.7	
	% full-time (≥ 35 hours)	48.4	
Car availability (% always access to a car)		54.8	
Housing characteristics			
Housing type (% apartments)		4.2	
Number of rooms		5.2	1.2
Year of move		1996	7.6
Attitudinal variables			
Importance distance to daily shops (5-point scale 'strongly disagree' (= -2) to 'strongly agree' (= 2)		3.90	0.73
Importance distance to non-daily shops (5-point scale 'strongly disagree' (= -2) to 'strongly agree' (= 2)		3.02	1.07
Importance dist. restaurant, pubs, etc. (5-point scale 'strongly disagree' (= -2) to 'strongly agree' (= 2)		2.53	0.90
Importance distance to cultural facilities (5-point scale 'strongly disagree' (= -2) to 'strongly agree' (= 2)		2.67	0.89
Importance distance to green areas (5-point scale 'strongly disagree' (= -2) to 'strongly agree' (= 2)		3.92	0.78
Importance distance to a railway station (5-point scale 'strongly disagree' (= -2) to 'strongly agree' (= 2)		3.18	1.07
Attitude towards car use			
- Travelling by car is relaxing (factor loading = 0.80)		0.58	1.28
- Travelling by car is fun (factor loading = 0.63)		1.13	1.06
Attitude towards cycling			
- Cycling is relaxing (factor loading = 0.77)		1.23	0.86
- Cycling is fun (factor loading = 0.83)		1.22	0.90
Attitude towards the use of public transportation			
- Travelling by public transportation is relaxing (factor loading = 0.77)		0.34	1.41
- Travelling by public transportation is fun (factor loading = 0.79)		-0.08	1.29
- Travelling by public transportation is comfortable (factor loading = 0.80)		0.60	1.15
Distances to activity locations (km)			
Shortest route to daily shops (supermarket, bakery and drug store)		2.94	1.60
Distance to green areas		1.05	1.09
Distance to a railway station		3.04	2.36
Distance to a city centre		3.35	2.22
Travel behaviour variables			
Total kilometres travelled per day		63.64	40.76
% of trips made by car		57.78	27.77

through the importance attached to distances to activity locations, but also through attitudes towards other characteristics of residential locations that were not measured.

Finally, the models also include direct influence between socio-demographic variables and distances to activity locations and travel behaviour, because not all mediating attitudes are included and income, for example, also places direct constraints on behaviour.

The measurement of the attitudinal and built-environment variables will be further explained below.

Attitudinal variables

Attitudes towards car use, cycling and the use of public transportation are included in the models as latent variables and thus derived from indicator variables (Table 4.1). The indicator variables are evaluations of the 'fun', 'comfort' and 'relaxedness' of the use of the travel modes. The respondents rated each item for each travel mode (e.g. 'cycling is comfortable') on a five-point Likert-type scale that ranged from 'strongly disagree' (= -2) to 'strongly agree' (= 2). To gain reliable measures of the latent variables, only the items with a factor loading of over 0.60 were sustained (as suggested by Kline, 2005).

The importance of distances to daily shops, non-daily shops, pubs, restaurants, cultural facilities, green areas and the nearest railway station in residential choice match were measured directly. Using a five-point scale (very unimportant to very important), the respondents had to rate the importance they would attach to the distance to each of the activity locations if they were to move to a new residential location.

Built-environment characteristics

The activity locations we included were the nearest city centre, the nearest railway station, the nearest green area and the shortest route to visit a bakery, drug store and supermarket. The distances to the activity locations were the shortest road distances between the respondent's home and the nearest activity locations. They were calculated using a geographical information system (GIS) (source of road network: NAVTEQ 2006). The coordinates of the respondents' home were derived from the GPS-survey and coordinates of bakeries, supermarkets and drug stores to calculate 'the shortest route to daily shops' were obtained from a retail database (Locatus 2006). Green areas of at least 5 square kilometres, were included, using Falkplan maps.

The importance of distances to activity locations are only related to the specific built-environment characteristics to which they apply (e.g. the importance of green areas is only related to the distance to green areas and not to the distance to daily shops). In the initial models, the importance of distances to pubs, restaurants, non-daily shops and cultural facilities were all related to the distance to the nearest city centre. Because it was assumed that the

distances to the activity locations share explanatory factors that were not included, such as spatial planning principles (e.g. city centres are not located in the middle of green areas) that explain the variances in their error terms, covariances were drawn between their error terms.

4.4 Results

4.4.1 Model fit, latent variables and covariances between error terms

The Tables 4.2-4.3 (total kilometres travelled) and 4.4-4.5 (share of car trips) show the direct and total effects in the four final models and also include some of the most frequently used goodness of fit measures. They show that all models have acceptable model fits. The relative chi-squares (NC, chi-square/degrees of freedom) are all below 2, while values between 1 and 3 indicate an acceptable fit, with the closer to 1 the better. TLI (the Tucker-Lewis coefficient) and CFI (comparative fit index) should be above 0.90 and the closer to 1 the better. RMSA below 0.05 also represents a good fit (Kline, 2005; Ory and Mokhtarian, 2009).

The loadings of the indicator variables on the latent variables are presented in Table 4.1. Because it is recommended that all factor loadings should be above 0.60 (Kline, 2005), all indicators with lower loadings were removed from the measurement models. The covariance between the error terms of the distance to green areas and the shortest route to daily shops was removed because of its low probability.

4.4.2 Direct effects of attitudes towards travel mode use and built environment characteristics on travel behaviour

Tables 4.2-4.5 show that in all four models, there are only a few significant direct effects of distances to activity locations and attitudes towards travel mode use on the total number of kilometres travelled and the share of car trips. Respondents who live further from green areas travel fewer kilometres, while those who live further from a railway station travel more kilometres. In line with previous research (e.g. Handy, 1996; Cervero and Kockelman, 1997), the share of car trips increases as the distance to a city centre increases. As might be expected, a more positive attitude towards the use of public transportation leads to a smaller share of car trips. Attitudes towards car use and cycling show no significant direct effect, except for a positive effect of attitudes towards car use on the share of car trips in the model without reverse causality. Similar to the results of a study by Næss (2009), car availability has a

Table 4.2 Estimated direct and total* effects total kilometres travelled model without influence of behaviour and built environment on attitudes

	Exogenous variables							
Endogenous variables	**Age**	**Gender**	**Partner**	**Child**	**Low educated**	**High educated**	**Income >2x average income**	**Paid work part-time**
Model 1								
Importance of distance daily shops	0.089	-0.067						
	0.089	*-0.067*						
Importance of distance non-daily shops			0.110			-0.115		-0.136
			0.110			*-0.115*		*-0.136*
Importance of distance restaurant, pubs etc.				-0.120				
				-0.120				
Importance of distance cultural facilities	0.185	-0.074						
	0.185	*-0.074*						
Importance of distance green areas					-0.074			
					-0.074			
Importance of distance railway station	0.186	-0.126		-0.088		0.088		
	0.186	*-0.156*	*-0.023*	*-0.088*		*0.088*		
Attitude towards car use		0.234						
		0.234						
Attitude towards use of PT			-0.098					
			-0.098					
Shortest route to daily shops	-0.173					-0.077		-0.138
	-0.173					*-0.077*		*-0.138*
Distance to green areas								
			0.010		*0.012*			
Distance to railway station	-0.148					-0.091		
	-0.156	*0.007*	*0.008*	*0.004*		*-0.095*		
Distance to city centre	-0.164					-0.088		
	-0.170	*0.003*		*0.008*		*-0.088*		
Total kilometres travelled		0.187				0.081	0.091	
	-0.015	*0.188*			*-0.001*	*0.072*	*0.091*	

Chi-square: 355.258, 251df, p: 0.000, NC: 1.415, RMSA: 0.024, p-close: 1.000, TLI: 0.974, CFI: 0.984

* Total effects are presented in italics.

					Endogenous variables						
Paid work full-time	Housing type	Nr of rooms	Year of move	Car availability	Importance of distance cultural facilities	Importance of distance green areas	Importance of distance railway station	Attitude towards car use	Attitude towards use of PT	Distance to green areas	Distance to railway station
-0.200											
-0.200											
				-0.107				-0.127	0.236		
				-0.152				*-0.127*	*0.236*		
				-0.192							
				-0.192							
-0.109	-0.113		0.224	0.067							
-0.109	*-0.113*		*0.224*	*0.067*							
	0.138					-0.166			-0.105		
	0.138			*0.020*		*-0.166*			*-0.105*		
	-0.260	-0.084	0.201	0.079			-0.045		-0.070		
	-0.260	*-0.084*	*0.201*	*0.099*			*-0.045*	*0.006*	*-0.080*		
	-0.244	-0.078	0.252	0.092	-0.034				-0.079		
	-0.244	*-0.078*	*0.252*	*0.107*	*-0.034*				*-0.079*		
0.150										-0.077	0.098
0.150	*-0.036*	*-0.008*	*0.020*	*0.008*		*0.013*	*-0.004*	*0.001*		*-0.077*	*0.098*

Table 4.3 Estimated direct and total* effects total kilometres travelled model with influence of behaviour and built environment on attitudes

Endogenous variables	Exogenous variables								
	Age	Gender	Partner	Child	Low educated	High educated	Income >2x average income	Paid work part-time	Paid work full-time
Model 2									
Importance of distance daily shops	0.064	-0.066							
	0.078	*0.066*		*-0.007*		*0.007*		*0.013*	*0.010*
Importance of distance non-daily shops			0.108			-0.114		-0.126	-0.190
			0.108			*-0.114*		*-0.126*	*-0.190*
Importance of distance restaurants, pubs etc.				-0.130					
	-0.011			*-0.123*		*-0.007*			
Importance of distance cultural facilities	0.174	-0.075							
	0.174	*-0.075*							
Importance of distance green areas					-0.071				
					-0.071				
Importance of distance railway station	0.158	-0.124		-0.084		0.083			
	0.179	*-0.156*		*-0.095*		*0.098*			
Attitude towards car use		0.241							
	-0.017	*0.241*		*0.010*		*-0.011*			
Attitude towards use of PT									
	0.021			*-0.011*		*0.015*			
Shortest route to daily shops	-0.148			0.075		-0.079		-0.144	-0.119
	-0.148			*0.075*		*-0.079*		*-0.144*	*-0.119*
Distance to green areas									
Distance to railway station	-0.136			0.071		-0.097			
	-0.136			*0.071*		*-0.097*			
Distance to city centre	-0.140			0.083		-0.090			
	-0.146	*0.002*		*0.083*		*-0.090*			
Total kilometres travelled		0.187				0.081	0.091		0.150
	-0.013	*0.187*		*0.007*		*0.072*	*0.091*		*0.150*

Chi-square: 312.788, 246 df, p: 0.003, NC: 1.271, RMSA: 0.019, p-close: 1.000, TLI: 0.983, CFI: 0.990

* Total effects are presented in italics

Endogenous variables										
Housing type	**Nr of rooms**	**Year of move**	**Car availability**	**Importance of distance cultural facilities**	**Attitude towards car use**	**Attitude towards use of PT**	**Shortest route to daily shops**	**Distance to green areas**	**Distance to railway station**	**Distance to city centre**
							-0.088			
0.010		*-0.020*	*-0.006*				*-0.088*			
										0.077
-0.018	*-0.007*	*0.020*	*0.009*	*-0.002*						*0.077*
								-0.210		
-0.032								*-0.210*		
			-0.091		-0.133	0.227			-0.105	
0.032	*0.014*	*-0.033*	*-0.141*	*0.001*	*-0.133*	*0.227*		*-0.048*	*-0.140*	*-0.016*
								0.105		0.119
-0.012	*-0.011*	*0.031*	*0.013*	*-0.004*				*0.105*		*0.119*
			-0.149					-0.151	-0.152	
0.016	*0.014*	*-0.031*	*-0.164*					*-0.151*	*-0.152*	
-0.108		0.228	0.069							
-0.108		*0.228*	*0.069*							
0.153										
0.153										
-0.255	-0.092	0.206	0.102							
-0.255	*-0.092*	*0.206*	*0.102*							
-0.240	-0.092	0.259	0.112	-0.032						
-0.240	*-0.092*	*0.259*	*0.112*	*-0.032*						
								-0.078	0.099	
-0.037	*-0.009*	*0.020*	*0.010*					*-0.078*	*0.099*	

Table 4.4 Estimated direct and total* effects car trip share model without influence of behaviour and built environment on attitudes

	Exogenous variables							
Endogenous variables	**Age**	**Gender**	**Partner**	**Child**	**Low educated**	**High educated**	**Income < average income**	**Paid work part-time**
Model 1								
Importance of distance daily shops	0.089	-0.067						
	0.089	*-0.067*						
Importance of distance non-daily shops			0.102			-0.115		-0.135
			0.102			*-0.115*		*-0.135*
Importance of distance restaurant, pubs etc.			-0.054	-0.106				
			-0.054	*-0.106*				
Importance of distance cultural facilities	0.179	-0.072						
	0.179	*-0.072*	*-0.006*					
Importance of distance green areas					-0.074			
					-0.074			
Importance of distance railway station	0.192	-0.111		-0.088		0.080		
	0.192	*-0.152*	*-0.026*	*-0.088*		*0.080*		
Attitude towards car use		0.251						
		0.251						
Attitude towards use of cycling		-0.083	0.079			0.097		
		-0.083	*0.079*			*0.097*		
Attitude towards use of PT			-0.099					
			-0.099					
Shortest route to daily shops	-0.173					-0.077		-0.138
	-0.173					*-0.077*		*-0.138*
Distance to green areas								
					0.013			
Distance to railway station	-0.148					-0.091		
	-0.156	*0.007*	*0.010*	*0.004*		*-0.095*		
Distance to city centre	-0.163					-0.087		
	-0.169	*0.002*	*0.011*			*-0.087*		
Car trip share						-0.086	-0.105	
	-0.029	*0.045*	*0.011*			*-0.101*	*-0.105*	

Chi-square: 499.095, 352 df, p: 0.000, NC: 1.418, RMSA: 0.024, p-close: 1.000, TLI: 0.971 CFI: 0.981

* Total effects are presented in italics.

					Endogenous variables					
Paid work full-time	Housing type	Nr of rooms	Year of move	Car availability	Importance of distance cultural facilities	Importance of distance green areas	Importance of distance railway station	Attitude towards car use	Attitude towards use of PT	Distance to city centre
-0.199										
-0.199										
									0.056	
				-0.011					*0.056*	
								-0.163	0.262	
				-0.082				*-0.163*	*0.262*	
				0.184						
				0.184						
				-0.199						
				-0.199						
-0.109	-0.113		0.224	0.067						
-0.109	*-0.113*		*0.224*	*0.067*						
	0.135					-0.169				
	0.135					*-0.169*				
	-0.259	-0.084	0.200	0.078			-0.045		-0.090	
	-0.259	*-0.084*	*0.200*	*0.100*			*-0.045*	*0.007*	*-0.102*	
	-0.242	-0.077	0.251	0.091	-0.033				-0.113	
	-0.242	*-0.077*	*0.251*	*0.113*	*-0.033*				*-0.115*	
0.167				0.250				0.177	-0.097	0.171
0.167	*-0.041*	*-0.013*	*0.043*	*0.321*	*-0.006*			*0.177*	*-0.117*	*0.171*

Table 4.5 Estimated direct and total* effects car trip share model with influence of behaviour and built environment on attitudes

	Exogenous variables							
Endogenous variables	**Age**	**Gender**	**Partner**	**Child**	**Low educated**	**High educated**	**Paid work part-time**	**Paid work full-time**
Model 2								
Importance of distance daily shops	0.066	-0.069						
	0.079	*-0.069*		*-0.007*		*0.007*	*0.013*	*0.012*
Importance of distance non-daily shops			0.106			-0.114	-0.125	-0.190
			0.106			*-0.114*	*-0.125*	*-0.190*
Importance of distance restaurant, pubs etc.				-0.130				
	-0.011			*-0.123*		*-0.007*	*-0.001*	
Importance of distance cultural facilities	0.175	-0.078						
	0.175	*-0.078*						
Importance of distance green areas					-0.066			
	0.004	*-0.015*		*0.005*	*-0.066*	*0.011*		*-0.019*
Importance of distance railway station	0.153	-0.104		-0.089		0.071		
	0.182	*-0.146*		*-0.099*		*0.100*	*-0.007*	*-0.026*
Attitude towards car use		0.199						
	-0.007	*0.227*		*-0.010*		*-0.020*	*0.001*	*0.037*
Attitude towards cycling								
	0.011	*-0.019*		*0.002*		*0.018*		*-0.024*
Attitude towards use of PT								
	0.044			*-0.030*		*0.037*	*-0.036*	*-0.031*
Shortest route to daily shops	-0.151			0.075		-0.079	-0.150	-0.130
	-0.151			*0.075*		*-0.079*	*-0.150*	*-0.130*
Distance to green areas								
Distance to railway station	-0.151			0.090		-0.106		
	-0.139			*0.082*		*-0.095*	*-0.010*	*-0.009*
Distance to city centre	-0.150			0.096		-0.095		
	-0.147	*0.002*		*0.090*		*-0.088*	*-0.007*	*-0.006*
Car trip share		0.137		-0.067		-0.074		0.172
	-0.032	*0.137*		*-0.047*		*-0.095*	*0.003*	*0.174*

Chi-square: 430.894 327 df, p: 0.000, NC: 1.318, RMSA: 0.021, p-close: 1.000, TLI: 0.978 CFI: 0.985

* Total effects are presented in italics.

				Endogenous variables							
Housing type	Nr of rooms	Year of move	Car availability	Importance of distance cultural facilities	Attitude towards car use	Attitude towards use of PT	Shortest route to daily shops	Distance to green areas	Distance to railway station	Distance to city centre	Car trip share
							-0.089				
0.010		*-0.020*	*-0.006*				*-0.089*				
										0.077	
-0.017	*-0.007*	*0.020*	*0.010*	*-0.002*		*0.012*	*0.003*	*-0.003*	*-0.008*	*0.077*	
								-0.211			-0.112
-0.027	*0.002*	*-0.006*	*-0.036*	*0.001*		*0.007*	*0.002*	*-0.213*	*-0.004*	*-0.021*	*-0.112*
					-0.136	0.228			-0.106		-0.084
0.049	*0.024*	*-0.041*	*-0.078*	*0.001*	*-0.136*	*0.174*	*0.049*	*-0.042*	*-0.214*	*-0.021*	*-0.112*
			0.106								0.210
-0.011	*-0.005*	*0.011*	*0.174*	*-0.001*		*-0.013*	*-0.004*	*0.003*	*0.008*	*0.039*	*0.210*
									-0.050		-0.139
0.019	*0.007*	*-0.017*	*-0.051*	*0.001*		*-0.004*	*-0.001*	*0.001*	*-0.047*	*-0.026*	*-0.139*
							0.282	-0.244	-0.622		
0.079	*0.053*	*-0.059*	*-0.059*			*-0.153*	*0.239*	*-0.207*	*-0.527*		
-0.108		0.228	0.070								
-0.108		*0.228*	*0.070*								
0.153											
0.153											
-0.258	-0.100	0.215	0.144			0.289					
-0.236	*-0.085*	*0.198*	*0.127*			*0.245*	*0.069*	*-0.060*	*-0.153*		
-0.242	-0.097	0.265	0.140	-0.029		0.188					
-0.227	*-0.087*	*0.254*	*0.129*	*-0.029*		*0.160*	*0.045*	*-0.039*	*-0.099*		
			0.291			-0.108				0.187	
-0.051	*-0.022*	*0.054*	*0.322*	*-0.005*		*-0.061*	*-0.017*	*0.015*	*0.038*	*0.187*	

strong influence on travel behaviour when attitudes towards car use are controlled for.

4.4.3 Residential self-selection concerning built environment characteristics

In the models without assumed influence from built-environment characteristics on travel-related attitudes, the significant relationships between attitudinal variables and the built environment characteristics of the residential locations do suggest that residential self-selection took place. In both models, the more importance the respondents attach to the distance to green areas, the closer they live to green areas; the more important the distance to cultural facilities, the closer they live to a city centre; and the more important the distance to railway station, the closer they live to a railway station. However, in the extended models, the only significant relationships that suggest residential self-selection took place is between the importance of the distance to cultural facilities and the distance to a city centre.

One remarkable result was the strong reverse effect between the respondents' attitudes towards using public transportation and the distance to a railway station in the extended car share model. In this model, respondents with positive attitudes to using public transportation actually live further from railway stations, and self-selection does not seem to have occurred concerning the distance to a railway station. However, in three of the models, attitudes towards car use and attitudes towards public transportation respectively do positively and negatively influence the distance to a railway station through the importance attached to the distance to a railway station. These results support the argument put forward in the introduction that the aggregation levels of attitudes and behaviour should match in order to determine whether residential self-selection has taken place. Attitudes towards using public transportation do influence the distance to the nearest railway station as expected, but only through the importance attached to the distance to a railway station, specifically. Other non-measured factors will have caused the unexpected direct relationship, whereby people with positive attitudes to public transportation actually live further from a railway station. One of these unmeasured factors may be underlying attitudes towards the use of other public transportation modes. People's attitudes towards public transportation include their evaluation of other public transportation modes such as buses or ferries. Positive attitudes towards public transportation may be caused by experiences with modes other than trains.

Again, attitudes towards cycling and car use are not significantly related to any of the built environment variables, while car availability has the expected positive effect on the distance to daily shops, the nearest railway station and the nearest city centre.

The significant effects of housing type, number of rooms and year of move on the distance to activity locations indicate that the location of a household's new house was largely influenced by the availability of houses at the time of their move. Predictably, because apartments are located in more densely populated areas and many of them are close to a city centre, respondents who live in apartments live further from green areas but closer to daily shops, a railway station and the city centre than respondents in single-family houses. The more recently that respondents moved, the farther they live from daily shops, and railway stations. The year of the last move is strongly positively related to the distance to a city centre. This is not surprising since, particularly in Amersfoort, every new residential area has been built further from the city centre than the previous one.

4.4.4 The indirect effect of travel-related attitudes on travel behaviour (the effect of residential self-selection)

As in the study by Bagley and Mokhtarian (2002), because the characteristics of the built environment hardly influence travel behaviour, travel-related attitudes have a very limited indirect influence on travel behaviour through residential self-selection. Tables 4.2 and 4.4 show that in the models without reverse causality, the direct influence of attitudinal variables on the built environment characteristics implies that households do self-select concerning travel behaviour; however, the indirect effect of this self-selection on travel behaviour variables is still very limited. The importance of the distance to cultural facilities and attitudes towards using public transportation both have a very small negative indirect effect on the share of car trips. The importance of the distance to a railway station has a very small negative indirect effect on the total distance travelled and the importance of the distance to green areas and attitudes towards car use both have a very small positive indirect effect on the total distance travelled. For example, the indirect effect of the importance of the distance to cultural facilities is caused by its effect on the distance to a city centre. Respondents who prefer to live closer to cultural facilities choose a residential location relatively close to a city centre, and this in turn is associated with a lower share of trips by car.

The largest, but still small, indirect effect in the extended models is the positive indirect effect of attitudes towards public transportation on the share of trips by car. In the study by Scheinen and Holz-Rau (2007), the largest indirect effect was, similarly, that of the importance of public transportation on the share of car trips. We found that this indirect influence counteracts the negative direct effect of attitudes towards using public transportation on the share of car trips. This indirect effect is caused by the unexpected strong positive relationship between attitude towards public transportation and the distance

to a railway station and, vice versa, a very strong negative effect of the distance to a railway station on respondents' attitudes towards public transportation. Thus for some reason, as discussed in the previous section, respondents with a positive attitude towards using public transportation live further from the nearest railway station and because they live farther away their attitude towards public transportation becomes more negative.

4.4.5 Reverse causality: the influence of travel behaviour and distance to activity locations on travel-related attitudes

The extended models seem to indicate that travel behaviour and built environment characteristics (residential location choice) have a greater effect on travel-related attitudes than vice versa. The share of car trips negatively influences the respondents' attitude towards cycling, the importance they attach to the distance to green areas and the importance of the distance to a railway station. It also influences their attitude towards car use positively. As discussed in the previous section, the distance to a railway station has a strong negative effect on respondents' attitudes towards using public transportation. In both models, a greater distance to green areas leads to a more negative attitude towards public transportation, while attitudes towards public transportation increase with the distance to daily shops. Both are relatively strong relationships.

The distance to daily shops, green areas and a railway station all have significant negative effect on the importance attached to these distances. Thus respondents who live further from these locations attach less importance to them. This indicates that people adjust their attitudes to their circumstances, as argued by Chatman (2009) and complies with the cognitive dissonance theory by Festinger (1957).

4.4.6 Do attitudes add to the explanation by socio-demographic characteristics?

The significant effect of attitudinal variables shows that they play a role in explaining the number of kilometres travelled and the share of car trips by socio-demographic characteristics; however, socio-demographic characteristics and car availability together explain most of the variation of the travel behaviour variables. Being a male, being highly educated, earning at least twice the modal income and working full-time all have a significant positive effect on the number of kilometres travelled. Men and respondents who work full-time also make a higher share of trips by car. Respondents with a child and who are highly educated more often use other modes than the car.

Additionally, the models show many significant relationships between the

socio-demographic variables and distances to activity locations. Increasing age, being highly educated and being childless all result in shorter distances to daily shops, railway stations and city centres. Respondents in employment also live closer to daily shops.

Furthermore the socio-demographic variables are significantly related to the attitudinal variables. Older people and women attach more importance to proximity to daily shops, cultural facilities and a railway station. Men have a more positive attitude towards car use. Respondents with children attach less importance to proximity to restaurants and pubs and a railway station. Highly educated respondents attach less importance to proximity to non-daily shops and more to proximity to a railways station.

4.5 Conclusions and recommendations

This paper has presented two structural equation models to explain the number of kilometres travelled daily and the percentage of trips made by car daily, in relation to travel-related attitudes, distances to activity locations, and distances to activity locations. The main aim of these analyses is to evaluate the effect of including causality between travel behaviour and residential choice and travel-related attitudes in both directions. Therefore two versions of each model were constructed: one with and one without the assumed influence of travel behaviour and distance to activity locations on travel-related attitudes. After comparing the models, it was possible to conclude that, the reversed influence of behaviour on attitudes had a large impact which, if ignored, could lead to the overestimation of residential self-selection. The results also show that if aggregation levels of attitudes and behaviour are not compatible, residential self-selection may be underestimated.

In the extended models, the only direct effect of attitudes towards travel mode use is that respondents with more positive attitudes towards using public transportation use their car relatively less often. By contrast, total kilometres travelled and the share of trips made by car do influence the attitudes towards travel mode use. Therefore the results back up what Tardiff concluded in 1977: that the influence of travel behaviour on travel-related attitudes may be stronger than the influences of these attitudes on travel behaviour. The models also show car availability influences attitudes towards travel mode use.

The significant relationships between attitudinal variables and characteristics of the built environment in which they live suggest that the respondents did self-select in terms of the distances between their residential location and activity locations, but also that other preferences and the housing market were of equal or greater importance. However, in the extended models that measure causality in both directions the influence of distances to activ-

ity locations on the travel-related attitudes is stronger than the reverse effect, which indicates that people were less able to self-select, but subsequently adjusted their attitudes to the characteristics of the built environment characteristics of their residential location (e.g. if they end up living far from green areas, they decrease the importance they attach to the distance to green areas).

The strong positive effect between the respondents' attitudes towards using public transportation and the distance to a railway station indicates many of the respondents were not able to self-select. Conversely, the distance to a railway station has a strong negative influence on the respondents' attitude towards using public transportation. However, in the models without reversed causality, positive attitudes towards using public transportation do indirectly lead to shorter distances to the nearest railway station through the importance attached to the distance to a railway station. This supports our assumption, and the argument of Aizen and Fishbein (1977), that aggregation levels of attitudes and behaviour should match in order to determine whether residential self-selection has taken place.

Because residential self-selection itself is limited, the influence of residential self-selection on the total number of kilometres travelled and the share of trips made by car is also very limited. The largest indirect effect is the unexpected positive indirect effect of attitudes towards public transportation on the share of trips made by car.

Relevance for spatial policy

The results do not provide evidence that the effect of residential self-selection on travel behaviour is important. However, it is still possible that if households had more occasion to self-select, their travel behaviour would be different, especially if households decided not to have a second car. The results do suggest that the characteristics of the built environment have a stronger influence on travel-related attitudes than vice versa. The fact that a shorter distance to railway stations lead to a decrease in the share of car trips through its effect on attitudes towards public transportation means that more accessible public transportation may tempt people to reduce their car use. Currently, the trend in the Netherlands is to redevelop areas near railways into attractive, high-density residential areas; this trend seems promising in the light of the results of our study. Moreover, the results show that people's attitudes towards travel mode use can be influenced by spatial planning. People's negative attitude towards using public transportation may be caused by bad accessibility of public transportation. Improvements to public transportation systems may improve their attitudes.

Recommendations for future research

Based on the results of our analyses, several recommendations for future re-

search can be formulated. Firstly, the strong influence of travel behaviour and distance to activity locations on travel-related attitudes, shows the importance of including both directions of causality in research into travel-related attitudes and travel behaviour. For spatial policy, it would be of interest to conduct further analyses on the influence of the characteristics of the built environment on travel-related attitudes.

Secondly, as argued by Cao *et al.* (2008) because residential self-selection relates to past attitudes (at the moment of residential choice) and current attitudes, the use of panel data and longitudinal analyses seems most appropriate. The strong influence of travel behaviour and the characteristics of the built environment on travel-related attitudes in the two extended models indicate that attitudes are not stable over time, especially not after a residential move. Cross-sectional attitudinal data are therefore not very appropriate for identifying the role of residential self-selection on travel behaviour and attitudes should be measured at the moment of residential choice and for some time after a residential move, once people have had a chance to adjust their attitudes to their new situation and these attitudes have stabilised again.

Thirdly, the results show that more thought should be given to the aggregation level of the variables included. If travel-related attitudes, residential choice and travel behaviour choice are not measured at the same level, residential self-selection may be overlooked.

Finally, the results show that household interaction should be included in residential self-selection studies. As can be deduced from the influence of gender on travel-related attitudes, two partners within a household may have different travel-related attitudes that will not both be met at a new residential location. Moreover, almost every household in the sample had a car, but car availability still influenced the distances to activity locations and car trip share strongly.

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5 Travel-related attitudes, beliefs and residential self-selection

A focus on trip distances and mode choice

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Abstract
Since the development of spatial policies such as New Urbanism in the United States and Compact City Policy in Europe there has been growing interest in determining the influence of the built environment on daily travel behaviour. However, the complexity of this link causes considerable disagreement on the extent of the assumed effects. It is possible that discrepancies between research findings can be partly attributed to ignorance of the role of residential self-selection. People do not always adjust their travel behaviour in accordance with the opportunities available in a residential location, but may instead choose a location that facilitates their travel preferences. Since the mid-1990s many studies have analysed residential self-selection with respect to travel behaviour, often by including travel-related attitudes. However, to the authors' knowledge this paper is the first to analyse underlying beliefs, such as the fun of car use and the flexibility of cycling and their effect on mode choice and residential self-selection, which are found to underlie general attitudes towards travel behaviour. The analyses show that the influence of these beliefs vary depending on trip distance and purpose. Their influence on residential self-selection in relation to the distance to activity locations also varies depending on the type of activity location. Finding a residential location that complies with a household's travel-related attitudes depends on the importance and evaluation of housing, neighbourhood and location characteristics, with some characteristics easier to combine than others. Furthermore, a majority of households experience important demographic or lifestyle changes over time and these may lead to a mismatch of travel preferences and attitudes to housing location despite residential self-selection.

5.1 Introduction

There are now many spatial concepts in Western spatial planning that aim to increase the sustainability of travel behaviour. Well-known examples are New Urbanism and Smart Growth in the United States. In this paper we focus on the relationship between distances to activity locations and the choice of walking/cycling or car use in the Netherlands. From the 1960s the aim of Dutch Spatial Policy was to decrease car use by reducing travel distances and by encouraging people to opt for alternatives. Recently, shifts have appeared in spatial policy in the Netherlands and the aim now is to facilitate accessibil-

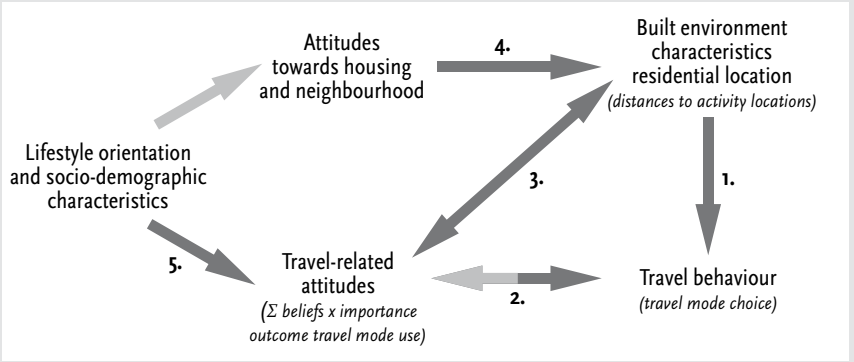
ity rather than reduce the use of cars. Nonetheless, sustainability is still one of the basic principles, with walking, cycling and travelling by public transport being encouraged (Ministry of Transport, Public Works and Water Management 2008).

Numerous empirical studies have shown that distances to activity locations influence travel mode choice. However, given their results, the strength of this influence is questionable (Handy, 1996; Ewing and Cervero, 2001; Dieleman *et al.*, 2002; Schwanen *et al.*, 2004; Handy *et al.*, 2005; Cao *et al.*, 2007; Maat and Timmermans, 2009). It is possible that discrepancies between research findings can be partly attributed to ignorance of the role of residential self-selection. Since the mid-1990s many studies have included attitudes towards travel behaviour in their analyses of the influence of the built environment on travel behaviour. The results of these analyses show that attitudes influence travel behaviour both directly and indirectly through residential choice (Parkany *et al.*, 2003; Cao *et al.*, 2009). Most households select a residential location that complies with their travel-related attitudes at least to some degree, and therefore attitudes influence the relation between the built environment and travel behaviour through residential self-selection. However, the general conclusions that can be drawn from studies of the role of residential self-selection are still limited, due to such issues as the use of different methodologies, different attitude measures, the difficulty of measuring attitudes at all and limited data availability (Mokhtarian and Cao, 2008; Bohte *et al.*, 2009).

The main aim of this paper is to examine the relationship between travel mode choice, beliefs about travel mode use, distances to activity locations and residential self-selection. To add to existing studies that include travel-related attitudes, this study includes beliefs that are psychological constructs that underlie attitudes. In attitude-behaviour theory beliefs are very important. They refer to the probability of associations or linkages between the behaviour and various outcomes. Examples of such beliefs are 'cycling is environmental-friendly' or 'cycling is fun'. Beliefs about the likely outcomes of the behaviour and the evaluations of these outcomes together determine the attitude towards the behaviour (Eagley and Chaiken, 1993).

There are now a handful of studies that analyse the influence of beliefs about travel mode use on mode choice (e.g. Steg, 2005; Dill and Voros, 2007; see Section 5.2). However, none of these studies takes into account the role of travel distance and residential self-selection. This paper assumes that the explanation of travel mode choice and residential self-selection by beliefs about travel mode use depends on the distance to an activity location and the type of activity location. For example, it can be expected that the health benefits attached to using a particular travel mode is more important for leisure trips than for daily shopping trips, while for daily shopping trips the ease of carrying groceries and time-saving are of greater importance. Furthermore,

Figure 5.1 Conceptual model of the influence of attitudes and residential self-selection on travel behaviour (In brackets the focus of this paper)



we expect that at different distances different attributes will be decisive for mode choice. For example, the importance people attach to using a time-saving travel mode and beliefs about the time-saving benefit of the different travel modes will probably change with trip distance. Ultimately, if the travel attitudes of households are understood in more detail, spatial policy that aims to influence travel behaviour by reducing distances to activity locations can be made more specific and effective.

The degree of residential self-selection with respect to travel-related and underlying beliefs depends on what types of houses are available in what locations. If housing options do not satisfy all of the housing, neighbourhood and location preferences of a household, the strength and combinations of these preferences will determine whether or not the household location matches the householder's attitudes towards travel behaviour.

An additional aim of the paper is to explore how socio-demographic characteristics and lifestyle affect beliefs about travel mode use. For example, it can be expected that an increase in working hours will increase the importance of travelling by a time-saving mode, especially when distances are great. However, when someone is very career-oriented they will generally be willing to commute over greater distances. Moreover, it is not only the importance attached to outcomes of travel mode use, but also beliefs related to these outcomes that may change with socio-demographic and lifestyle changes. For example, when a third child arrives a bicycle may no longer be that flexible. Such changes in household characteristics imply that earlier self-selection of a household on the basis of the travel-related characteristics of a residential location may later lead to a mismatch.

Figure 5.1 summarises the assumed relationships. This paper will first examine the assumed influence of travel-related attitudes and underlying beliefs about travel mode use and the influence of the distance from the home to activity locations on travel behaviour (arrow 1 and 2). Secondly, the analyses will test the assumption that the distance to activity locations influences travel-related attitudes and beliefs (arrow 3). Thirdly, to indicate whether residential self-selection has taken place, the influence of these beliefs on distances from home to activity locations is analysed. Subsequently, the anal-

ysis focuses on the trade-off between housing, neighbourhoods and travel-related characteristics in residential relocations (arrow 3 and 4). Finally, the influence of socio-demographic characteristics and lifestyle on beliefs about travel mode use, including the effect of changes of these beliefs will be examined (arrow 5).

As shown in Figure 5.1 some influences between the variables that are included in our analyses fall beyond the scope of this paper. We do acknowledge that travel behaviour may influence travel-related attitudes (Chatman, 2009).

This paper also adds to existing studies by presenting analyses of data collected in the Netherlands. Most previous empirical research on residential self-selection and mode choice originates from the United States. Factors such as differences in the housing market, cultural differences and differences in the built environment mean that mode choice as well as residential self-selection mechanisms in countries such as the Netherlands, differ significantly from the US (Næss, 2009). In particular, the infrastructure for walking and cycling is better and distances are shorter in the Netherlands. In 2001, 49 percent of all trips in the Netherlands were car trips, 26 percent were by bicycle and 19 percent by foot (Statistics Netherlands, 2009), while in the US, 86 percent of all trips were by personal vehicle (including motorcycle), 9 percent were made on foot, and only 1 percent of all trips were by bicycle (U.S. Department of Transportation & Bureau of Transportation Statistics, 2003; Iacono *et al.*, 2008). Due to the extent that people walk and cycle in the Netherlands, it could be expected that the evaluation of walking and cycling would be closer to that of car use than in the US. Therefore, it would be more likely that people in the Netherlands would seriously address the trade-off involved in the use of different travel modes and that more households consider to self-select into a residential location within walking or cycling distance of an activity location.

The paper comprises five sections. Following this introduction, Section 5.2 will discuss existing research on the relationship between the built environment, mode choice, residential self-selection and travel-related attitudes. Section 5.3 will describe the data collection and the methods of analyses that were applied, while Section 5.4 will present the empirical results. Finally, in Section 5.5, the conclusions and recommendations will be presented.

5.2 Literature review

This section will discuss what is already known from the literature about the relationship between beliefs about travel mode use, trip distance, mode choice and residential self-selection, as well as underlying socio-demographic characteristics and lifestyle orientation.

5.2.1 Beliefs about travel mode use, distances and mode choice

While many studies analyse the relation between travel-related attitudes and actual travel behaviour, this paper includes beliefs that underlie attitudes towards travel behaviour. Attitudes towards travel mode use are often constructed or derived from underlying beliefs and the importance of these beliefs. However, they are usually not discussed or analysed separately (Bohte *et al*., 2009). As was argued in the introduction, the diversity of dimensions determining the use of travel modes implies that underlying beliefs would provide additional relevant information. The study by Steg (2005) is one of the few that further investigated the role of underlying motives. She found that car use motives can be divided into symbolic (e.g. 'My car indicates who and what I am'), affective (e.g. 'I like to drive just for fun'), and instrumental motives (e.g. 'I only have a car to travel from A to B'). Despite the functional character of commuting, commuter car use was mostly associated with symbolic and affective motives. Most group differences were also found in these two categories. In particular, frequent drivers, people with a positive attitude to the car, male and younger respondents valued symbolic and affective motives. Dill and Voros (2007) found significant differences in beliefs about travel modes and travel (e.g. 'Cycling can sometimes be easier for me than driving' and 'Fuel efficiency is an important factor for me in choosing a vehicle') between regular cyclists and people who do not cycle regularly. They also seem to have found a relationship between environmental values (e.g. 'Air quality is a major problem in this region') and cycling.

The study by Steg (2005) showed that the motives for car use are different for different trip purposes. Other studies have shown that distinguishing trip purposes also improves the explanation of mode choice by trip distance. Trips which are more discretionary, such as social visits, recreation and shopping, as opposed to work and school-related trips, are more often walked or cycled (Cervero and Kockelman, 1997; Cervero and Duncan, 2003; Schwanen *et al*., 2004; Iacono *et al*., 2008). In relation to shopping, Handy and Clifton (2001) discuss the distinction between trips to buy convenience goods (e.g. food) and trips taken to shop for comparison goods (e.g. clothing). It is assumed that people are willing to travel further and visit more shops when buying comparison goods, while travel time is decisive in decisions concerning where to shop for convenience goods. Iacono *et al*. (2008) found that people who cycle to work or school are willing to cycle up to 20 kilometres, while those who cycle purely for fun tend to cover shorter distances.

To our knowledge, research that relates the influence of distance and of beliefs about mode use is scarce. It might be assumed that attributes such as comfort and time-saving in relation to the different travel modes will be evaluated differently for different distances, especially for the active and relative-

ly slow modes of walking and cycling. Moreover, these evaluations could be expected to differ between individuals and between trip purposes. The results of a study by Loukopoulos and Gärling (2005) showed that the more exertion that was attributed to walking, the lower the distance threshold for driving, while the more often one walked the greater the threshold.

5.2.2 Residential self-selection

Travel-related attitudes influence travel behaviour not only directly, but also through residential choice. The notion that households self-select into a residential location that suits their travel-related attitudes is supported by several studies of residential choice. Empirical findings show that attitudes towards travel mode use and accessibility significantly influence residential choice, albeit several housing and neighborhood attributes are of more importance (Filion *et al*., 1999; Van Wee *et al*., 2002; Molin and Timmermans, 2003).

Several empirical studies have included analyses of the role of residential self-selection in relation to travel mode choice. They have found a significant influence, but the inclusion of residential self-selection in analysis models does not entirely negate the influence of the characteristics of the built environment (e.g. Kitamura *et al*., 1997; Krizek, 2003; Schwanen and Mokhtarian, 2005, Cao *et al*., 2006; Khattak and Rodriguez, 2005; Frank *et al*., 2007; Næss, 2009). For example, Kitamura *et al*. (1997) found that the distance to the nearest bus stop or the nearest park influenced the proportion of car trips, but when attitudes such as 'pro-environment', 'suburbanite' and 'time pressure' were added to their models, the influence of these built environment characteristics decreased. The results of a study by Cao *et al*. (2006) showed that individuals who rate shops within walking distance as being more important in their decision to live in their current neighbourhood, take strolls more frequently and more often walk to the shops. After controlling for residential self-selection, neighbourhood characteristics such as the pedestrian environment and distance to shops are still important.

In summary, evidence suggests that in the trade-off between all the various attributes of a new house, travel-related attributes are less important than other housing and neighbourhood attributes. Because these other attributes prevent households from self-selecting on the basis of travel-related characteristics, they often determine whether or not people can travel according their preferences.

5.2.3 The role of socio-demographic characteristics and lifestyle

Studies by Cervero and Duncan (2003) and Handy and Clifton (2001) suggested that designing walkable neighbourhoods for specific demographic groups

that like to walk is probably more effective in increasing walking than reducing distances and providing pedestrian-friendly design in general. For example, for diverse reasons, people who do not prefer walking that much more than car use often ignore the nearest shop or visit many different shops for one purchase. Therefore the effect of building a shop within walking distance does not significantly decrease car kilometres for most individuals (Handy and Clifton 2001). Mulder and Hooimeijer (1999) described how the relative importance of site and situation characteristics of people's homes varies between different life-cycle stages. In the earlier stages, being close to work or study locations is of primary importance, while for households with children or anticipating having children, the characteristics of the house and neighbourhood are more important. This implies that households with children may accept longer commuting distances. The longitudinal study by Krizek (2003) included life-cycle changes in an analysis of residential self-selection, finding several significant relationships between changes in socio-demographics (such as the number of vehicles, number of children, level of income, etc.) and changes in the built environment after a residential relocation and the number of trips/tours and miles travelled.

Walker and Li (2007) estimated lifestyle groups with similar relationships between the importance of housing attributes and residential location choice. They expected respondents with different lifestyles to make different trade-offs between attributes such as: local parks, shops/services entertainment, walking time to local shops, bus fares, travel time to shops, travel time to work by auto, travel time to work by public transport, bicycle paths and the quality of schools. The best model fit was accomplished by a division of respondents into three latent lifestyle segments: suburban dwellers (car, school orientations), urban dwellers (high-density, near-urban-activity and auto orientations) and transit riders (public transport, house orientations).

The framework created by Salomon (1982) is very useful for studying the influence of lifestyle. He distinguishes between lifestyle, lifestyle decisions and orientation towards the roles of family member, worker and consumer of leisure. There are at least three highly interdependent lifestyle decisions: the decision to form a household, the decision to participate in the labour force and the orientation towards leisure. These all influence long-term decisions about where to live, where to work, car ownership and the travel mode to work, as well as short-term travel decisions. Lifestyle is defined as the pattern of behaviour which reflects an individual's orientation to the three roles mentioned and the constraints on the available resources. Research by Bootsma (1995) on the influence of a work-oriented lifestyle on the choice of residential location by couples showed that women who see themselves as equal to their partners more often live in urban areas rather than elsewhere, and women in urban areas also proved to be more work-oriented than women living elsewhere. In their study of residential self-selection, Bagley and Mokhtar-

ian (2002) found that of all the variables included, attitudinal and lifestyle variables had the greatest impact on travel demand, while residential location had little impact on travel behaviour.

5.3 Data description

This section first describes the data collection, fieldwork area and respondents, before turning to an explanation of the measurements used and the choice of the attitudinal constructs included in the analyses.

5.3.1 Data collection and fieldwork area

The data was collected in 2005 through an internet survey. This approach was chosen primarily because it offered user friendly routing options, as the survey was very complex. The survey was conducted among a sample of residents from Amersfoort (137,000 inhabitants), Veenendaal (61,000 inhabitants) and Zeewolde (19,000 inhabitants), three municipalities in the centre of the Netherlands. Amersfoort is situated in the northeast of the Randstad. It has a historical centre and includes many outlying developments to the north. Veenendaal is situated 18 kilometres to the southeast of Amersfoort and is known for its shopping facilities, bicycle-friendliness and green areas. Zeewolde is a relatively new town to the north of Amersfoort built on reclaimed land, and is on the water with a small beach. All three municipalities are surrounded by green areas, including woods. Both Amersfoort and Veenendaal have three railway stations, while the nearest railway station to Zeewolde is 13 kilometres away.

5.3.2 Respondents and response

Because our research focuses on residential choice and in the Netherlands renting does not provide many options due to low availability and regulated distribution, we limited our research to homeowners. The ten districts included in our fieldwork all have a high percentage of owner-occupied houses. The districts vary on period of development, density, distance to a railway station and to city centre. Since the analyses were to be performed at the household level at a later date, the participants were randomly selected from the municipal births register on the basis of household level and both partners were asked to respond. We received 3,979 completed questionnaires from the 12,836 people who were approached. This meant a response rate of 31.0 percent, which is fairly high for an internet survey. The analyses include 2,733 respondents. Because the analyses were performed at the individual level, one of the partners was randomly selected. Because of the low response rate

among single persons, this selection did not lead to the underrepresentation of people with a partner.

Due to the selection of house owners, the majority of the participants had a medium or high level of education and a relatively high income. People aged 65 and over were less well represented, with a response rate of 9.5 percent and thus the results are less representative for this age group.

5.3.3 The measurement of beliefs about outcomes of travel mode use

Various methods are used to measure attitudes in travel behaviour research, while additional methods are also available from social psychology (Ajzen, 2002). In the survey, the measurement of attitudes was broken down into beliefs about different outcomes of travel mode use and the importance of these outcomes, because as was argued in the introduction they may both vary with trip distances and underlying socio-demographics and lifestyle. The chosen measure is similar to the measure used in the PhD study by Anable (2002) (see Bohte *et al.*, 2009) and is based on expectancy-value theory, where the expected values are determined by the cognitive evaluation or subjective probability that an attitude object possesses the attribute or outcome multiplied by the affective evaluation of the attribute/outcome. It is assumed that the behaviour for which the expectancy-value product is the highest will be chosen (Eagly and Chaiken, 1993; Gärling and Garvill, 1993).

Beliefs about (outcomes of) cycling and car use were measured by first asking the respondents to rate various characteristics or outcomes of the use of each travel mode (e.g. cycling is comfortable) on a 5-point Likert-type scale that ranged from 'strongly disagree' (= -2) to 'strongly agree' (= 2) and then by asking them to rate the importance of these aspects (e.g. the importance of comfortable travel mode use) on a 5-point scale (very important = 5, very unimportant = 1). The final evaluation of each characteristic was calculated by multiplying the score for its importance and the score for its original evaluation.

In the analyses, travel mode choice is limited to walking/cycling versus car use because they are the predominant travel modes the respondents used for daily shopping (99 percent), non-daily shopping (96 percent) and for trips to green areas (99 percent). Because the main interest of this paper is in how beliefs about travel mode use and distance affect people's choice to leave the car at home and use a more sustainable mode of transportation, the analyses include both walking and cycling. Some people will walk to an activity location rather than driving, while others will prefer to cycle. Although our analyses include walking, beliefs about walking were not measured or used, because it was expected that they would depend on the travel circumstances more than on attitudes towards cycling or car use, making it very difficult to rate outcomes of walking without a specific description of these circumstanc-

es. For example, the fun and comfort of walking will vary greatly with distance and whether or not someone is carrying heavy groceries. Someone may like to walk, but be strongly disinclined to walk while carrying groceries. Driving or cycling with groceries, on the other hand, usually has less influence on how people evaluate these modes. However, we do acknowledge that including these characteristics would have contributed to the value of the analyses.

The choice of the specific outcomes of cycling and car use to include in these analyses were based on existing studies (Tardiff, 1977; Bamberg, 1994; Anable, 2002 unpublished PhD thesis; Steg, 2005). Beliefs about the cheapness and environmental- friendliness of cycling were omitted in the logit and regression analyses, because the skewness of the answers of the respondents was above 3.

5.3.4 The evaluation of house, neighbourhood and location characteristics

The importance of and satisfaction with house and neighbourhood characteristics and distances to activity locations were measured by asking the respondents to indicate the importance of the characteristic and their level of satisfaction with it at the time, both measured on a 5-point scale (very unimportant to very important and very unsatisfied to very satisfied, respectively). The more extensive analyses of the distance to activity locations were limited to the activity locations of 'daily shops', 'non-daily shops' and 'green areas'. These activity location categories were chosen because they can be influenced by spatial planning, are relatively homogenous categories and are visited relatively often, for example cultural facilities include theatres as well as cinemas, which attract different audiences.

5.3.5 Mismatches and residential self-selection concerning the distance to activity locations

In this paper, respondents mismatched with respect to the distance to an activity location are those who attached importance to the distance to the activity location and claimed they were 'not satisfied' with the current distance on a scale that also included the categories 'neutral', 'unsatisfied' and 'very unsatisfied'. However, as was discussed by Mokhtarian and Cao (2008) and Bohte *et al.* (2009), because only current attitudes were measured, true residential self-selection could not be identified by analyses of these current attitudes, as these attitudes may differ from those held at the time of residential choice.

5.3.6 The measurement of lifestyle orientation

Lifestyle orientation was measured by translating and using statements from the Life Role Salience Scale (LRSS) developed by Amatea *et al.* (1986) (Table 5.1).

Table 5.1 Reliability analyses of statements that measure lifestyle orientation

Statements	Cronbach's Alpha
The importance of having children (N=2607)	**0.78**
If I chose not to have children, I would regret it	
It is important to me to feel I am (will be) an effective parent	
The whole idea of having children and raising them is not attractive to me	
The importance of having a career (N=2606)	**0.77**
Having work/a career that is interesting and exciting to me is my most important life goal	
It is important to me that I have a job/career in which I can achieve something of importance	
It is important to me to feel successful in my work/career	
The importance of having partner (N=2607)	**0.87**
Having a successful marriage/relationship is the most important thing in life to me	
Being married/having a relationship with a person I love is more important to me than anything else	
I expect the major satisfactions in my life to come from my (marriage) relationship	
The importance of having a nice home (N=2608)	**0.64**
It is important to me to have a home of which I can be proud	
Having a comfortable and attractive home is of great importance to me	
Having a nice home is something to which I am very committed	
The importance of leisure time out of home (N=2635)	**0.79**
Undertaking leisure activities out of home is of great importance to me	
Leisure activities out of home largely determine my happiness in life	
It is important to me to have enough time for leisure activities out of home	
The importance of leisure time in home (N=2635)	**0.73**
Undertaking leisure activities in home is of great importance to me	
Leisure activities in home largely determine my happiness in life	
It is important to me to have enough time for leisure activities in home	

The LRSS uses direct measures to create constructs that represent the importance attributed to the roles of worker, spouse, parent and homemaker, and consists of 40 items (e.g. It is important to me to feel successful in my work/career) which are rated on a 5-point Likert-type scale that ranges from 'strongly disagree' (= 1) to 'strongly agree' (= 5) (Cinamon and Rich, 2002). The reliability of the LRSS has been demonstrated in various studies (Rajadhyaksha and Bhatnagar, 2000; Van der Velde *et al*., 2005). After testing the statements, we decided to measure the importance of each role with three statements. Following Salomon (1982, see literature review section), the analyses also include an orientation towards leisure. However, because of their different effects on travel behaviour, the orientation towards leisure was split into leisure time outside the home and inside the home. To measure leisure orientation, statements similar to those in the LRSS were constructed. Statements on the importance of having a spouse were transformed into statements about having a partner.

5.4 Data analyses and results

This section will first identify the percentage of respondents who are mismatched with respect to the distance from their home to activity locations

Table 5.2 Percentage of mismatched (MM) respondents concerning the distance from their home to activity locations and consequences for their travel behaviour

	% Very important, important	% Mismatched**	% MM less frequent visit	% MM other mode	% MM car instead of walk/cycle
Work *	82.5% (N = 2114)	25.5% (N = 1744)	7.7%	22.1%	7.9%
School *	83.9% (N = 1521)	12.7% (N = 1276)	9.5%	17.8%	NA
Daily shopping	82.0% (N = 2626)	7.9% (N = 2151)	29.2%	31.0%	27.1%
Non-daily shopping	36.7% (N = 2626)	18.0% (N = 961)	32.9%	26.0%	27.7%
Restaurants, pubs, etc.	16.8% (N = 2625)	24.2% (N = 438)	30.2%	33.0%	30.2%
Cultural facilities	22.4% (N = 2626)	26.2% (N = 588)	39.0%	26.0%	5.2%
Sport facilities	45.7% (N = 2625)	13.9% (N = 1198)	20.5%	17.5%	7.2%
Green areas	78.6% (N = 2625)	9.6% (N = 2061)	34.5%	26.9%	11.1%
Railway station	42.8% (N = 2626)	29.4% (N = 1121)	NA	NA	NA

* Respondents with paid work/children.

** Mismatched = neutral, unsatisfied or very unsatisfied, while distance to activity location type is important or very important.

and the consequences of these mismatches for their travel behaviour. Subsequently, beliefs about outcomes of travel mode use are introduced. Binomial logit models show the influence of these beliefs on travel mode choice for daily shopping trips, non-daily shopping trips and trips to green areas in relation to the distance to these locations. To assess residential self-selection, the regression analyses that follow reveal the influence of beliefs about travel mode use on the distance to daily shops, non-daily shops and green areas. Subsequently, the analysis focuses on the trade-off between housing, neighbourhoods and travel-related characteristics in residential relocations. Finally, the influence of socio-demographic characteristics and lifestyle on beliefs about travel mode use will be examined.

5.4.1 Mismatches of distances to locations, trip frequency and travel mode choice

The overview in Table 5.2 shows that the percentage of respondents who attach importance to the distance to activity locations and the percentage that are mismatched in relation to these distances varies according to the activity location type. Respondents are most often mismatched in relation to the distance to work or a railway station. Most mismatches related to the distance to a railway station occurred in Zeewolde, which lacks a railway station. The numbers of respondents who attach importance to distances to cultural facilities, restaurants and pubs, etc. are relatively low, although relatively many of them are mismatched.

Some responded to a mismatch by visiting a location less often, while others visited the location using a other than the preferred travel mode. In many cases, choosing another travel mode implies travelling by car rather than walking or cycling. Whether a longer distance than preferred has consequences for mode choice and/or trip frequency significantly differs between

Table 5.3 Percentage of mismatched (MM) respondents per trip distance to activity locations and consequences for their travel mode choices

	Daily shopping *		Non-daily shopping **		Green areas ***	
	% Mismatch	% MM car instead of walk/ cycle	% Mismatch	% MM car instead of walk/ cycle	% Mismatch	% MM car instead of walk/ cycle
0-250 m	8.8% (N = 125)	18.2% (N = 11)	0.0% (N = 46)	NA	1.7% (N =464)	0.0% (N = 8)
250-500 m	5.1% (N = 392)	10.0% (N = 20)	5.9% (N = 68)	0.0% (N = 4)	6.0% (N =486)	3.4% (N = 29)
500-750 m	3.4% (N = 589)	15.0% (N = 20)	12.5% (N = 104)	0.0% (N = 13)	5.6% (N =266)	6.7% (N = 15)
750-1000 m	4.1% (N = 386)	25.0% (N = 16)	10.4% (N = 192)	25.0% (N = 20)	7.6% (N =185)	7.1% (N = 14)
1000-1250 m	3.3% (N = 243)	12.5% (N = 8)	5.6% (N = 143)	0.0% (N = 8)	9.4% (N =53)	20.0% (N = 5)
1250-1500 m	4.5% (N = 88)	25.0% (N = 4)	16.9% (N = 71)	16.7% (N = 12)	4.5% (N =22)	0.0% (N = 1)
1500-2000 m	15.3% (N = 85)	23.1% (N = 13)	29.0% (N = 93)	14.8% (N = 27)	22.2% (N = 117)	23.1% (N = 26)
2000-2500 m	25.4% (N = 134)	41.2% (N = 34)	31.9% (N = 94)	36.7% (N = 30)	32.3% (N = 167)	7.4% (N = 54)
2500-3000 m	52.1% (N = 73)	34.2% (N = 38)	39.1% (N = 92)	22.2% (N = 36)	21.5% (N = 93)	10.0% (N = 20)
3000-4000 m	NA	NA	28.6% (N = 7)	0.0% (N = 2)	17.1% (N = 70)	0.0% (N = 12)

* Distance to the closest daily shop = the shortest road distance to the nearest supermarket (sources: Locatus 2006; NAVTEQ 2006).

** Distance to the closest non-daily shop = the shortest road distance to the nearest woman's clothing shop (because present in all substantial shopping malls, while e.g. department stores are not) (sources = Locatus 2006; NAVTEQ 2006).

*** Distance to the closest green area = direct route x 1.2 to closest border of the green area of at least 5 km².

trip purposes. As could be expected, because visits to the workplace are often fixed in time and space, respondents who are mismatched concerning the distance to work do not often decrease their trip frequency. Almost one-quarter travel by other than their preferred travel mode. Respondents who are mismatched concerning the more flexible activity locations such as non-daily shops and restaurants and pubs often use other than the preferred mode. However, even more likely is that they visit the location less frequently.

Table 5.3 presents the percentage of respondents who are mismatched in relation to distance class with respect to daily shopping, non-daily shopping and green areas. It is notable that, in many of the distance classes, non-daily shopping has the highest percentages of mismatched respondents. The percentage mismatched in relation to the distance to green areas decreases in the last three distance classes. From 2,500 metres or more the percentages are low compared to 'daily shopping' and 'non-daily shopping'. One reason might be that travel time and therefore distance is less relevant to people for a leisure activity such as visiting green areas, while the attractiveness of the area is of greater importance. Because of differences in attractiveness, some respondents may choose to visit a green area that is not necessarily the closest while others may visit a closer, smaller area not included in this analysis. Relatively few people use a car to visit green areas, while preferring to cycle or walk. The percentages of respondents who are mismatched in relation to the distance to daily shopping are relatively low in most distance classes, but a relatively high proportion of respondents switch to car use in such cases.

Table 5.4 Mean scores and standard deviation of beliefs about outcomes of car use and cycling and the importance attached to these outcomes (N = 2481)

	Beliefs car use*		Beliefs cycling*		Importance of outcomes	
	Mean	SD	Mean	SD	Mean	SD
Status	-0.88	1.165	-0.72	1.022	1.85	0.883
Environmental-friendliness	-1.06	0.891	1.23	0.595	3.65	0.742
Relaxing	0.57	1.293	1.34	0.771	3.96	0.619
Comfortable	1.54	0.633	0.62	1.149	4.15	0.565
Time-saving	1.33	0.809	0.09	1.174	4.14	0.625
Flexible	1.39	0.679	1.34	0.933	4.28	0.569
Cheap	-0.99	0.942	1.31	0.652	3.79	0.793
Fun	1.17	1.031	1.31	0.843	4.15	0.550
Private	1.34	0.830	0.82	1.095	3.67	0.885
Healthy	-0.70	0.890	1.32	0.562	3.85	0.755
Safe	0.86	1.169	0.63	1.167	4.35	0.607

* Paired sample t-test shows all pairs have a significant difference ($p < 0.05$) between beliefs cycling and car use.

5.4.2 Beliefs about travel mode use

Table 5.4 shows the means scores of the beliefs about the outcomes of cycling and car use and the mean scores of the importance attached to these outcomes. Apart from 'Status' the mean score for the importance attached to all of the outcomes is greater than 'important', with the highest importance attached to 'Safety' and 'Flexibility'. All of the outcomes are significantly differently evaluated for cycling and car use. In particular, cycling received higher evaluations in relation to 'Environmental-friendliness', 'Relaxing', 'Cheap' and 'Healthy'. The comfort, time-saving and privacy aspects of car use are given far higher value.

It is expected that the significance and strength of the relationship between travel-related attitudes and beliefs and the percentage of respondents who walk or cycle differ between distance classes as well as between trip purposes. Table 5.5 shows that the percentage of respondents that walk or cycle in the different distance categories, differ between the three trip purposes. The more discretionary the trip purpose – with daily-shopping as the least discretionary and visiting green areas the most discretionary – the more people walk or cycle greater distances.

Table 5.6 presents three binomial logit models to explain mode choice (walk/cycling instead of car use) to most frequently visited daily shopping, non-daily shopping and green areas by beliefs about car use and cycling and their interaction with trip distance. It is assumed that trip distance and trip purpose influence beliefs about outcomes of travel mode choice and the importance of these outcomes. For example most people will belief cycling 2 kilometres is less comfortable than cycling 50 kilometres. However, because measuring beliefs in relation to distance and trip purpose (e.g. agreement with 'cycling 2 kilometre to a daily shop is comfortable') would have led to an unacceptable long questionnaire, it was chosen to measure beliefs on a more aggregate level ('cycling is comfortable') and to model distance as a mediat-

Table 5.5 Percentage of respondents that walk/cycle per trip distance to most visited activity locations

	Daily shopping % walk/cycle	Non-daily shopping % walk/cycle	Green areas % walk/cycle
0-250 m	84.7% (N = 373)	94.2% (N = 138)	96.0% (N =398)
250-500 m	66.6% (N = 431)	86.2% (N = 58)	94.7% (N =262)
500-750 m	58.7% (N = 375)	76.1% (N = 67)	88.1% (N =235)
750-1000 m	43.5% (N = 239)	75.0% (N = 124)	86.1% (N =144)
1000-1250 m	30.7% (N = 176)	74.5% (N = 141)	77.9% (N =68)
1250-1500 m	27.3% (N = 143)	65.4% (N = 133)	78.6% (N =42)
1500-2000 m	21.3% (N = 240)	58.5% (N = 265)	58.0% (N = 50)
2000-2500 m	13.8% (N = 94)	51.8% (N = 85)	68.4% (N = 38)
2500-3000 m	36.4% (N = 11)	44.1% (N = 34)	63.9% (N = 36)
3000-4000 m	14.3% (N = 7)	44.9% (N = 98)	45.7% (N = 116)
> 4000 m	14.3% (N = 14)	7.5% (N = 372)	14.6% (N = 158)

ing variable in the relation between beliefs about outcomes of travel mode use and mode choice. For example it can be expected that the importance of the relaxedness of cycling increases with trip distance. Because it is assumed that the importance of the expected outcomes of travel mode use will sometimes decrease and sometimes increase with distance and this influence may be non-linear, the utility equation is formulated as follows:

$$U_i = \sum_{i=1}^{n} \beta_j \cdot \left[\frac{d_j}{\bar{d}} \right]^{\gamma_j} \cdot x_{ij} + \varepsilon_i$$

Where:
U_i = utility of mode i
β_j = parameter estimate respective to variable x_{ij}
d_j = actual distance to the relevant activity location for observation j
$\bar{d}$ = average distance to the relevant activity location
x_{ij} = value of attitudinal variable j for mode i
γ_j = estimate of the distance sensitivity of variable x_{ij}
n = number of variables included per mode
ε_i = error term

If the exponent γ becomes zero, it must be assumed that the influence of attitudinal variable j is independent of the distance, since the addition multiplicand is 1 for all distances. If γ is negative the influence of the attitude is higher for small distances, while a positive exponent means its influence is smaller for short distances. A value of 1 means the influence of distance is linear.

The binomial logit models were estimated with BIOGEME, a software program used to estimate discrete choice models (Bierlaire, 2003). The results of the estimates show that the influence of beliefs indeed differs between trip purposes (Table 5.6). It can therefore be assumed that they may help explain

Table 5.6 Binomial logit models of mode choice explaining the choice of walking/cycling instead of car use for the most frequently visited daily shops, non-daily shops and green areas by beliefs about car use and cycling and car availability and their interaction with distance

	Daily-shopping Coefficient estimate	Non-daily shopping Coefficient estimate	Green Area Coefficient estimate
Car_status	-0.137 *	-0.220 *	
Car_environmental-friendliness	-0.102 ***	-0.679 *	
Car_relaxing	-0.111 *	-0.414 *	
Car-comfortable		0.222 *	
Car_time-saving			-0.189 **
Car_flexible	0.356 *		0.296 *
Car_cheap	-0.149 *		
Car_fun	-0.238 *		
Car_private			0.269 *
Car_healthy		-0.189 **	
Car_safe			-0.162
Cycling_status		0.395 *	0.151 ***
Cycling_relaxing	-0.230 *		
Cycling_comfortable	0.243 *	0.192 *	0.209 *
Cycling_time-saving	0.207 *	0.300 *	
Cycling_fun			0.182 ***
Cycling_healthy	-0.147 ***		-0.345 *
Cycling_safe			
Car always available	-1.00 *	-0.910 *	-0.312 ***
γ Car_environmental-friendliness		1.67 *	
γ Car_relaxing		0.550 *	
γ Car_fun	0.452 *		
γ Car_safe			0.495 **
γ Cycling_relaxing	0.623 *		
γ Cycling_comfortable			-0.211 **
γ Cycling_healthy			0.621 *
γ Car always available	0.369 *		
Rho^2	0.242	0.380	0.499
Adjusted Rho^2	0.232	0.369	0.487
Mean distance	843 m	1,391 m	3,060 m

* Significant at $p < 0.01$ level; ** significant at $p < 0.05$ level; *** significant at $p < 0.10$ level

the differences in the percentages of respondents that choose to walk or cycle as depicted in Table 5.5. Moreover, the strength of the influence of some of these beliefs can change with trip distance.

The extent to which car use is both environmentally friendly and relaxing is relatively strongly and positively related to the choice to walk/cycle to non-daily shops, somewhat positively related for trips to daily shops and not significantly related to visits to green areas. An explanation for the differences in the perceived relaxedness of car use is that it is possible that people

who find car use less relaxing negatively evaluate the relaxedness of driving in busy areas, such as inner cities, where the respondents most often do their non-daily shopping, while they find driving to green areas is more relaxing. The absence of a significant relationship between the extent to which car use is perceived as environmentally friendly and the choice to walk/cycle to green areas may be partly attributed to respondents that have contradictory 'green' attitudes. Some respondents may attach importance to the environmental aspects of car use but also attach greater importance to their visits to green areas. They may therefore more often choose an area that is better accessible by car.

While most 'positive' beliefs about cycling relate positively to the choice to cycle or walk, the more healthy the respondents evaluate cycling, the less often they cycle or walk. One possible explanation may be that some respondents associate healthiness with physical effort. This explanation is supported by the significant relationship between beliefs about the healthiness of cycling, mode choice and the distance to green areas. The longer the trip to green areas, the stronger the negative relationship between beliefs about the healthiness of cycling and the choice to walk or cycle. Moreover, in the survey the respondents were also asked to indicate the maximum number of minutes they would cycle for in order to reach a recreational activity location when the weather was nice. These answers also show a significant negative relationship with the evaluation of the healthiness of cycling (B = -2,979). The more they evaluate cycling as healthy, the fewer minutes the respondents are willing to travel. The comfort and flexibility aspects of car use and the relaxedness of cycling also correlate negatively with the choice of those modes of transport. It can therefore be expected that they also correlate strongly with beliefs about an outcome that were not measured – but should have been – as is probably the case with beliefs about the healthiness and effort of cycling.

Of all the beliefs that were included in the analyses, only three failed to show any significant relationship with choice of mode – namely, beliefs about the flexibility, safety and privacy of cycling. The only belief that shows a significant relationship for all three trip purposes is the belief about the comfort of cycling. Whether or not a car is always available is three times significantly related. Because trips to green areas probably often include the whole family and most respondents (97 percent) belong to 'at least one-car households', it is likely that car availability influences the choice of travel mode for trips to green areas less often. The high percentage of respondents that walk or cycle to a green area is of course explained by the fact that most people visiting a green area see walking or cycling there as part of the activity itself. The degree to which respondents evaluate cycling as time-saving does influence their choice of mode for shopping trips, but not their choice of mode for trips to green areas; this would also indicate that walking and cycling to green areas is not simply a means of reaching the activity location.

Several estimates of the gammas are significant and therefore indicate that beliefs about travel mode use have different influences on mode choice, depending on the distance to the activity locations. In the daily-shopping model, the fun of car use, the relaxedness of cycling and car availability have significant positive estimates of γ, which indicates that the influence of these outcomes increases with trip distance. The influence of the environmental impact of car use on the mode choice for non-daily shopping and the influence of the safety of car use and healthiness of cycling on mode choice for visits to green areas also come with significant positive estimates of γ. The influence of the relaxedness of cycling on mode choice for trips to green areas is associated with a negative γ, indicating that its influence decreases with trip distance.

When interpreting the results of the models, it should be acknowledged that mode choice does not necessarily correspond to choice of activity location, but this may also be the other way around. People who like to do their daily shopping by car may decide to choose a supermarket with good parking facilities.

5.4.3 Residential self-selection

Some of the beliefs about outcomes of travel mode use multiplied by their importance are significantly related to the distances to daily shops, non-daily shops and green areas (Table 5.7). Positive scores of the time-saving aspect of cycling are associated with living closer to daily and non-daily shops. Positive scores of the comfort and fun of car use and the availability of a car are associated with living greater distances from non-daily shops. This indicates residential self-selection may have taken place.

Other relationships indicate that respondents were unable to self-select. For example, the more negative their scores concerning the fun of cycling, the closer respondents lived to daily and non-daily shops. However, positive attitudes to cycling do not necessarily imply that people want to live as close as possible to an activity location. The positive relationship between the fun of cycling and the distance to daily shops may suggest that even those with a more positive attitude towards car use, prefer to cycle to do their daily shopping. It could be expected that the absence of any significant relationship concerning the distance to green areas may have been caused by respondents with a 'green' attitude who have difficulties combining their wish to live close to green areas and live in a residential location that facilitates cycling. Many of the larger green areas in the fieldwork locations are closest to car-oriented neighborhoods.

The respondents' attitudes may influence not only their residential choice, but the direction of causality could also work the other way around. Several of the significant relationships may possibly be attributed to the influence

Table 5.7 Regression analyses explaining the distances to daily and non-daily shops and green areas by beliefs about the outcomes of car use and cycling x the importance of these outcomes (of respondents who attach importance to the distance to the activity location)

	Distance to daily-shopping[a)] (supermarket)	Distance to non-daily shopping[a)] (women's clothes)	Distance to green areas[a)]
	B	B	B
(Constant)	747,716 *	692,194 *	350,082
Car_status x importance	9,194	8,625	-327,421
Car_env.-friendliness x importance	12,716 *	12,189	-75,083
Car_relaxing x importance	5,723 ***	0,739	-271,952
Car_comfortable x importance	17,904	105,805 **	-292,059
Car_time-saving x importance	6,884	5,432	-247,985
Car_flexible x importance	-8,936	-20,488 ***	380,325
Car_cheap x importance	-4,290	-4,474	-217,817
Car_fun x importance	3,374	14,480 ***	-310,140
Car_private x importance	-14,206	-1,311	772,254
Car_healthy x importance	-8,255 ***	-5,962	485,335 ***
Car_safe x importance	-0,774	4,846	226,307
Cycling_status x importance	3,297	-11,841	582,426
Cycling_relaxing x importance	-1,158	14,985	276,923
Cycling_comfortable x importance	15,830	11,804	-1,540
Cycling_time-saving x importance	-15,673 *	-27,435 *	-233,690
Cycling_fun x importance	10,848 **	11,951	-28,571
Cycling_healthy x importance	6,193	-35,670 **	-176,082
Car always available (=1, else 0)	10,587	124,621 ***	1935,429
	N = 2153	N = 964	N = 2064
	R = 0.179	R = 0.266	R = 0.069
	R^2 = 0.032	R^2 = 0.071	R^2 = 0.009
	Adj R^2 = 0.023	Adj R^2 = 0.050	Adj R^2 = 0.000

a) For an explanation of the measurement of the distance to the closest location see notes Table 5.3.

* Significant at p < 0.01 level; ** significant at p < 0.05 level; *** significant at p < 0.10 level

of the built environment on the respondents' beliefs about travel mode use. For example, traffic in inner cities is usually much more chaotic than in the suburbs, which may be the reason for the positive relationship between the fun of cycling and the distance to shops. Even more obvious is that long distances to locations will have a negative effect on beliefs about the time-saving aspect of cycling. Moreover, according to the widely recognized cognitive dissonance theory (Festinger, 1957), people are inclined to reduce any dissonance between their attitudes and their behaviour either by adjusting their behaviour or by adjusting their attitudes. Thus, if their new residential location does not correspond with their travel-related attitudes, respondents may change these attitudes.

It can be hypothized that an important reason for not being able to self-select a residential location that complies with people's travel-related attitudes is that households have preferences concerning other housing and

Table 5.8 Significant correlations between beliefs about the outcomes of car use and cycling x the importance of these outcomes and the importance of and satisfaction with housing, neighbourhood and location characteristics

	Environmental-friendliness of car use		Relaxedness of car use		Comfort of cycling	
	Correlation with importance	Correlation with satisfaction[a)]	Correlation with importance	Correlation with satisfaction[a)]	Correlation with importance	Correlation with satisfaction[a)]
House_status	0.127 *		0.089 *	0.058 **	0.055 *	
House_environment-friendliness	-0.179 *	-0.070 *	-0.041 **	-0.061 *	0.143 *	-0.086 *
House_comfortable			0.051 *	-0.058 *	0.124 *	-0.106 *
House_cheap					0.085 *	-0.098 *
House_private				-0.035 ***	0.095 *	-0.061 *
House_size		-0.057 *	0.033 ***		0.093 *	-0.058 *
House_type			0.043 **		0.105 *	
House_size garden	-0.080 *	-0.060 *		-0.070 *	0.141 *	
Neighbourhood_social safe	-0.079 *	0.032 ***	-0.048 **	-0.055 *	0.093 *	-0.058 *
Neighbourhood_traffic safe	-0.064 *		-0.032 ***	-0.049 **	0.172 *	
Neighbourhood_density				-0.033 ***	0.117 *	
Neighbourhood_population mixture			0.033 ***	-0.036 ***	0.143 *	-0.067 *
Neighbourhood_image	0.069 *		0.085 *	-0.042 **	0.139 *	-0.090 *
Neighbourhood_enough parking	0.169 *		0.120 *		0.073 *	
Neighbourhood_car infrastructure	0.186 *		0.147 *	-0.037 ***	0.041 **	
Neighbourhood_cycle infrastructure	-0.082 *		-0.069 *	-0.052 *	0.209 *	-0.082 *
Distance to work	-0.118 *		-0.063 *		0.078 *	0.068 *
Distance to school		-0.085 *			0.052 **	0.058 **
Distance to daily shops	-0.046 **	-0.061 *	-0.049 **	-0.063 *	0.100 *	0.063 *
Distance to non-daily shops		-0.073 **	-0.056 ***		0.062 *	
Distance to restaurants, pubs, etc.	0.067 *					
Distance to cultural facilities		-0.095 **				
Distance to sport facilities	-0.050 **	-0.052 ***	-0.047 **		0.113 *	
Distance to green areas	-0.121 *		-0.051 **		0.103 *	0.052 **
Distance to railway station	-0.164 *	-0.120 *	-0.178 *	-0.080 *	0.053 *	

a) Satisfaction with housing, neighbourhood and location characteristics only concerns the respondents who attach importance to the characteristic.

* Significant at $p < 0.01$ level; ** significant at $p < 0.05$ level; *** significant at $p < 0.10$ level

neighbourhood characteristics that are difficult to satisfy in combination with their travel-related attitudes, because of limited housing opportunities. Households will probably not find all of their preferred travel-related, neighbourhood and housing characteristics combined in one house and its location. Table 5.8 gives an example of how the environmental-friendliness and relaxedness of car use and the comfort of cycling, which are significantly related to mode choice in the logit models in the previous subsection, may interfere or coincide with preferences for housing and neighbourhood characteristics.

Respondents who value environment-friendliness and belief car use is not environment-friendly also attach importance to 'green' and 'leftist' housing

priorities relating to neighbourhood and location characteristics. The more negative the respondents' score of the environmental-friendliness of car use the less importance they attach to the image of their neighbourhood, parking spaces, car infrastructure and the distance to restaurants and pubs, etc., and the more importance they attach to such aspects as the environmental-friendliness of their house, the size of their garden and the distance to green areas, a railway station and daily shops. It appears that these respondents are relatively often unable to self-select with respect to an environmentally friendly house and house- and garden size of their choice. However, they are relatively satisfied with the distance to activity locations.

Respondents with positive scores of the comfort of cycling seem to self-select on the distance to activity locations. These distances are relatively important to them and they are relatively more often satisfied with them, while their satisfaction with the characteristics of their housing is relatively low. For respondents with a more positive score of the relaxedness of car use, the distance to the activity locations is less important. They are less satisfied than others about all the types of characteristics that were included in the analyses. However, as far as housing characteristics are concerned, only a few relationships are significantly negatively related and these correlations are not very strong either.

5.4.4 Household characteristics and changes to them over time

The multiple regression analyses in Table 5.9 show the influence of socio-demographic and lifestyle characteristics on three beliefs about travel mode use that are expected to be influenced by socio-demographic and lifestyle characteristics. To analyse the effect of household variables in more detail, in these regression analyses beliefs about the outcomes of travel mode use and the importance of these outcomes are analysed separately.

Most socio-demographic variables are significantly related to several of the attitudinal variables. The strongest relationships are positive relationships between age and the importance of environmental-friendliness and between gender and the relaxedness of car use and a negative relationship between being highly educated and the environmental-friendliness of car use. Our results support the hypothesis put forward in the introduction that examining lifestyle orientation adds to our understanding of attitudes towards travel characteristics by socio-demographic variables. For example, having children and the orientation towards having children are both significantly related to the evaluation of the environmental-friendliness of car use.

Some of the other significant positive relationships between lifestyle orientation and the attitudinal variables occur between the importance of having a career, a partner and a nice home and the importance attributed to time-sav-

Table 5.9 Regression analyses of the influence of lifestyle orientation, household composition and other socio-demographic variables on beliefs about the outcomes of car use and cycling and the importance of these outcomes

	Cycling time-saving	Importance of time-saving	Car environment-friendliness	Importance of environment-friendliness	Car relaxedness	Importance of relaxedness
Lifestyle orientation						
Having children	0.033	0.016	-0.054 **	0.154 *	-0.006	0.111 *
Having a career	-0.008	0.053 **	0.066 *	0.050 **	0.063 *	0.014
Having a partner	-0.015	0.065 *	0.029	-0.036	0.051 *	0.011
Having a nice home	-0.000	0.149 *	0.040 ***	-0.034	0.054 *	0.117 *
Leisure time out of home	0.006	-0.004	-0.040 **	0.064 *	-0.040 *	0.066 *
Leisure time in home	-0.011	0.057 *	-0.002	0.023	0.009	0.030
Socio-demographic variables						
Age 1 January 2005	0.028	-0.114 *	-0.007	0.239 *	-0.106 *	0.047 ***
Dummy gender (male = 1)	-0.055 **	-0.068 *	0.078 *	-0.102 *	0.147 *	-0.013
Dummy partner (yes = 1)	-0.002	-0.020	-0.047 **	-0.015	-0.084 *	-0.016
Child (yes = 1)	0.018	-0.024	-0.043 ***	-0.032	0.050 **	-0.014
Low education (yes =1)	-0.004	-0.031	0.058 *	-0.016	0.033	0.018
High education (yes =1)	0.009	-0.006	-0.143 *	0.010	-0.070 *	-0.051 **
Income < average income (yes =1)	0.035	-0.049 **	-0.043 ***	0.063 *	-0.003	-0.003
Income > 2 x average income (yes =1)	-0.048 **	0.036 ***	0.051 **	-0.058 *	0.031	-0.010
Paid work part-time (yes =1)	-0.018	0.025	-0.074 *	0.026	-0.025	-0.003
Paid work full-time (yes =1)	-0.090 *	0.096 *	-0.057 ***	-0.001	-0.007	0.000
	R = 0.175	R = 0.280	R = 0.270	R = 0.319	R = 0.245	R = 0.222
	R^2 = 0.031	R^2 = 0.078	R^2 = 0.073	R^2 = 0.102	R^2 = 0.060	R^2 = 0.049
	Adj. R = 0.024	Adj. R = 0.073	Adj. R = 0.067	Adj. R = 0.096	Adj. R = 0.054	Adj. R = 0.044

* Significant at p < 0.01 level; ** significant at p < 0.05 level; *** significant at p < 0.10 level

ing, the relaxedness of car use and the environmental impact of car use. An increase in the importance of these life roles may thus lead to increased car use.

Again, the results indicate that a positive attitude to car use coincides with more importance attached to the house; one of the strongest links is that between the importance attached to having a nice house and the importance attached to the relaxedness of travel, while having a nice house is also significantly positively related to the evaluation of the relaxedness of car use.

In the survey, the respondents also had to indicate what important changes in the household they had experienced while they were living in their current home. Table 5.10 relates these changes to mismatches concerning the distance to activity locations. Of all respondents, 82 percent experienced a significant change in their household. Changes in household and individual characteristics may cause related changes in travel-related attitudes and beliefs. As a result, people may become mismatched concerning the distance to activity locations. Table 5.10 confirms that some of the socio-demographic changes analysed are related to an increase in mismatches, indicating that respond-

ents who possibly self-selected their housing location become mismatched after a change in circumstances. Nevertheless, some changes are accompanied by an increase in the percentage of respondents who are matched. For example respondents who had a child after their last move are less often mismatched concerning the distance to cultural facilities, compared to respondents with children who did not have another child after their move. Divorced or separated respondents are less often mismatched concerning the distance to green areas than respondents who did not live with a partner when they moved.

Changes following a residential move most often seem to increase the percentage of respondents with a mismatch in relation to the distance to work. Moving in with a partner may mean that people are less willing to spend time travelling to work. The increase in mismatches after a job change indicates that respondents are not always able to self-select with respect to their work location, while if they plan a residential move they more often find a house suitably close to work. It is notable that respondents with fewer cars in their household than before they moved are less often mismatched in their new location than others. Satisfaction with distances to activity locations may have led them to decide that fewer cars were required and that other travel modes were available. Satisfaction with the distance travelled to work may also influence the decision to work more. Respondents whose number of working hours increased are less often mismatched concerning the distance to work.

5.5 Conclusions and recommendations

The main aim of this paper was to analyse the relationship between attitudes towards travel behaviour, distances from home to activity locations and travel mode choice. The main contribution to the literature is a more in-depth analysis of the role of travel-related attitudes, given by explicitly including beliefs about outcomes of travel mode use that underlie attitudes towards mode use. Moreover, while the majority of empirical studies use data collected in the US, these analyses are based on data collected in Europe, namely in the Netherlands. Knowledge on beliefs about outcomes of travel mode use can be used in spatial planning that aims to facilitate travel preferences and/or encourage sustainable travel behaviour.

The results show that the residential location of many of the respondents does not comply with some of their location preferences. Of all of the respondents who attached importance to the distance to a given activity location, 10 to 25 percent – depending on the type of activity location – were not located within a distance they were satisfied with and thus they were mismatched. Such a mismatch often leads to a change to a less preferred travel

Table 5.10 Percentage of respondents with change in household situation after residential move and percentages with mismatch concerning the distance to activity locations

		% With change	% Mismatch distance to work	% Mismatch distance to school	% Mismatch distance to daily shopping
Other job[a)]	Yes	41.6%	24.1% *		
(N = 2047)	No	58.4%	18.9% *		
More hours paid work[a)]	Yes	17.9%	17.2% *		4.1% **
(N = 2047)	No	82.1%	21.9% *		6.7% **
Less hours paid work[a)]	Yes	18.5%			
(N = 2047)	No	81.5%			
Partner moving in[b)]	Yes	7.3%	23.0% *		
(N = 2451)	No	92.7%	15.6% *		
Divorcec)	Yes	24.2%			
(N = 282)	No	75.5%			
Birth of child[d)]	Yes	51.4%			
(N = 1589)	No	48.6%			
Last child left home[e)]	Yes	28.0%	8.4% *		1.9% *
(N = 1144)	No	72.0%	17.1% *		6.3% *
More cars in household	Yes	20.2%	19.8% *	8.3% *	
(N = 2733)	No	79.8%	15.4% *	5.6% *	
Less cars in household	Yes	7.8%			
(N = 2733)	No	92.2%			

a) Respondents with a paid job, b) Respondents with a partner, c) Respondents without a partner,
d) Respondents with a child at home, e) Respondents without a child at home
* Significant at $p < 0.05$ level, ** significant at $p < 0.10$ level

mode and, with respect to trips to locations for less regular activities, trip frequencies often decrease.

Binomial logit models that explain mode choice by beliefs about outcomes of travel mode use and car availability confirmed our assumption that the influence of some beliefs differ according to trip distance and trip purpose. The significant correlations that were found between beliefs about the use of travel modes and the importance attached to and satisfaction with housing, neighbourhood and location characteristics imply that mismatches between travel-related preferences and residential locations can partly be attributed to the fact that some respondents have travel-related preferences and others housing, neighbourhood and location preferences that are difficult to combine in one residential location. An obvious 'underlying' attitude that could be identified is a 'green' attitude: people who evaluate car use as very environmentally unfriendly attach relatively more importance to having a large garden, having an environmentally friendly house and to the distance to green areas and railway stations, and they are relatively often mismatched or less satisfied concerning most housing characteristics, including the size of their garden and the environmental-friendliness of their house.

The multiple regression models that link lifestyle orientation and socio-

% Mismatch distance to non-daily shopping	% Mismatch distance to restaurants, pubs. etc.	% Mismatch distance to cultural facilities	% Mismatch distance to sport facilities	% Mismatch distance to green areas	% Mismatch distance to railway station
3.4% *					
6.2% *					
				1.4% **	
				7.5% **	
		3.2% **			11.0% **
		5.4% **			14.0% **
	2.2% *	4.1% *			7.2% *
	6.1% *	8.5% *			13.2% *
4.4% *			4.5% **		
6.8% *			6.5% **		
3.8% **	1.4% **			12.2% *	8.5% **
6.5% **	4.1% **			6.8% *	12.4% **

demographic variables to some beliefs about travel mode use also show significant relationships and confirm our hypothesis that lifestyle orientation, for example the importance of having children or a career, adds to the explanation of attitudes by socio-demographic variables.

The analyses of changes to households some time after residential choice show that residential self-selection may only temporarily result in a match between attitudes and location and could become a mismatch. A large majority of all respondents experienced important household changes, such as a change of job, having children and buying additional cars, after their last residential move. Often such changes will have consequences, possibly leading to a mismatch with respect to the distance to activity locations. People may also self-select in anticipation of future changes such as having children, which implies that they may be temporarily mismatched.

5.5.1 Relevance to spatial planning

The results indicate that spatial planning which aims to increase the sustainability of travel behaviour could benefit from more in-depth, low-scale data. Spatial planning may become more effective if it is known better which peo-

ple can be tempted by which changes in the characteristics of travel mode use and trip distance to use a more sustainable travel mode. The development of new neighbourhoods with specific combinations of housing, neighbourhood and location characteristics that meet most of people's preferences can help increase the sustainability of travel behaviour and neighbourhoods. If households that are inclined to cycle or walk find the ideal house in a car-oriented neighbourhood, they will use their car far more often than if they lived in the same house in a walking and cycling-oriented neighbourhood. In the Netherlands there are a number of neighbourhoods built according to a sustainable design and with a reduced number of parking spaces that, nonetheless, because of other housing characteristics especially attracted car-oriented households. As a consequence, the streets of these neighbourhoods are now filled with cars.

5.5.2 Recommendations for future research

Firstly, the results emphasise the importance of the collection and use of longitudinal data in research on residential self-selection and travel behaviour. A majority of the respondents experienced important socio-demographic changes while living at the same residential location. It appears that these changes have meant that some former matches achieved through residential self-selection have become mismatches, and vice versa. The significant relationships between socio-demographic and lifestyle characteristics and beliefs about travel mode use indicate that these changes may influence travel-related attitudes and therefore the existence of mismatches concerning travel behaviour. The use of current attitudes, socio-demographic characteristics, travel behaviour and characteristics of the built environment – as in most residential self-selection studies – implies that self-selection cannot be reliably determined.

Secondly, the results suggest that trip distance and trip purpose influence beliefs about outcomes of travel mode use and their importance for travel mode choice. If these beliefs are measured specifically for each different trip purpose (e.g. measuring the comfort of cycling to the supermarket rather than measuring the comfort of cycling in general), for different distances and beliefs related to walking are also measured, better recommendations can be obtained concerning which people choose which mode in which circumstances.

Finally, this paper did not address the interaction between people within a household and it might be expected that the mismatches concerning travel-related preferences and residential locations can be partly attributed to the different preferences of the partners in relation to housing, neighbourhood and/or location and other travel-related characteristics. To the authors' knowledge, at present there is no empirical research on the role of residential self-selection and travel behaviour that includes the interaction between partners.

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6 Conclusions and discussion

6.1 Introduction

Travel behaviour research suggests that the location and spatial structure of residential areas have at least some influence on peoples' travel behaviour. Nevertheless, the extent of the influence is heavily debated. One of the issues in the debate is the assumption that the spatial policy applied in the development of residential areas may influence travel behaviour. However, the relationship between the built environment and travel behaviour is very complex, and studies or spatial planning that do not take into account important mediating factors may either overestimate or underestimate the influence of the built environment on travel behaviour.

This thesis addressed one of the most important mediating factors, namely residential self-selection with respect to travel-related characteristics of the built environment. Households may not only adjust their travel behaviour to the characteristics of the built environment but may also choose to move to a residential location that complies with their travel-related attitudes. Several studies have found evidence that residential self-selection has an impact on travel and thus should be accounted for in travel behaviour studies. However, because the scope of these studies varies due to their focus on different attitudes, various characteristics of the built environment and travel behaviour, and also due to the different methodologies used, comparing the results of these studies and deriving general conclusions about residential self-selection is very difficult. Moreover, as addressed by Cao *et al.* (2009) in their extensive review, most studies do not compare the influence of self-selection and the built environment on travel behaviour. It can be argued that the ambiguity of the results is partly due to the fact that the studies do not address all of the important mediating factors and relationships.

This thesis examined the relationship between travel-related attitudes, travel behaviour and residential location choice, as this is crucial to identify the factors involved in residential self-selection. Social-psychological theories and some travel behaviour studies suggest that travel-related attitudes not only influence travel behaviour and residential choice, but also that travel behaviour and the characteristics of the built environment of the residential location will also influence peoples' travel-related attitudes. To the authors' knowledge, all of the self-selection studies that explicitly include attitudes have used cross-sectional data and most have only considered the influence of attitudes on behaviour and not the reverse. Consequently, the relationship between attitudes and behaviour, as found in the literature, has not been adequately addressed, as the influence of behaviour on attitudes may also be important. Furthermore, this thesis also addressed the measurement of attitudes in self-selection studies. These measurements have received little attention; however, they are of crucial importance if they are used to identify the factors involved in residential self-selection.

Overall, this thesis aimed to improve the understanding of the role of travel-related attitudes in residential self-selection and in turn the latter's impact on the relationship between the built environment and travel behaviour. Therefore, the central research question of the thesis was:

To what extent does residential self-selection affect travel behaviour – and can this effect be identified by estimating the impact of travel-related attitudes on travel behaviour that is otherwise due to the characteristics of the built environment in the residential location?

The thesis consists of one theoretical, one methodological and two empirical papers. Two have been published in peer-reviewed journals, one is conditionally accepted (the resubmitted version is included here), while the other paper is currently under review. The analyses in the empirical chapters are based on data that was collected through an internet survey in 2005 and a GPS-based survey in 2007. These surveys were conducted among homeowners in ten districts of Amersfoort, Veenendaal and Zeewolde, three municipalities located in the centre of the Netherlands. This chapter summarises the findings of the four papers. Subsequently, the general conclusions are discussed in relation to the research questions. This chapter also includes some reflections on the findings and implications for further research.

6.2 Overview of the results

In this section the results of the four papers are discussed in relation to the four secondary research questions that were formulated.

1. How can travel-related attitudes best be included in research into the role that residential self-selection plays in the relationship between the characteristics of the built environment and travel behaviour?
The review of travel-related attitudes in travel behaviour research as well as social-psychological and travel behaviour theories in Chapter 2, identified several mediating factors and relationships that are highly relevant, but rarely receive attention in the modelling of residential self-selection. These are the 'reverse' influence of behaviour on attitudes, the compatibility of the aggregation levels of the behavioural and attitudinal variables included, and the relevance of perceptions and habits. It is suggested that previous studies of residential self-selection have over or underestimated its role in the relationship between the built environment and travel behaviour. The empirical studies in Chapters 4 and 5 focused on two of these factors.

First, as will be further discussed in relation to research question 3, it was found that travel behaviour and the built environment influence travel-relat-

ed attitudes. Moreover, after testing the 'reverse' influence of built environment characteristics and travel behaviour on travel-related attitudes, residential self-selection effects largely disappeared. Thus, these results show that models which assume a unidirectional influence of attitudes on travel behaviour through residential location choice may overestimate the role of residential self-selection.

Second, the structural equation models in Chapter 4 also suggest that residential self-selection can best be identified when the aggregation levels of attitudes and behaviour are compatible. Attitudes towards public transportation and car use have no direct influence on the distance of the household to the nearest railway station, but the results do show that there is a direct influence of the importance attached to the distance to the nearest railway station. As argued by Ajzen and Fishbein (1977), if attitudes and behaviour are measured at different aggregation levels this may cause links between them to remain undetected. Consequently, analyses that include attitudes and behaviour at different aggregation levels may underestimate the role of residential self-selection. The best results are obtained if the action, target, context and time are measured with the same degree of specificity or generality.

The second part of Chapter 2 discussed the measurement of attitudes. Because attitudes are latent psychological constructs, their measurement is indirect, and various choices have to be made about what items to include, the number of items and which response scales to use. Several consequences of these decisions have to be considered: the validity and reliability of the measurement, the value of addressing the multiple underlying dimensions of an attitude and the length of the survey in relation to the response. The review of self-selection studies showed that a large variety of measures are used and that despite the need for careful consideration, little explanation of the choice of measurement methods is given.

The analyses in Chapter 5 revealed that multi-item indirect measures do add to the understanding of residential self-selection mechanisms. Beliefs about the outcomes of travel mode use that underlie attitudes towards travel mode use (such as the time-saving and comfort aspects of cycling), have different impacts on the relationship between distances to activity locations such as green areas and shops and the travel mode choice. An advantage of indirect measures in comparison to direct measures is that underlying aspects are taken into account. However, many of the studies reviewed used exploratory factor analysis to construct attitudinal factors, clustering diverse items into one factor. Subsequently, these items are hardly referred to in the description of the analyses. This reduces the benefit of using multi-item measures.

Probably the most important shortcoming in residential self-selection studies is that they only measure attitudes at one moment in time. The empirical analyses of Chapters 4 and 5 subscribe to the idea that both current atti-

tudes and attitudes at the moment of residential choice must be measured. It is commonly known from social psychology that while current attitudes are difficult to measure, reconstructions of attitudes from the past are even less reliable.

2. How can GPS technologies be implemented to improve the reliability, efficiency and spatial and temporal detail of the measurement of travel behaviour?
To collect the travel behaviour data that was needed for the empirical analyses in this thesis, a GPS-based data collection method was developed that can be used for collecting data on travel times and distances, travel modes and trip purposes. Evaluations suggest that when state-of-the-art GPS data loggers are used, the method can collect more accurate data than with conventional methods such as paper diaries, while limiting the burden on the respondents.

The method developed consists of an interpretation and a validation process. Three data sources are combined in the interpretation process: GPS logs, individual characteristics of the respondents and GIS data concerning the location of facilities and railway infrastructure. In the interpretation process, trip characteristics are reconstructed using several algorithms and then utilised in the validation process.

The interpretation process relates the GPS logs to GIS data to determine trip characteristics. Travel times and distances are derived directly from the positions and times recorded in the logs. However, determining travel modes and trip purposes is more complex. To lower the burden on the respondent and to avoid unreliable results due to respondents not being able to recall their behaviour, the aim was to derive as much data as possible from the GPS logs before asking the respondents to validate and adjust the data. For example, we used speed and distance to railways to calculate the probable travel mode use. The distance to facilities from home and work addresses were used to asses trip purposes. An option that is scarcely discussed in the literature is the use of individual characteristics such as household composition, possession of travel modes and home and work addresses as input for algorithms that derive trip characteristics from GPS logs. Our method uses the coordinates of home and work addresses.

In the web-based validation application, the data derived are presented to the respondents in maps and tables. At this stage, the respondents can correct and add to the derived trip characteristics. The link with the interpretation process is interactive and the new information that is provided by the respondents, such as the location of the homes of friends and family, is used for further interpretations.

The evaluation survey that was conducted among the participants of the GPS fieldwork showed that the participants did not consider that carrying and recharging the GPS device was a burden, and they were enthusiastic about viewing their trips on the maps of the validation application. The majority

of respondents were able to go through the validation application within a reasonably short period of time. The comparison with data from the national travel survey showed that the GPS-based method was able to record a larger number of trips. This indicates that fewer trips were overlooked.

The evaluation of the fieldwork also showed that there is room for further improvements. Firstly, far better quality GPS devices are now available than were used in the fieldwork in 2007. In particular, the device did not operate well inside trains and respondents had to remember to recharge their GPS data logger every night. Size, battery life and the satellite reception of GPS devices have improved greatly since then. The method is dependent on the quality of the GPS data loggers used. Secondly, although the majority of the respondents did not face huge problems, some did struggle, especially those with very few computer skills, old computers or complicated travel behaviour. By fine-tuning the algorithms that were used, in combination with GPS logs from improved GPS devices, the validation effort of the respondents can be lowered. For example, algorithms could be constructed that compare trips of the same respondents on different days.

3. To what extent does residential self-selection influence the relationship between characteristics of the built environment and travel behaviour?

The structural equation models in Chapter 4 show a small effect of residential self-selection concerning the distance to activity locations on travel mode use and daily kilometres travelled.

Chapter 4 analyses the effect of residential self-selection on the relationship between built environment characteristics and travel behaviour by estimating four structural equation models. These models were estimated to explain daily kilometres travelled and the daily percentage of trips travelled by car as a result of travel-related attitudes and distances to activity locations. Daily kilometres travelled and the daily percentage of trips travelled by car were measured with the GPS-based data collection method. To evaluate the effect of including causality in both directions, two models were estimated with, and two models without, an assumed influence of travel behaviour and distance to activity locations on the travel-related attitudes.

The models with only one direction of causality show that the importance that respondents attach to the distance from their home to green areas, a city centre and a railway station significantly affects the distance of their residence to these activity locations and therefore suggests that the respondents self-selected on this basis. Positive attitudes towards car use and positive attitudes towards public transportation have respectively positive and negative influences on the distance to a railway station, due to the importance attached to that distance in each case.

As discussed in relation to research question 1, in the models that include the 'reverse' influence of the distances to activity locations and travel behav-

iour on attitudes, residential self-selection largely disappears and the effects of built environment characteristics appear. This indicates people were less able to self-select and had adjusted their attitudes to the characteristics of the built environment in their residential location. In particular, there is a strong negative influence of distance to the railway station on attitudes towards public transportation. The only significant relationship that suggests residential self-selection did take place is that between the importance of the distance to cultural facilities and the distance to a city centre. It should be noted that results concerning the direction of casualty should be interpreted conditionally, because no panel data were used and therefore changes in attitudes, travel behaviour and built environment characteristics are not properly accounted for.

The effect of self-selection on travel behaviour is also limited because residential self-selection itself is limited. In the models with unidirectional causality, the largest self-selection effect is the positive effect of attitudes towards car use on the relative number of car trips, related to self-selection concerning the distance to a city centre. In the extended models, the largest indirect effects are not self-selection effects, but the effects that the distance to activity locations in relation to attitudes towards public transportation had on car trip share. Thus, the built environment not only influences travel behaviour directly but also indirectly through attitudes.

After accounting for the residential self-selection effects, the built environment characteristics included in the models still significantly influence one or both of the dependent travel behaviour variables. Moreover their influence is much stronger than the residential self-selection effects. In line with other studies, the strongest influence is the positive influence that the distance to a city centre has on car trip share.

4. To what extent is residential self-selection explained by socio-demographic characteristics, lifestyle orientation, attitudes towards housing and the neighbourhood in residential choice, and beliefs that underlie travel-related attitudes?

Chapter 5 revealed that beliefs about the outcomes of travel mode use that underlie attitudes towards mode use, socio-demographic variables, lifestyle orientation and attitudes towards housing and neighbourhood all contribute to the explanation of residential self-selection concerning distances to activity locations.

First, binomial logit models that explain mode choice (walk/cycle or car) in terms of beliefs about the outcomes of cycling and car use (such as the environmental unfriendliness of car use and the flexibility of cycling) confirmed the assumption that the influence of some of the beliefs concerning travel mode use differs according to trip distance and trip purpose.

Second, analyses of the correlations between beliefs about travel mode use and the importance of and satisfaction with housing, neighbourhood and

location characteristics show that some respondents may be mismatched concerning their travel-related preferences because they attach greater importance to other housing, neighbourhood and location characteristics which cannot be found in one residential location. An obvious 'underlying' attitude that could be identified is a 'green' attitude: people who evaluate car use as being very environmentally unfriendly attach relatively more importance to having a large garden, having an environmentally friendly house and the distance to green areas and railway stations. However, they did not seem to be able to self-select concerning their preferences for housing characteristics, and thus are often relatively mismatched concerning such characteristics as the size of their garden and the environmental friendliness of their house.

Third, multiple regression models show significant relationships between lifestyle orientation and socio-demographic variables and beliefs about the outcomes of travel mode use. The outcomes of travel mode use vary in importance and are evaluated differently according to household type, life-cycle and lifestyle characteristics. Furthermore, the results confirm the assumption that lifestyle orientation, for example the importance of having children or a career, adds to the explanation in terms of socio-demographic variables.

Fourth, the analyses of the effect of household changes between the time of residential choice and the time of the survey show that – contrary to what was expected – respondents who experienced a specific household change such as a change of job, having children or buying additional cars are less often mismatched concerning several of the distances to activity locations than respondents who did not experience the change.

Finally, the structural equation models of Chapter 4 also included socio-demographic variables and housing type, number of rooms and year of move. In addition to the direct effect on travel behaviour, the models also show many significant relationships between the socio-demographic variables and distances to activity locations and the attitudinal variables. Therefore, the results suggest that socio-demographic variables influence residential self-selection.

In summary, it can be concluded that the empirical analyses show there is a limited effect of residential self-selection on the relationship between distances to activity locations and travel mode use and daily kilometres travelled. However, the results should be interpreted conditionally because only cross-sectional data were used. The main aim of many of the analyses performed was to show what underlying relationships should be accounted for in residential self-selection studies, rather than identifying the role of residential self-selection itself.

As such, the empirical analyses show the importance of including the 'reverse' influence of behaviour and built environment characteristics on travel-related attitudes. This finding complies with the traditional assumption that characteristics of the built environment influence travel behaviour.

While the assumed influence of residential self-selection implies that attitudes influence the choice of certain built environment characteristics, it was found that the reverse influence is stronger. Thus if characteristics of the built environment induce changes in travel-related attitudes they can change travel behaviour not only directly but also indirectly through influencing these attitudes. In addition, this influence of behaviour and characteristics of the built environment on travel-related attitudes implies that attitudes change over time. Therefore, if changes in the built environment which are the result of residential relocation change peoples' travel-related attitudes, residential self-selection studies should measure current attitudes as well as the attitudes held at the time of residential choice. A further finding is that to determine the 'exact' role of self-selection it is important that the data on attitudes, the built environment and travel behaviour are measured at the same level of aggregation.

Regarding the explanation of the factors involved in residential self-selection, it was found that lifestyle orientation factors, such as the importance of having children, further contribute to the explanation of residential self-selection in terms of socio-demographic variables. Beliefs about the outcomes of travel mode use, such as the environmental unfriendliness of car use and the fun of cycling, influence the importance that is attached to distances to activity locations, while these distances influence mode choice through their influence on attitudes towards travel mode use. Finally, the GPS-based data collection method that was developed overcomes some previous shortcomings and has proved it performs well in comparison to handwritten diary methods. Nevertheless, significant improvements can be made if current technological developments continue and the algorithms are developed further. Recently, Biljecki (2010) improved the algorithms that divide trips into single-mode segments and that derive travel modes, by analysing the data collected for this thesis.

6.3 Reflections

This section offers a critical discussion of several issues and recommendations for further research that are related to the present research and which brings the results into a broader perspective.

First, the results strongly suggest that the reverse influence of behaviour and characteristics of the built environment on attitudes should be accounted for in studies of residential self-selection. Moreover, this implies that attitudes change over time and particularly after residential relocation. The use of attitudinal panel data therefore seems essential. Analysing such data would improve the study of the relationship between travel behaviour, characteristics of the built environment and travel-related attitudes by identify-

ing the factors involved in residential self-selection more precisely. In future research, collecting panel data and performing longitudinal analyses should be a precondition of analysing the role of residential self-selection.

Second, attitudes cannot be included without a trade-off between the need for extensive attitude measurements and for a number of other variables to be included in a questionnaire and the length and complexity of the questionnaire. If choices that are made in this regard are well explained and justified, this will benefit the further development of attitude measures. The originally broader scope of the analyses in this thesis meant a rather lengthy questionnaire, with possible consequences for the response rate and reliability of the respondents answers. As a result, several attitudinal variables were measured with only one item or scale, while for reliability reasons multiple items would have been preferred.

Third, the review of theories and the empirical results demonstrated the value of measuring attitudes and behaviour at the same aggregation level. This means that attitudes towards travel mode use should be measured more specifically in the empirical analyses of the influence of distances to specific activity locations on mode choice, namely in relation to the distance to the specific activity location. The analysis of beliefs about the outcome of travel mode use reveals that the influence of beliefs changes depending on the distance to activity locations and activity location types. One of the few examples of matching attitudes and behaviour is the residential self-selection study by Cao *et al*. (2006), which was able to identify the role of residential self-selection by analysing the importance of having shops within walking distance, residential location choice (miles to the nearest shop) and travel behaviour (frequency of walking trips to a shop).

Fourth, another issue that needs further exploration is the role of habits and perceptions. Many studies have shown the significant role of habits in travel behaviour (Verplanken *et al*., 1997; Gardner and Abraham, 2008). Therefore, it can be assumed that habits are also of importance in residential self-selection analyses. Travel habits that developed at a previous residential location may temporarily persist at a new location, meaning that new travel opportunities are not recognised. After a residential move, new habits can develop that affect the relationship between travel-related attitudes and travel behaviour. The few studies that have included perceptions of the characteristics of the built environment found that they influence travel behaviour in addition to actual characteristics of the built environment.

Fifth, the selective sample of homeowners means that certain socio-demographic characteristics of the Dutch population as a whole were underrepresented. An interesting aspect of Dutch travel behaviour compared to that in the United States, where most studies are conducted, is that both the people and the built environment are less car-oriented. However, in the sample used in this thesis, car ownership is relatively high, with almost every respondent

belonging to a household with at least one car and a majority with one car per person. Therefore, the role and effect of residential self-selection by households without a car could not be assessed. Several studies have shown the significant mediating role of car ownership in the relationship between the built environment and travel behaviour (Maat and Timmermans, 2009; Simma and Axhausen, 2003; Van Acker, 2010). The results of this thesis also indicate that characteristics of the built environment influence car ownership.

Sixth, the sample was restricted to homeowners because of their assumed greater freedom within the housing market compared to renters, and therefore their greater ability to self-select concerning travel behaviour. In this phase of the research on self-selection, focusing on groups with greater opportunities to self-select seemed likely to deliver the greatest insight into self-selection mechanisms. However, an interesting future direction of research would be the effect of restrictions on the rental market on peoples' ability to self-select and the effects of travel-related mismatches that result from these restrictions. Moreover, such a focus would also imply the study of the behaviour of less educated households. It would be interesting to analyse the effect of restrictions on the rental market by comparing homeowners and renters in future travel behaviour studies.

Seventh, future research should address the interaction between individuals within the household. To the authors' knowledge, at present there is no empirical research on the role of residential self-selection and travel behaviour that includes the interaction between partners. However, studies on residential choice and travel behaviour have revealed that partners and household interaction affect both (Ettema *et al.*, 2007; Maat and Timmermans, 2009). Therefore, it might be expected that individual mismatches between travel-related preferences and residential locations can be partly attributed to differences in the preferences of partners in relation to housing, neighbourhood and/or location and other travel-related characteristics.

Eighth, an issue that was not addressed in the analyses is self-selection concerning work locations. If people have a paid job they usually move to a residential location within reasonable travel time of the job location, and when looking for a new job they will take into account the amount of travel from their home to the work location (Maat and Timmermans, 2009). However, little is known about peoples' willingness to change jobs due to a residential relocation or their willingness to move because of new job opportunities and especially the effect of these factors on self-selection mechanisms concerning travel to work: to what degree do people self-select a work location that they are able to reach by their preferred travel mode and within their preferred travel time. As argued by Salomon (1982), residential location and job location are interrelated mid-term decisions. Therefore, it is recommended that they are analysed simultaneously.

Finally, there may be some criticism of the relatively large effort that was put

into the development of the GPS-based data collection method. Nonetheless, the evaluation of this method reveals that it does measure travel behaviour more accurately than more conventional methods. The future of GPS-based data collection is promising and current technological developments promise even better performance of such methods. The introduction of the European equivalent of GPS Galileo (expected in 2013) will double the number of satellites that can be used to determine coordinates, while major improvements are also being made in the integration of GPS, mobile phones and the internet.

6.4 Policy recommendations

The previous section offers numerous directions for further research. Due to the limited scope of the empirical analyses and their exploratory character, the emphasis of this final chapter is on methodological recommendations rather than policy recommendations. Nonetheless, a few recommendations for spatial policy can be formulated.

Before discussing these recommendations it is important to acknowledge that this study found only limited evidence of a role being played by residential self-selection in the relationship between the distances to activity locations and travel behaviour. Nonetheless, the results of this dissertation reveal underlying aspects of residential self-selection that could be relevant for spatial planning.

First, spatial planning that aims to influence travel behaviour will be most successful if it takes into account differences between specific groups of the population in terms of their preferences for housing and neighbourhood characteristics and their travel-related attitudes. More tailored policies can avoid situations such as that described in the introduction to this thesis, where a newly built residential area in Amersfoort, the Netherlands, with limited parking space, attracted car-oriented households with a high level of car ownership. If it had been known beforehand that in spite of the environmentally friendly character of the residential area, the neighbourhood and housing characteristics would attract car-oriented households, more parking space could have been planned and the current parking problems would have been avoided. The results of this thesis show that travel-related attitudes and attitudes towards housing and neighbourhood characteristics are significantly related to socio-demographic and lifestyle characteristics, therefore these individual and household characteristics can be used to divide the population into segments that can be used in spatial policy. Walker and Li (2007) have already shown that respondents can be segmented according to their travel and housing choices, while Redmond (2000) used lifestyle and socio-demographic variables to segment the population based on their travel behaviour.

By tailoring policies to segments of the population, national, regional and local authorities can avoid investing in slow mode and public transport infrastructure in areas that predominantly attract car-oriented households. To reduce congestion and improve accessibility, these car-oriented households should also be provided with easy access to motorways and sufficient parking spaces, amongst other measures. Moreover, households that prefer public transportation or slow modes, or only slightly prefer car use, should be able to self-select to areas that support the use of public transportation, walking and cycling. This can be done using information about what housing and neighbourhood characteristics they prefer. Moreover, this thesis and studies by Iacono *et al.* (2008) and Scheiner (2009) provided evidence that detailed information about the influence of distances and trip purposes on mode choice is crucial. If it is known at what distances and for what purposes a specific segment of the population will consider using a mode other than the car, spatial planning could take this threshold into consideration. For example, Iacono *et al.* (2008) found that in the US the often used standard threshold of a quarter of a mile as the walking distance for several trip purposes is exceeded by many people.

The second policy recommendation is related to the first. The results suggest that limitations in the housing market at the time of residential choice mean households cannot self-select. In the past decades in the Netherlands, new houses were predominately built in large, newly developed residential areas, which implied that a large part of the available housing shared the same built environment characteristics (e.g. distance to the city centre or to a railway station). It is recommended that the spatial and temporal dimensions involved in building residential areas should be expanded, because this will increase the opportunities for households to self-select. The recent Dutch trends of creating housing within urban areas will provide more diversity and thus greater choices.

Third, the results suggest that characteristics of the built environment have a stronger influence on travel-related attitudes than the other way around. This implies that spatial planning can influence travel behaviour by influencing peoples' travel-related attitudes. This thesis found that shorter distances to railway stations lead to a decrease in the share of car trips, through the positive effect on attitudes towards public transportation, meaning that more accessible public transportation may seduce people into reducing their car use. The current trend in the Netherlands is to redevelop areas close to railway stations into attractive, high-density housing areas and this seems promising, considering these results. However, planners should be careful when changing existing characteristics of the built environment because households do self-select to some degree. For example, if a railway station is opened in a residential area that was developed ten years earlier, the effect on mode choice may be limited due to the fact that the area did not attract public transport-oriented households in the first place.

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Samenvatting

Woonlocatiekeuze, zelfselectie en verplaatsingsgedrag

De relatie tussen attitudes ten opzichte van verplaatsingsgedrag, ruimtelijke kenmerken van de woonlocatie en verplaatsingsgedrag

Wendy Bohte

Inleiding

In de meeste Westerse landen wordt bij de ontwikkeling van woonlocaties in zekere mate rekening gehouden met het effect dat de ruimtelijke kenmerken en situering van deze locaties hebben op het dagelijks verplaatsingsgedrag van de bewoners. Het verbeteren van de bereikbaarheid vanwege de economie, de uitputting van fossiele brandstoffen en het verminderen van de uitstoot van koolstofdioxide zijn voor overheden belangrijke redenen om het dagelijks verplaatsingsgedrag te willen beïnvloeden.

Nederland is waarschijnlijk sinds decennia het land met de meest duidelijke mobiliteitsdoelen in het ruimtelijke ordeningsbeleid. In de jaren negentig leidde de *Vierde Nota over de Ruimtelijke Ordening Extra* (1991) onder meer tot de ontwikkeling van de zogeheten VINEX-locaties. Deze grootschalige nieuw ontwikkelde woongebieden liggen binnen of aansluitend aan middelgrote tot grote steden en hadden onder andere als doelstelling een goede bereikbaarheid per fiets en openbaar vervoer te bieden. Wonen, werken en gebruik van dagelijkse voorzieningen dienden zich binnen de stadsregio af te spelen om mobiliteit te beperken en landelijke gebieden te beschermen. Recent is met de *Nota Ruimte* (2004) en de *Nota Mobiliteit* (2004) het beleid meer verschoven naar het faciliteren in plaats van het reduceren van automobiliteit. Openbaar vervoer, fietsen en lopen worden nog steeds gestimuleerd, maar de focus ligt nu meer op het versterken van stedelijke netwerken door concentratie van wonen en werkgelegenheid rond knooppunten van openbaar vervoer en snelwegen.

Hoewel ruimtelijk beleid dus wordt ingezet om mobiliteit te sturen, is het echter de vraag in hoeverre dat werkt. Dat er een relatie bestaat tussen ruimtelijke kenmerken en verplaatsingsgedrag is veelvuldig aangetoond in wetenschappelijke studies. Door de complexiteit van deze relatie bestaat er echter geen eenduidig beeld van de omvang van de gevonden effecten. Verschillende aspecten beïnvloeden deze relatie en wanneer ze buiten beschouwing worden gelaten kan de invloed van ruimtelijke inrichting op verplaatsingsgedrag onder- of overschat worden.

Dit proefschrift onderzoekt de invloed van verplaatsingsvoorkeuren via de woonlocatiekeuze op verplaatsingsgedrag, in de wetenschappelijke discussie doorgaans aangeduid met residentiële zelfselectie. Huishoudens zullen hun

verplaatsingsgedrag niet alleen aanpassen aan de mogelijkheden van hun nieuwe woonlocatie, maar bij de keuze van een nieuwe woonlocatie ook rekening houden met de verplaatsingen die ze vanuit hun woning willen maken. Mensen die graag autorijden, zullen bijvoorbeeld vaker voor een meer afgelegen ruim opgezette buitenwijk kiezen, terwijl mensen die graag met het openbaar vervoer reizen eerder in een meer stedelijke locatie in de nabijheid van een treinstation zullen gaan wonen. Anders gezegd: door middel van zelfselectie kunnen huishoudens ervoor zorgen dat de verplaatsingsmogelijkheden op hun nieuwe woonlocatie aansluiten bij de manier waarop zij zich het liefst willen verplaatsen. Als zelfselectie niet wordt meegenomen in studies naar de invloed van ruimtelijke kenmerken op verplaatsingsgedrag, zal de invloed van ruimtelijke kenmerken mogelijk overschat worden. Er zijn al verschillende onderzoeken uitgevoerd die hebben aangetoond dat zelfselectie inderdaad een rol speelt. Echter, omdat deze studies onderling vrijwel niet vergelijkbaar zijn door verschillen in focus en gebruikte methoden zijn er nog nauwelijks algemene conclusie te trekken over de mate van invloed van zelfselectie.

Om te bepalen welke factoren en relaties van belang zijn bij onderzoek naar de rol van zelfselectie, onderzoekt dit proefschrift de relatie tussen attitudes ten opzichte van verplaatsingsgedrag, de ruimtelijke kenmerken van de woonlocatie en verplaatsingsgedrag. Een attitude is een houding of mening ten opzichte van een object of onderwerp en kan zowel affectief ('ik houd van autorijden'), cognitief ('autorijden is duur'), als gedragsmatig (het rijden in een auto) zijn. Hoewel in diverse zelfselectiestudies alleen sociaal-demografische persoonskenmerken zijn opgenomen, kan het expliciet bestuderen van de rol van attitudes meer inzicht geven in de werking van zelfselectie.

Verschillende studies nemen attitudes wel expliciet op in hun analyses en uit deze studies blijkt het nut van de bestudering daarvan voor het vaststellen van de rol van zelfselectie. De analyses in dit proefschrift richten zich op een aantal aspecten die tot nu toe nog nauwelijks onderzocht zijn, namelijk de 'omgekeerde' invloed van gedrag op attitudes, het meten van attitudes en de verklaring van de rol van attitudes.

Samengevat heeft dit proefschrift als doel om het inzicht te verbeteren in de rol van attitudes bij zelfselectie via woonlocatiekeuze en in de impact van deze zelfselectie op de relatie tussen ruimtelijke kenmerken van de woonlocatie en verplaatsingsgedrag. Dit heeft geleid tot de volgende hoofdvraag:

In welke mate beïnvloedt zelfselectie via woonlocatiekeuze verplaatsingsgedrag – en kan deze invloed worden bepaald door het analyseren van de invloed van attitudes ten opzichte van verplaatsingsgedrag op ruimtelijke kenmerken van de woonlocatie en verplaatsingsgedrag?

De resultaten van het onderzoek zijn beschreven in een theoretisch hoofdstuk, een methodologisch hoofdstuk en twee empirische hoofdstukken. De

empirische analyses richten zich op zelfselectie via woonlocatiekeuze ten aanzien van de afstand tot activiteitenlocaties, zoals de afstand tot groengebieden en winkels. Om de interactie tussen attitudes, ruimtelijke kenmerken en verplaatsingsgedrag juist te kunnen analyseren is het meten van deze factoren van groot belang. Daarom is er in dit onderzoek veel aandacht besteed aan de dataverzameling. Ten eerste wordt er, zoals al eerder is beschreven, veel aandacht besteed aan het meten van attitudes en ten tweede is er een nieuwe methode ontwikkeld voor de verzameling van verplaatsingsdata. Deze methode combineert de mogelijkheden van GPS, GIS en internet en is uitgebreid beschreven in hoofdstuk 3.

De data zijn verzameld in drie gemeenten in het midden van Nederland: Amersfoort (137.000 inwoners), Veenendaal (61.000 inwoners) en Zeewolde (19.000 inwoners). In 2005 hebben bijna 4.000 respondenten een internetenquête ingevuld met onder andere vragen over attitudes ten opzichte van verplaatsingsgedrag, woonlocatiekeuze, leefstijloriëntatie en persoonskenmerken. Het tweede deel van het veldwerk vond plaats in 2007. Met de GPS- dataverzamelingsmethode is toen het verplaatsingsgedrag van 1.200 van de respondenten een week lang geregistreerd.

Resultaten

In hoofdstuk 2 wordt besproken welke theorieën over attitudes en gedrag kunnen bijdragen aan studies naar zelfselectie via woonlocatiekeuze betreffende verplaatsingsmogelijkheden. Daarnaast worden er een overzicht en evaluatie gegeven van studies over woonlocatiekeuze, zelfselectie en verplaatsingsgedrag die expliciet attitudes analyseren. Uit deze studies komt duidelijk naar voren dat zelfselectie van invloed is op verplaatsingsgedrag en ook dat de bestudering van attitudes bijdraagt aan het inzicht in zelfselectie. Echter, als gevolg van de beperkte beschikbaarheid van data over attitudes, de manier waarop attitudes zijn gemeten en de methoden die zijn gebruikt, kennen de uitgevoerde analyses nog verschillende verbeterpunten.

Op basis van relevante sociaal-psychologische theorieën en studies over de relatie tussen attitudes en gedrag, theorieën over attitudes en verplaatsingsgedrag en naar aanleiding van de evaluatie van bestaande studies, kunnen er een aantal aanbevelingen worden gegeven voor het onderzoeken van zelfselectie door het analyseren van de rol van attitudes. Ten eerste is het belangrijk om er rekening mee te houden dat attitudes in de tijd kunnen veranderen. Attitudes beïnvloeden niet alleen de woonlocatiekeuze, maar de nieuwe woonlocatie kan ook iemands houding ten opzichte van verplaatsingen veranderen. Zo kan bijvoorbeeld een persoon die graag overal met de auto naar toe gaat, dankzij mooi aangelegde paden, wandelen en fietsen leuker gaan vinden. Ook kunnen veranderingen in het huishouden, zoals het krijgen van kinderen, invloed hebben op de wijze waarop mensen over hun verplaatsingen denken. Volgens de bekende theorie van Festinger (1957) zijn mensen

ertoe geneigd om dissonantie tussen hun attitudes en gedrag te verminderen door of hun gedrag of hun attitudes aan te passen.

Ten tweede is het, om de rol van zelfselectie te kunnen bepalen, van belang om attitudes, gedrag en kenmerken van de ruimtelijke inrichting op hetzelfde schaalniveau te meten. Als mensen bijvoorbeeld van fietsen en wandelen houden, kan er niet vanuit worden gegaan dat men ook met zware boodschappen van de winkel naar huis wil lopen of bezweet van het fietsen op het werk wil aankomen. Toch worden in veel onderzoeken meer algemenere attitudes zoals attitudes ten opzichte van autorijden gekoppeld aan meer specifiek verplaatsingsgedrag (bijvoorbeeld vervoermiddel naar een winkel) en meer specifieke kenmerken van de ruimtelijke inrichting (bijvoorbeeld afstand tot een winkel). In andere onderzoeken worden juist ruimtelijke kenmerken heel globaal gemeten (bijvoorbeeld buitenwijk versus stedelijk gebied) en de overige factoren meer specifiek.

Ten derde is het belangrijk om attitudes weloverwogen te meten. Het meten van attitudes is complex en lastig en het is daarom ook niet mogelijk om hier simpele suggesties voor te geven. Attitudes worden vaak gemeten aan de hand van verschillende stellingen. Dat kan door een attitude indirect te meten aan de hand van stellingen over onderliggende aspecten (bijvoorbeeld 'autorijden is milieuvervuilend' en 'autorijden is ontspannend') of door op verschillende manieren direct te meten (bijvoorbeeld 'autorijden is goed'). Doordat in het ene onderzoek totaal andere stellingen worden gebruikt dan in het andere, zijn de verschillende studies slechts beperkt vergelijkbaar. Bovendien is het voor een juiste interpretatie van onderzoeksresultaten nodig om te weten hoe een attitude is gemeten, maar dat is niet altijd duidelijk aangegeven. Het gebruik van indirecte stellingen is vooral interessant als die inhoud van die stellingen in de verdere analyses wordt meegenomen, maar dat is vaak niet het geval.

Tot slot kan op basis van de geëvalueerde theorieën en studies verwacht worden dat percepties en gewoonten niet alleen van invloed zijn op verplaatsingsgedrag zelf, maar ook op zelfselectie ten aanzien van verplaatsingsgedrag. Wanneer mensen niet bekend zijn met de (kwaliteit van) verplaatsingsmogelijkheden van een woonlocatie, kan er ook geen bewuste zelfselectie plaatsvinden. Een klein aantal studies heeft al de invloed van percepties laten zien. Gewoonten zijn nog niet of nauwelijks onderzocht in relatie tot zelfselectie, maar ze zullen zeker beïnvloeden of mensen hun huidige verplaatsingsgedrag voortzetten op een nieuwe woonlocatie. Ook is bijvoorbeeld te verwachten dat naarmate mensen sterker de gewoonte hebben om een bepaald vervoermiddel te gebruiken, ze minder geneigd zullen zijn om een woonlocatie te overwegen die vooral het gebruik van een ander vervoermiddel faciliteert.

Hoofdstuk 3 beschrijft en evalueert de dataverzamelingsmethode, gebaseerd op GPS. De ontwikkeling van deze methode was een belangrijk subdoel van

het promotieonderzoek. Met deze methode was het mogelijk om de verplaatsingen van de respondenten gedurende een hele week te meten zonder dat ze gegevens hoefden te noteren. De belasting bleef hiermee beperkt.

Het Global Positioning System (GPS) is een plaatsbepalingssysteem dat gebaseerd is op het ontvangen van signalen van satellieten. Wanneer van ten minste drie satellieten een signaal wordt ontvangen kan de huidige locatie en het tijdstip met behulp van een GPS-ontvanger worden geregistreerd in een log. De ontwikkelde methode kan worden gebruikt voor het verzamelen van reisafstanden en -tijden, vervoermiddelengebruik, en bestemmingstypen en bestaat uit een interpretatieproces en een validatieproces. In het interpretatieproces worden de GPS-logs van de respondenten gekoppeld aan een database met de beschikbare individuele kenmerken van de respondenten (zoals in dit onderzoek onder andere de x- en y-coördinaten van de woonlocatie, autobezit en huishoudensamenstelling) en gegevens uit Geografische Informatie Systemen (GIS) (zoals de locatie van stations, winkels en wegen). Door het toepassen van verschillende algoritmes worden zoveel mogelijk verplaatsingsgegevens uit de GPS-logs afgeleid. Zo wordt bijvoorbeeld op basis van gemiddelde en maximale snelheden en de locatie van spoorwegen bepaald, welk vervoermiddel waarschijnlijk gebruikt is.

De uitkomsten van het interpretatieproces worden vervolgens ter validatie aan de respondenten aangeboden. Dit gebeurt in een internetapplicatie, waarin de resultaten per dag gepresenteerd worden in tabellen en geografische kaarten. De respondenten kunnen de gegevens corrigeren en aanvullen. Bij sommige langzame autoverplaatsingen kan het bijvoorbeeld voorkomen, dat een rit ten onrechte als fietsrit is geïnterpreteerd. Of als een respondent een bepaalde periode vergeten is de GPS-ontvanger mee te nemen, kunnen niet geregistreerde ritten alsnog worden toegevoegd. De link met het interpretatieproces is interactief; als een respondent nieuwe informatie levert, zoals de woonlocatie van vrienden, dan wordt deze informatie gelijk weer gebruikt bij de interpretatie van de verplaatsingen van de volgende dagen.

De methode is geëvalueerd door de uitkomsten van de voor dit proefschrift verzamelde gegevens te vergelijken met de uitkomsten van het Mobiliteitsonderzoek Nederland (MON) 2006 (uitgevoerd door het Ministerie van Verkeer en Waterstaat). In het MON moesten de respondenten hun verplaatsingsgedrag gedurende één dag schriftelijk bijhouden. Uit de vergelijking blijkt dat in beide onderzoeken de verdeling van trips naar vervoermiddel en naar bestemming vrijwel gelijk zijn, terwijl in het GPS-onderzoek meer ritten per verplaatsing werden geregistreerd. Dit kan erop duiden dat er door het gebruik van GPS trips zijn geregistreerd die in het MON gemist zijn. De evaluatie-enquête die onder de respondenten is gehouden liet zien dat de meeste respondenten er geen moeite mee hadden om de GPS-ontvanger de hele week bij zich te dragen. Ook had de meerderheid weinig problemen met het corrigeren van de data in het validatieprogramma.

De hoofdstukken 4 en hoofdstuk 5 presenteren de analyses over de relatie tussen attitudes ten opzichte van vervoermiddelengebruik, het belang dat mensen hechten aan de afstand tot activiteitenlocaties, woonlocatiekeuze en dagelijks verplaatsingsgedrag. Een belangrijk doel van de analyses in hoofdstuk 4 was om te onderzoeken of in studies naar zelfselectie ook de invloed van verplaatsingsgedrag en woonlocatiekeuzes op attitudes moet worden meegenomen. In de meeste studies wordt alleen de omgekeerde relatie, namelijk hoe attitudes keuzes en gedrag beïnvloeden, onderzocht.

Om dit te kunnen onderzoeken zijn er vier causale modellen opgesteld: twee modellen zonder een invloed van gedrag op attitudes en twee met deze 'omgekeerde' invloed. Twee modellen verklaren de totaal afgelegde reisafstand en twee modellen verklaren het aandeel van autogebruik in het totaal aantal verplaatsingen. Uit de structureel-vergelijkingsmodellen ('structural equation models') die vervolgens zijn geschat, kan geconcludeerd worden dat in de modellen zonder de omgekeerde relatie de rol van zelfselectie via woonlocatiekeuze overschat wordt.

In de modellen zonder omgekeerde invloed van gedrag op attitudes, lijkt er duidelijk sprake te zijn van zelfselectie. Respondenten die belang hechten aan de afstand van hun huis tot groengebieden, een stadscentrum of een treinstation, kiezen vaker voor een woning die relatief dicht bij deze locaties ligt. Zelfselectie heeft echter maar een beperkte indirecte invloed op het aandeel autogebruik en het aantal gereisde kilometers via woonlocatiekeuzes. Het grootste effect van zelfselectie is dat mensen met een positieve attitude ten opzichte van autogebruik verder van een stadcentrum wonen en daardoor meer met de auto reizen.

In de modellen waarin gedrag wel attitudes kan beïnvloeden, verdwijnen de zelfselectie-effecten en de invloed van de ruimtelijke kenmerken van de woonlocatie op het verplaatsingsgedrag vrijwel geheel. De invloed van het belang van de afstand tot culturele voorzieningen op de afstand tot een stadscentrum is de enige significante relatie die op zelfselectie wijst. De ruimtelijke kenmerken van de woonlocatie hebben juist wel een significante invloed op de attitudes ten opzichte van verplaatsingsgedrag. Dit duidt er dus op dat mensen hun attitudes aanpassen aan de verplaatsingsmogelijkheden van hun woonlocatie. Vooral de afstand tot een treinstation heeft een sterke negatieve invloed op de attitudes van mensen ten opzichte van het gebruik van het openbaar vervoer. Een opmerkelijke uitkomst is dat mensen met een positieve houding ten opzichte van het openbaar vervoer juist relatief verder van een treinstation wonen en daardoor ook nog eens relatief iets vaker met de auto reizen. Mogelijk was voor hen zelfselectie geen optie, omdat ze andere woning- of buurtkenmerken belangrijker vonden dan de afstand tot een treinstation.

Dat het belang van de afstand tot een treinstation positief en attitudes ten opzichte van het openbaar vervoer negatief gerelateerd zijn aan de nabij-

heid van een treinstation, geeft aan dat, zoals in hoofdstuk 2 al aan de orde is geweest, het van belang is om bij het bepalen van zelfselectie gedrag en attitudes op hetzelfde schaalniveau te meten. Als alleen het meer algemene 'attitudes ten opzichte van openbaar vervoer gebruik' zou zijn gemeten, zou de rol van zelfselectie minder zichtbaar geweest zijn. Positieve attitudes ten op zichtte van openbaarvervoergebruik leiden wel via het belang dat aan de afstand tot een station wordt gehecht tot een woonlocatie dichterbij het station.

De eerste analyses van hoofdstuk 5 laten zien dat een belangrijk deel van de respondenten ontevreden is over de afstand tot activiteitenlocaties, zoals de werklocaties, horeca of culturele voorzieningen. Dit betekent dat zelfselectie bij de keuze voor hun huidige woning niet mogelijk was of dat hun wensen ten aanzien van de afstand tot de activiteitenlocaties veranderd zijn na hun verhuizing. Wanneer mensen niet op de door hen gewenste afstand wonen, reizen ze vaak met een ander vervoermiddel dan ze eigenlijk zouden willen. Wanneer het de reis naar minder frequent bezochte locatie betreft, zoals naar culturele voorzieningen, besluiten mensen ook vaak om een dergelijke locatie minder vaak te bezoeken dan ze eigenlijk zouden willen.

In verdere analyses is dieper ingegaan op de invloed van attitudes ten opzichte van vervoermiddelengebruik op vervoermiddelenkeuze en zelfselectie door een focus op onderliggende verwachtingen over uitkomsten van vervoermiddelengebruik (bijvoorbeeld autorijden is duur of milieuonvriendelijk) en het belang dat mensen hechten aan deze uitkomsten. Binomiale logit modellen bevestigen de hypothese dat de invloed van sommige verwachtingen over uitkomsten van vervoerwijzekeuze verschilt naar reisafstand en reisdoel. Een voorbeeld hiervan is dat naarmate de afstand tot een winkel voor de dagelijkse boodschappen groter is, de keuze om te fietsen naar deze winkel sterker afhangt van hoe ontspannen mensen het vinden om te fietsen.

Significante correlaties tussen verwachtingen over vervoermiddelengebruik en het belang dat mensen aan bepaalde woning- en buurtkenmerken hechten, geven een indicatie dat het niet slagen in zelfselectie deels kan worden verklaard door woning- en buurtvoorkeuren die niet samengaan met de gewenste afstanden. Een voorbeeld hiervan is dat mensen met een 'groene' attitude autogebruik milieuonvriendelijk vinden en daarom minder met een auto willen reizen en dichtbij een station willen wonen. Tegelijkertijd willen ze door hun groene instelling ook juist een grote tuin bij hun huis. Omdat ze echter moeilijk een huis vinden dat aan al deze kenmerken voldoet, komen ze vaak terecht in een huis dat niet aan al hun woonvoorkeuren voldoet, of met een kleinere tuin dan gewenst.

Daarnaast is onderzocht hoe verschillen in verwachtingen ten aanzien van vervoermiddelengebruik verklaard kunnen worden. Zoals verwacht blijkt dat naast sociaal-demografische variabelen ook leefstijloriëntatie bijdraagt aan de verklaring. Zo wordt de mening van mensen over de milieuvriendelijkheid

van autorijden niet alleen negatief beïnvloed door het hebben van kinderen, maar ook door het belang dat gehecht wordt aan het hebben van kinderen.

Ten slotte is gekeken naar de gevolgen van belangrijke veranderingen in het huishouden sinds de laatste verhuizing. De meerderheid van de respondenten heeft één of meerdere grote veranderingen meegemaakt, maar deze leiden minstens zo vaak tot een grotere tevredenheid over de afstand tot activiteitenlocaties als tot een groei van het aantal 'mismatches'. Eén van de redenen hiervoor kan zijn, dat mensen bij een verhuizing anticiperen op toekomstige veranderingen, zoals het krijgen van kinderen.

Aanbevelingen

Mede omdat een belangrijk deel van het onderzoek methodologisch van aard is, leveren de conclusies verschillende aanbevelingen voor toekomstig onderzoek op. In de eerste plaats laten de analyses zien dat zelfselectie ten aanzien van de afstand tot de activiteitenlocatie van invloed is op de relatie tussen de afstand tot activiteitenlocaties en verplaatsingsgedrag. Hoewel deze invloed beperkt is, sluit deze conclusie aan bij eerdere studies en kan gesteld worden dat zelfselectie via woonlocatiekeuze meegenomen moet worden in onderzoek naar de relatie tussen ruimtelijke kenmerken van een woonlocatie en verplaatsingsgedrag.

Ten tweede kan geconcludeerd worden dat om de rol van zelfselectie daadwerkelijk te kunnen bepalen, attitudes ten opzichte van verplaatsingsgedrag op meerdere momenten in de tijd gemeten moeten worden. De analyses laten zien dat in de tijd na een verhuizing, de nieuwe ruimtelijke kenmerken van de woonlocatie, veranderd verplaatsingsgedrag en sociaal-demografische veranderingen en veranderingen in leefstijloriëntatie ervoor kunnen zorgen dat attitudes van mensen veranderen. Dit betekent dat op het moment van enquêteren voor een onderzoek attitudes mogelijk niet meer hetzelfde zijn als op het moment van de verhuizing en dus niet meer gebruikt kunnen worden om vast te stellen of er sprake is geweest van zelfselectie.

Ten derde kan worden geconcludeerd dat, om de rol van zelfselectie te kunnen bepalen, het nodig is dat attitudes, gedrag en ruimtelijke kenmerken op hetzelfde schaalniveau worden gemeten. Ook kan er nog veel verbeterd worden in de uitleg van gekozen meetmethoden en items of stellingen. Daarbij zou het onderzoek naar zelfselectie erg gebaat zijn bij een standaardisering van het meten van attitudes, zodat studies vergelijkbaar worden.

Een vierde aanbeveling is om bij de verklaring van de invloed van zelfselectie op verplaatsingsgedrag ook gewoonten, percepties en verwachtingen over uitkomsten van verplaatsingsgedrag te analyseren. Veel studies hebben aangetoond dat gewoonten een grote invloed hebben op verplaatsingsgedrag. Over het effect van gewoonten bij zelfselectie en na een verhuizing is minder bekend. Door het kleine aantal zelfselectie-studies dat percepties van kenmerken van de ruimtelijke inrichting heeft onderzocht, wordt gecon-

cludeerd dat deze percepties een significante invloed hebben. Uit de analyses in dit proefschrift blijkt dat verwachtingen over uitkomsten van vervoermiddelengebruik variëren naar reisafstand, reisdoel en ook naar kenmerken van het huishouden. Door deze relaties te onderzoeken, kunnen woonlocatiekeuzes en verplaatsingskeuzes duidelijker verklaard worden.

Andere mogelijke onderzoeksrichtingen die in dit onderzoek niet aan de orde zijn geweest, maar wel interessant kunnen zijn, zijn de gevolgen van de beperkingen op de huurmarkt en de interactie binnen huishoudens. Beperkingen op de huurmarkt zorgen ervoor dat huurders veel minder dan kopers de mogelijkheid hebben om op de door hen gewenste locatie te gaan wonen. Een vergelijking van de mate van zelfselectie van kopers en huurders en de gevolgen van (on)mogelijke zelfselectie voor hun dagelijks reisgedrag zou interessante informatie kunnen opleveren. Studies naar verplaatsingsgedrag en studies naar woonlocatiekeuze hebben aangetoond dat interactie tussen leden van een huishouden een belangrijke invloed op het uiteindelijk gedrag hebben. Echter, in studies naar de invloed van zelfselectie via woonlocatiekeuze op verplaatsingsgedrag, is deze interactie nog niet of nauwelijks bestudeerd.

Tot slot kan met de ontwikkelde GPS-dataverzamelingsmethode op een efficiënte manier verplaatsingsdata verzameld worden. Zeker met de voortgang van de huidige technologische ontwikkelingen en met verbeterde algoritmes voor het afleiden van data is deze methode veelbelovend voor toekomstige dataverzameling en levert het gebruik verschillende voordelen op ten opzichte van meer conventionele methoden.

Vanwege de enigszins beperkte omvang van de empirische analyses en hun experimentele karakter, heeft dit proefschrift met name methodologische aanbevelingen opgeleverd. Toch kunnen ook enkele aanbevelingen voor het ruimtelijke ordeningsbeleid worden gegeven. Ruimtelijke ordeningsbeleid, waarin gestreefd wordt om het dagelijks verplaatsingsgedrag van individuen te beïnvloeden, zal de meeste kans van slagen hebben wanneer rekening wordt gehouden met verschillen tussen specifieke groepen van de bevolking wat betreft hun woon- en buurtvoorkeuren en hun attitudes ten opzichte van verplaatsingsgedrag. Hiermee kan worden voorkomen dat situaties ontstaan zoals in de Amersfoortse wijk Nieuwland. Nieuwland is opgezet als milieuvriendelijke wijk, maar heeft desondanks veel huishoudens met meerdere auto's aangetrokken. Omdat bij de planning van parkeerruimte geen rekening is gehouden met zo'n hoog autobezit, staat de wijk nu overvol met auto's. Wanneer beter rekening gehouden wordt met attitudes ten opzichte van vervoermiddelengebruik kunnen investeringen in fiets- en openbaarvervoer infrastructuur vooral toegespitst worden op wijken waarin veel mensen een voorkeur voor fietsen of het openbaar vervoer hebben, terwijl in wijken waar meer mensen dan gemiddeld een grote voorkeur voor de auto hebben, vooral in een betere autobereikbaarheid wordt geïnvesteerd. Mensen die maar een

lichte voorkeur voor de auto hebben, zullen door de juiste investeringen verleid kunnen worden om vaker voor een alternatief vervoermiddel te kiezen. De uitkomsten van dit proefschrift laten zien dat de beste resultaten bereikt kunnen worden als er per type bestemming wordt gekeken bij welke afstand de doelgroep nog voor een alternatief voor de auto kiest.

De tweede aanbeveling is gerelateerd aan de eerste. Uit de resultaten kan worden afgeleid dat door beperkingen op de woningmarkt op het moment van de woningkeuze, huishoudens mogelijk geen woonlocatie hebben kunnen vinden die aansluit bij hun verplaatsingsvoorkeuren. In de afgelopen decennia heeft in Nederland nieuwbouw voornamelijk plaatsgevonden in grote, nieuw ontwikkelde woonwijken. Dit betekent dat een groot deel van de woningen die op een bepaald moment beschikbaar zijn, dezelfde locatiekenmerken heeft (bijvoorbeeld de afstand tot een stadscentrum of een station). Om meer mogelijkheden tot zelfselectie te bieden zou het beter zijn om de ontwikkeling van nieuwe woongebieden meer in tijd en ruimte te spreiden. De recente ontwikkeling om in Nederland meer woningen op kleinschalige locaties binnen bestaand stedelijk gebied te bouwen, zal meer diversiteit bieden en dus meer keuzemogelijkheden.

Tot slot suggereren de analyses dat ruimtelijke ordeningsbeleid verplaatsingsgedrag kan beïnvloeden via het beïnvloeden van attitudes. Uit de resultaten blijkt dat kortere afstanden van woningen tot stations indirect, via een positieve invloed op de attitudes van mensen ten opzichte van het openbaar vervoer, leiden tot een kleiner aandeel van het autogebruik in het totale aantal verplaatsingen. Gezien deze resultaten lijkt de huidige trend van de herontwikkeling van stationsgebieden, waar in hoge dichtheid woningen worden gebouwd, veelbelovend.

Appendix 1 Questionnaires

Internet questionnaire version Amersfoort

Onderzoek verplaatsingsgedrag van de gemeenten Amersfoort, Veenendaal en Zeewolde en de TU Delft

Mocht u tijdens het invullen van de vragenlijst problemen tegen komen of indien u andere vragen over het onderzoek heeft dan kunt u contact op nemen met Wendy Bohte (TU Delft): info@verplaatsingsgedrag.nl

Uw huishouden

De eerste twee vragen gaan over de samenstelling van uw huishouden.

1. ***Tot welk type huishouden behoort uw huishouden?***
❍ alleenstaand zonder thuiswonende kinderen
❍ alleenstaand met thuiswonende kinderen
❍ gehuwd/samenwonend zonder thuiswonende kinderen
❍ gehuwd/samenwonend met thuiswonende kinderen
❍ overig
–> Indien u geen thuiswonende kinderen heeft, kunt u doorgaan met vraag 3

2. ***Hoeveel thuiswonende kinderen heeft u en welke leeftijden hebben zij?***
Kinderen onder de zes jaar:
Kinderen van 6 tot 12 jaar:
Kinderen van 12 tot 18 jaar:
Kinderen van 18 jaar en ouder:

Beschikbaarheid van vervoermiddelen

Er volgen nu een aantal vragen over de verplaatsingsmogelijkheden die u heeft.

3. ***Heeft u een rijbewijs?***
❍ ja
❍ nee

4. ***Over welke vervoermiddelen beschikt uw huishouden?*** (meerdere antwoorden mogelijk)
❑ geen
❑ auto's, het aantal is:
❑ motoren, het aantal is:
❑ brommers/scooters, het aantal is:
❑ fietsen, het aantal is:
–> Indien uw huishouden niet over een auto beschikt, kunt u doorgaan met vraag 8

5. ***Beschikt uw huishouden over lease–auto's? Zo ja, hoeveel?***
❍ nee
❍ ja, het aantal lease–auto's is:

6. ***Beschikt uw huishouden over de volgende typen auto's:***
❑ stationwagon
❑ MPV/ruimtewagen/spacewagon (zoals Scenic, Espace, Zafira, Sharan, Touran, Multipla, Alhambra, etc.)
❑ SUV of terreinwagen (zoals X3, X5, Tuscon, X–trail, Touareg, XC90)
❑ geen van bovenstaande auto's

7. ***Kunt u altijd over een auto beschikken?***
❍ ja, wanneer ik maar wil
❍ nee, dat gaat in overleg met mensen binnen mijn huishouden
❍ nee, dat gaat in overleg met mensen buiten mijn huishouden
❍ nee, (vrijwel) nooit

8. ***Beschikte uw huishouden over een auto toen u naar uw huidige woning verhuisde?***
❍ ja, mijn huishouden beschikte al over één of meerdere auto's
❍ nee
❍ nee, er was nog geen auto, maar er waren wel plannen om er één aan te schaffen

9. ***Heeft u een abonnement of kortingskaart voor het openbaar vervoer?***
❍ ja
❍ nee

10. ***Heeft u een handicap, die u beperkt in de vervoermiddelen die u kunt gebruiken?***
❍ ja
❍ nee

Uw mening over de verschillende vervoermiddelen

De volgende vragen gaan over uw mening over verschillende vervoermiddelen. Het is niet de bedoeling dat u lang over de vragen nadenkt, maar dat u 'op gevoel' antwoord geeft.

11. ***Met welk vervoermiddel verplaatst u zich het liefst (even afgezien van de afstand) en welke vervoermiddelen komen op de tweede, derde en vierde plaats?***
Wilt u uw voorkeuren aangeven met de nummers 1 (meeste voorkeur) tot en met 4 (minste voorkeur).

	rangorde
auto	
trein	
bus	
fiets	

12. ***Hoe vaak reist u met de auto in vergelijking met andere vervoermiddelen als het openbaar vervoer, fietsen of lopen?***
Ook indien u geen auto en/of rijbewijs heeft, deze vraag graag beantwoorden.

❍ bijna altijd met de auto en bijna nooit met andere vervoermiddelen
❍ meestal met de auto, maar soms met andere vervoermiddelen
❍ vaak met de auto, maar regelmatig met andere vervoermiddelen
❍ net zo vaak met de auto als met andere vervoermiddelen
❍ vaak met andere vervoermiddelen, maar regelmatig met de auto
❍ meestal met andere vervoermiddelen, maar soms met de auto
❍ bijna nooit met de auto en bijna altijd met andere vervoermiddelen

13. ***Stel dat het mooi weer is en u gaat alleen op weg naar een locatie voor een vrijetijdsactiviteit en er is geen tijdsdruk. Tot welke reistijd zou u waarschijnlijk nog op de fiets gaan?***
reistijd in minuten:
–> Indien u geen rijbewijs heeft, kunt u doorgaan met vraag 15

14. ***Hoe vindt u het om auto te rijden?***
Ik vind autorijden:

	sterk mee eens	mee eens	niet mee eens/niet mee oneens	mee oneens	sterk mee oneens
statusverlenend					
milieuvriendelijk					
ontspannend					
comfortabel					
tijdsbesparend					
flexibel					
goedkoop					
plezierig					
privacy biedend					
goed					
gezond					
veilig					

15. ***Hoe vindt u het om met het openbaar vervoer te reizen?***
Ik vind met het openbaar vervoer reizen:

	sterk mee eens	mee eens	niet mee eens/niet mee oneens	mee oneens	sterk mee oneens
statusverlenend					
milieuvriendelijk					
ontspannend					
comfortabel					
tijdsbesparend					
flexibel					
goedkoop					
plezierig					
privacy biedend					
goed					
gezond					
veilig					

16. ***Hoe vindt u het om te fietsen?***
Ik vind fietsen:

	sterk mee eens	mee eens	niet mee eens/niet mee oneens	mee oneens	sterk mee oneens
statusverlenend					
milieuvriendelijk					
ontspannend					
comfortabel					
tijdsbesparend					
flexibel					
goedkoop					
plezierig					
privacy biedend					
goed					
gezond					
veilig					

17. ***Hoe belangrijk vindt u het dat het vervoermiddel waarmee u reist de volgende kenmerken heeft:***

	zeer belangrijk	belangrijk	niet belangrijk /niet onbelangrijk	onbelangrijk	zeer onbelangrijk
statusverlenend					
milieuvriendelijk					
ontspannend					
comfortabel					
tijdsbesparend					
flexibel					
goedkoop					
plezierig					
privacy biedend					
gezond					
veilig					

Uw woning

De volgende vragen gaan over uw huidige woning.

18. ***Vanaf welk jaar woont u in uw huidige woning?***

19. ***Welk type woning bewoont u?***
❍ flat, portiekwoning, boven− of benedenwoning, appartement
❍ huis in rij
❍ twee−onder−één−kapwoning
❍ vrijstaande woning
❍ anders, namelijk

20. ***Hoeveel kamers (slaap, woon−, studeer− en werkkamers) heeft uw woning?***

21. ***Heeft u een tuin, balkon of terras bij uw woning?*** (meerdere antwoorden mogelijk)
❑ geen balkon, tuin of terras
❑ balkon
❑ voortuin
❑ zijtuin
❑ achtertuin
❑ (dak)terras

22. ***In welk gebied heeft u gezocht toen u op zoek was naar uw huidige woning?***
❍ alleen huidige woning was een optie (bijv. omdat uw partner daar al woonde)
❍ alleen binnen huidige wijk
❍ alleen in Amersfoort, maar wel in meerdere wijken
❍ in Amersfoort en omliggende plaatsen
❍ in meerdere plaatsen in Midden−Nederland
❍ anders, namelijk:

23. ***Wat waren voor u belangrijke redenen om naar uw huidige woning te verhuizen?*** (meerdere antwoorden mogelijk)
❑ verandering van baan
❑ verandering van baan door mijn partner
❑ samenwonen/trouwen
❑ scheiding
❑ (planning) geboorte kind
❑ inkomensstijging
❑ inkomensdaling
❑ aantrekkelijker woning
❑ anders, namelijk:

24. ***Welke van onderstaande ontwikkelingen heeft u meegemaakt sinds u verhuisd bent naar uw huidige woning?*** (meerdere antwoorden mogelijk)
❑ verandering van baan
❑ verandering van baan door partner
❑ u bent meer gaan werken (tenminste 4 uur meer)
❑ u bent minder gaan werken (tenminste 4 uur minder)
❑ uw partner is met u gaan samenwonen
❑ scheiding / u en uw partner zijn uit elkaar gegaan
❑ geboorte kind(eren)
❑ laatste kinderen zijn het huis uit gegaan
❑ het huishouden is over een (extra) auto komen te beschikken
❑ het huishouden is over minder auto's komen te beschikken
❑ een andere belangrijke verandering, namelijk:
❑ geen van bovenstaande gebeurtenissen

Woonvoorkeuren

De volgende vragen gaan over uw woonvoorkeuren. Wij willen u vragen om u voor te stellen dat u op dit moment op zoek zou gaan naar een nieuwe woning.

25. ***Welke van onderstaande typen woningen zou u serieus overwegen wanneer u op dit moment op zoek zou zijn naar een nieuwe woning?*** (uitgaande
❑ van uw huidige huishoudenssamenstelling en financiële situatie,
❑ meerdere antwoorden mogelijk)
❑ flat, portiekwoning, boven− of benedenwoning, appartement
❑ huis in een rij
❑ twee−onder−één−kapwoning
❑ vrijstaande woning
❑ seniorenwoning
❑ anders, namelijk:

26. ***Welke van onderstaande locaties zou u serieus overwegen wanneer u op dit moment op zoek zou zijn naar een nieuwe woning?*** (uitgaande van uw
❑ huidige huishoudenssamenstelling en financiële situatie, meerdere antwoorden mogelijk)
❑ in een stadscentrum
❑ tussen stadscentrum en stadsrand
❑ aan de rand van een stad
❑ in de bebouwde kom van een kleinere gemeente (of dorp)
❑ buiten de bebouwde kom
❑ anders, namelijk:

27. ***Zou u wanneer u op dit moment op zoek zou zijn naar een nieuwe woning een ruim opgezette buurt of een dichtbebouwde buurt overwegen?*** (uitgaande van uw huidige huishoudenssamenstelling en financiële situatie)
❍ alleen een ruim opgezette buurt
❍ alleen een dichtbebouwde buurt
❍ zowel een een ruim opgezette als een dichtbebouwde buurt
❍ weet niet

28. ***Welk kenmerk van een woning/woonlocatie vindt u het meest belangrijk en welke kenmerken komen op de tweede, derde en vierde plaats?***
Wilt u uw voorkeuren aangeven met de nummers 1 (meest belangrijk) tot en met 4 (minst belangrijk).

	rangorde
het woningtype (o.a. grootte en soort woning)	
de locatie van de woning (o.a. grootte van de plaats en ligging binnen een plaats)	
de inrichting van de buurt (o.a. bebouwingsdichtheid, voorzieningenniveau en groen)	
het type mensen in de buurt	

29. ***Hoe belangrijk vindt u het dat de woning waarin u woont de volgende kenmerken heeft:***

	zeer belangrijk	belangrijk	niet belangrijk /niet onbelangrijk	onbelangrijk	zeer onbelangrijk
statusverlenend					
milieuvriendelijk					
comfortabel					
goedkoop (ruim binnen budget)					
privacy biedend					
woninggrootte volgens mijn voorkeur					
woningtype volgens mijn voorkeur					
grootte van de tuin volgens mijn voorkeur					

30. ***In hoeverre bent u het er mee eens dat de woning waarin u op dit moment woont de volgende kenmerken heeft*** (de vragen zijn niet gesteld als het betreffende kenmerk onbelangrijk gevonden wordt)***:***

	sterk mee eens	mee eens	niet mee eens/niet mee oneens	mee oneens	sterk mee oneens
statusverlenend					
milieuvriendelijk					
comfortabel					
goedkoop (ruim binnen budget)					
privacy biedend					
woninggrootte volgens mijn voorkeur					
woningtype volgens mijn voorkeur					
grootte van de tuin volgens mijn voorkeur					

31. ***Hoe belangrijk vindt u het dat de buurt waarin u woont de volgende kenmerken heeft:***

	zeer belangrijk	belangrijk	niet belangrijk /niet onbelangrijk	onbelangrijk	zeer onbelangrijk
sociaal veilig					
verkeersveilig					
dichtheid bebouwing volgens mijn voorkeur					
bevolkingssamenstelling volgens mijn voorkeur					
uitstraling van de buurt volgens mijn voorkeur					
voldoende parkeerplaatsen					
goede auto−infrastructuur (congestie, afstand tot snelweg, etc.)					
goede fietsinfrastructuur (fietspaden, veiligheid, etc.)					

32. ***In hoeverre bent u het er mee eens dat de buurt waarin u op dit moment woont de volgende kenmerken heeft*** (de vragen zijn niet gesteld als het betreffende kenmerk onbelangrijk gevonden wordt)***:***

	sterk mee eens	mee eens	niet mee eens/niet mee oneens	mee oneens	sterk mee oneens
sociaal veilig					
verkeersveilig					
dichtheid bebouwing volgens mijn voorkeur					
bevolkingssamenstelling volgens mijn voorkeur					
uitstraling van de buurt volgens mijn voorkeur					
voldoende parkeerplaatsen					
goede auto−infrastructuur (congestie, afstand tot snelweg, etc.)					
goede fietsinfrastructuur (fietspaden, veiligheid, etc.)					

Werk en opleiding

Dit deel van de vragenlijst gaat over de betaalde arbeid en het vrijwilligerswerk die u verricht en over eventuele opleidingen die u volgt.

33. ***Werkt of studeert u?*** (meerdere antwoorden mogelijk)
(werk–gerelateerde) opleiding: niet onder werktijd en bedoeld als voorbereiding op een baan, dus niet als hobby
❑ nee
❑ ja, ik verricht betaalde arbeid
❑ ja, ik verricht vrijwilligerswerk
❑ ja, ik volg een (werk–gerelateerde) opleiding
–> Indien u geen betaalde arbeid verricht, kunt u doorgaan met vraag 42

34. ***Wat is uw beroep?***

35. ***Hoeveel uur per week werkt u gemiddeld?***
❍ minder dan 12 uur per week
❍ 12 tot 20 uur per week
❍ 20 tot 25 uur per week
❍ 25 tot 30 uur per week
❍ 30 tot 35 uur per week
❍ 35 of meer uur per week

36. ***Hoeveel dagen per maand werkt u gemiddeld thuis?***
❍ vrijwel altijd -> *ga verder met vraag 42*
❍ vrijwel nooit (minder dan 1x per maand)
❍ tenminste één maal per maand, aantal dagen is:

37. ***Heeft u één of meerdere vaste werklocaties?***
❍ ja, ik heb één of meerdere vaste werklocaties
❍ nee, de locatie waar ik werk wisselt per periode (bijv. kort uitzendwerk, bouwvakkers) -> *ga verder met vraag 42*
❍ nee, ik bezoek meerdere locaties per dag/week (bijv. vertegenwoordigers, consultants, thuiszorg) -> *ga verder met vraag 42*
❍ nee, ik ben altijd onderweg (bijv. buschauffeur, vuilnisman) -> *ga verder met vraag 42*

38. ***Op welke adressen verricht u gewoonlijk betaalde arbeid en hoeveel dagen per week bezoekt u deze locatie(s)?***
Wilt u bij twee of meer adressen eerst het adres waar u de meeste tijd doorbrengt noteren en dan het adres waar u daarna de meeste tijd doorbrengt?
eerste werklocatie:
straat en nr.:
postcode (geen postbus):
plaats:
dagen per week:

tweede werklocatie:
straat en nr.:
postcode (geen postbus):
plaats:
dagen per week:

39. ***Met welk(e) vervoermiddel(en) reist u meestal naar uw (eerste) werklocatie?***
Wilt u alle vervoermiddelen aankruisen die u meestal in combinatie gebruikt, bijv. fiets en trein, als u met de fiets naar het station gaat en dan verder met de trein reist
❑ auto
❑ trein
❑ bus/tram/metro
❑ motor/brommer/scooter
❑ fiets
❑ lopen
❑ anders,namelijk:

40. ***Hoeveel minuten doet u gemiddeld over uw woon−werkreis wanneer u met dit vervoermiddel naar uw werk gaat?*** (enkele reis)
aantal minuten:

41. ***Hoeveel minuten wilt u maximaal naar uw werk reizen?***
aantal minuten:
−> Indien u geen vrijwilligerswerk verricht, kunt u doorgaan met vraag 43

Vrijwilligerswerk

42. ***Hoeveel uur per week besteedt u gemiddeld thuis en elders aan vrijwilligerswerk?***
aantal uren thuis:
aantal uren elders:
−> Indien u geen opleiding volgt, kunt u doorgaan met vraag 44

Opleiding

43. ***Hoeveel uur per week besteedt u gemiddeld op de opleidingslocatie en thuis aan uw opleiding(en)?***
aantal uren opleidingslocatie:
aantal uren thuis:

Verplaatsingen

In de hierna volgende vragen wordt u gevraagd naar uw bezoek aan verschillende locaties en de vervoermiddelen die u gebruikt om daar te komen.

44. ***Hoe vaak doet u dagelijkse boodschappen (supermarkt, groenteboer, bakker, etc.)?***
❍ één of meerdere keren per week, namelijk:
❍ één of meerdere keren per maand, namelijk:
❍ één of meerdere keren per jaar, namelijk:
❍ zelden of nooit
−> Indien u minder dan 1x per maand dagelijkse boodschappen doet, kunt u doorgaan met vraag 48

45. ***Waar doet u meestal uw dagelijkse boodschappen?***
❍ Stadscentrum (inclusief de Kamp)
❍ De Nieuwe Hof
❍ Arnhemseweg/Julianaplein/Souverein
❍ Neptunusplein
❍ Winkelcentrum Emiclaer
❍ Euterpeplein
❍ Winkelcentrum Schothorst (P. Stastokerf)
❍ Leusderweg
❍ Balladelaan
❍ Kraailandhof/Hamseweg
❍ Elders in Amersfoort, namelijk:
❍ Elders buiten Amersfoort, namelijk:

46. ***Met welk vervoermiddel gaat u meestal naar deze locatie?***
❍ auto
❍ trein
❍ bus
❍ motor/brommer/scooter
❍ fiets
❍ lopen
❍ ander vervoermiddel, namelijk...

47. ***Waar doet u nog meer regelmatig uw dagelijkse boodschappen?***
❑ geen andere locatie
❑ Stadscentrum (inclusief de Kamp)
❑ De Nieuwe Hof
❑ Arnhemseweg/Julianaplein/Souverein
❑ Neptunusplein
❑ Winkelcentrum Emiclaer
❑ Euterpeplein
❑ Winkelcentrum Schothorst (P. Stastokerf)
❑ Leusderweg
❑ Balladelaan
❑ Kraailandhof/Hamseweg
❑ Elders in Amersfoort, namelijk:
❑ Elders buiten Amersfoort, namelijk:

48. ***Hoe vaak gaat u winkelen (niet–dagelijkse boodschappen: kleding, meubelen, kado's, etc.)?***
❍ één of meerdere keren per week, namelijk:
❍ één of meerdere keren per maand, namelijk:
❍ één of meerdere keren per jaar, namelijk:
❍ zelden of nooit
–> Indien u minder dan 1x per maand winkelt (geen dagelijkse boodschappen), kunt u doorgaan met vraag 52

49. ***Waar winkelt u meestal (niet–dagelijkse boodschappen)?***
❍ Stadscentrum (inclusief de Kamp)
❍ Neptunusplein
❍ Arnhemseweg/Julianaplein/Souverein
❍ Euterpeplein
❍ Winkelcentrum Emiclaer
❍ Leusderweg
❍ Winkelcentrum Schothorst (P. Stastokerf)
❍ Balladelaan
❍ Kraailandhof/Hamseweg
❍ De Nieuwe Hof
❍ Elders in Amersfoort, namelijk:
❍ Stadscentrum Utrecht
❍ Elders buiten Amersfoort, namelijk:

50. ***Met welk vervoermiddel gaat u meestal naar deze locatie?***
❍ auto
❍ trein
❍ bus
❍ motor/brommer/scooter
❍ fiets
❍ lopen
❍ ander vervoermiddel, namelijk...

51. ***Waar winkelt u nog meer regelmatig (geen dagelijkse boodschappen)? (meerdere antwoorden mogelijk)***
❑ geen andere locatie
❑ Stadscentrum (inclusief de Kamp)
❑ Neptunusplein
❑ Arnhemseweg/Julianaplein/Souverein
❑ Euterpeplein
❑ Winkelcentrum Emiclaer
❑ Leusderweg
❑ Winkelcentrum Schothorst (P. Stastokerf)
❑ Balladelaan Kraailandhof/Hamseweg
❑ De Nieuwe Hof
❑ Elders in Amersfoort, namelijk:
❑ Stadscentrum Utrecht
❑ Elders buiten Amersfoort, namelijk:

52. ***Hoe vaak bezoekt u een groengebied (park, bos, open gebied)?***
❍ één of meerdere keren per week, namelijk:
❍ één of meerdere keren per maand, namelijk:
❍ één of meerdere keren per jaar, namelijk:
❍ zelden of nooit
–> Indien u minder dan 1x per maand groengebieden bezoekt, kunt u doorgaan met vraag 56

53. ***Welk groengebied bezoekt u meestal?***
❍ Stadsdeelpark Schothorst
❍ Valleikanaal en omgeving in de stad
❍ Park Randenbroek en de Heiligenbergerbeek
❍ Nimmerdor (in het Leusderkwartier)
❍ de Galgenberg (in het Bergkwartier)
❍ Birkhoven/Bokkeduinen
❍ het Lockhorsterbos
❍ bos ten zuiden van Amersfoort: Den Treek/Henschoten/Austerlitz
❍ bos ten westen van Amersfoort: Soestduinen/Soest(erberg)/Den Dolder/Lage Vuursche
❍ Eemvallei ten noord(west)en van Amersfoort: Hoogland West/Baarn/Eemnes/Bunschoten–Spakenburg
❍ Gelderse vallei ten noordoosten van Amersfoort: Hoevelaken/Nijkerk
❍ Gelderse Vallei ten zuidoosten van Amersfoort: Leusden/Woudenberg/Scherpenzeel/Achterveld
❍ Groengebied elders, namelijk .....

54. ***Met welk vervoermiddel gaat u meestal naar deze locatie?***
❍ auto
❍ trein
❍ bus
❍ motor/brommer/scooter
❍ fiets
❍ lopen
❍ ander vervoermiddel, namelijk...

55. ***Welke groengebieden bezoekt u nog meer regelmatig?*** (meerdere antwoorden mogelijk)
❑ geen ander groengebied
❑ Stadsdeelpark Schothorst
❑ Valleikanaal en omgeving in de stad
❑ Park Randenbroek en de Heiligenbergerbeek
❑ Nimmerdor (in het Leusderkwartier)
❑ de Galgenberg (in het Bergkwartier)
❑ Birkhoven/Bokkeduinen
❑ het Lockhorsterbos
❑ bos ten zuiden van Amersfoort: Den Treek/Henschoten/Austerlitz
❑ bos ten westen van Amersfoort: Soestduinen/Soest(erberg)/Den Dolder/Lage Vuursche
❑ Eemvallei ten noord(west)en van Amersfoort: Hoogland West/Baarn/Eemnes/Bunschoten–Spakenburg
❑ Gelderse vallei ten noordoosten van Amersfoort: Hoevelaken/Nijkerk
❑ Gelderse Vallei ten zuidoosten van Amersfoort: Leusden/Woudenberg/Scherpenzeel/Achterveld
❑ Groengebied elders, namelijk .....

56. ***Hoe vaak gaat u op bezoek bij vrienden en/of familie?***
❍ één of meerdere keren per week, namelijk:
❍ één of meerdere keren per maand, namelijk:
❍ één of meerdere keren per jaar, namelijk:
❍ zelden of nooit
–> Indien u minder dan 1x per maand vrienden en familie bezoekt, kunt u doorgaan met vraag 58

57. ***Waar gaat u tenminste 6 keer per jaar op bezoek bij vrienden en/of familie?*** (meerdere antwoorden mogelijk)
❑ eigen wijk
❑ omringende wijken
❑ elders in Amersfoort
❑ elders in midden−Nederland
❑ buiten midden−Nederland

58. ***Hoe vaak bezoekt u horecavoorzieningen (bijv. restaurant, café, bar, discotheek)?***
❍ één of meerdere keren per week, namelijk:
❍ één of meerdere keren per maand, namelijk:
❍ één of meerdere keren per jaar, namelijk:
❍ zelden of nooit
−> Indien u minder dan 1x per maand horecavoorzieningen bezoekt, kunt u doorgaan met vraag 61

59. ***Waar bezoekt u meestal een horecavoorziening?***
❍ eigen wijk
❍ omringende wijken (geen stadscentrum)
❍ stadscentrum Amersfoort
❍ elders in Amersfoort
❍ stadscentrum Utrecht
❍ ander plaats, namelijk .....

60. ***Met welk vervoermiddel gaat u meestal naar deze locatie?***
❍ auto
❍ trein
❍ bus
❍ motor/brommer/scooter
❍ fiets
❍ lopen
❍ ander vervoermiddel, namelijk...

61. ***Hoe vaak bezoekt u een culturele of andere voorziening waar u toeschouwer bent (bijv. bioscoop, schouwburg, concert, museum, tentoonstelling, sportwedstrijd)?***
❍ één of meerdere keren per week, namelijk:
❍ één of meerdere keren per maand, namelijk:
❍ één of meerdere keren per jaar, namelijk:
❍ zelden of nooit
−> Indien u minder dan 1x per maand culturele voorzieningen of andere voorzieningen waar u toeschouwer bent, bezoekt, kunt u doorgaan met vraag 64

62. ***Waar bezoekt u meestal een culturele voorziening of sportwedstrijd?***
❍ eigen wijk
❍ omringende wijken (geen stadscentrum)
❍ stadscentrum Amersfoort
❍ elders in Amersfoort
❍ stadscentrum Utrecht
❍ ander plaats, namelijk .....

63. ***Met welk vervoermiddel gaat u meestal naar deze locatie?***
❍ auto
❍ trein
❍ bus
❍ motor/brommer/scooter
❍ fiets
❍ lopen
❍ ander vervoermiddel, namelijk...

64. ***Hoe vaak bezoekt u sport−/recreatieve voorzieningen waar u zelf actief bent (bijv. sporthal, sportpark, zwembad, overige sportvoorzieningen, speeltuin)?***
❍ één of meerdere keren per week, namelijk:
❍ één of meerdere keren per maand, namelijk:
❍ één of meerdere keren per jaar, namelijk:
❍ zelden of nooit
−> Indien u minder dan 1x per maand sport−/recreatieve voorzieningen bezoekt, kunt u doorgaan met vraag 67

65. ***Waar bezoekt u meestal een sport/recreatieve voorziening?***
❍ eigen wijk
❍ stadscentrum Amersfoort
❍ elders in Amersfoort
❍ Utrecht (stad)
❍ ander plaats,
❍ namelijk .....

66. ***Met welk vervoermiddel gaat u meestal naar deze locatie?***
❍ auto
❍ trein
❍ bus
❍ motor/brommer/scooter
❍ fiets
❍ lopen
❍ ander vervoermiddel, namelijk...
−> Indien u geen thuiswonende kinderen heeft, kunt u doorgaan met vraag 69

67. ***Hoe vaak brengt/haalt u uw kinderen ergens naartoe/vandaan?***
Wanneer u uw kind ergens naar toe brengt en later weer ophaalt telt dat als één keer
❍ één of meerdere keren per week, namelijk:
❍ één of meerdere keren per maand, namelijk:
❍ één of meerdere keren per jaar, namelijk:
❍ zelden of nooit

68. ***Welk vervoermiddel gebruikt u meestal om uw kind(eren) weg te brengen of op te halen?***
❍ auto
❍ trein
❍ bus
❍ motor/brommer/scooter
❍ fiets
❍ lopen
❍ ander vervoermiddel, namelijk...

69. ***Hoe vaak reist u met de trein?***
Een retourreis telt als één keer.
❍ één of meerdere keren per week, namelijk:
❍ één of meerdere keren per maand, namelijk:
❍ één of meerdere keren per jaar, namelijk:
❍ zelden of nooit
–> Indien u minder dan 1x per maand met de trein gaat, kunt u doorgaan met vraag 72

70. ***Naar welk treinstation gaat u meestal vanuit uw woning?***
❍ station Amersfoort Centraal
❍ station Amersfoort Schothorst
❍ een ander station, namelijk...

71. ***Met welk vervoermiddel gaat u meestal naar dit station?***
❍ auto
❍ bus
❍ motor/brommer/scooter
❍ fiets
❍ lopen
❍ ander vervoermiddel, namelijk...

72. ***Hoe vaak reist u met de bus?***
Een retourreis telt als één keer.
❍ één of meerdere keren per week, namelijk:
❍ één of meerdere keren per maand, namelijk:
❍ één of meerdere keren per jaar, namelijk:
❍ zelden of nooit

73. ***Wilt u aangeven in welke mate u het met onderstaande stellingen eens bent?***
Hoewel de stellingen onderling soms niet veel van elkaar lijken te verschillen, zijn ze toch allemaal nodig om uw 'algemene' oordeel te kunnen berekenen.

	helemaal mee eens	mee eens	niet mee eens/niet mee oneens	mee oneens	helemaal mee oneens
Het ondernemen van vrijetijdsactiviteiten buitenshuis (b.v. sporten, vrienden bezoeken, schouwburg) is erg belangrijk voor mij					
De vrijetijdsactiviteiten die ik buitenshuis onderneem (b.v. sporten, vrienden bezoeken, schouwburg) bepalen voor een groot gedeelte mijn levensgeluk					
Het is belangrijk voor mij om voldoende tijd vrij te maken voor het buitenshuis ondernemen van vrijetijdsactiviteiten (b.v. sporten, vrienden bezoeken, schouwburg)					
Het ondernemen van vrijetijdsactiviteiten thuis (bijv. lezen, tv kijken, computeren), is erg belangrijk voor mij					
De vrijetijdsactiviteiten die ik thuis (bijv. lezen, tv kijken, computeren) onderneem bepalen voor een groot gedeelte mijn levensgeluk					
Het is belangrijk voor mij om voldoende tijd vrij te maken voor het thuis ondernemen van vrijetijdsactiviteiten (bijv. lezen, tv kijken, computeren)					
Reistijd is niet per definitie verspilde tijd					
Het enige positieve aan reizen is het aankomen op je bestemming					
Ik verveel me vaak wanneer ik lang moet reizen om ergens naar toe te gaan					

Woonlocatie: belang en tevredenheid

Dit deel van de vragenlijst gaat over hoe belangrijk u de afstand vanuit uw woning naar verschillende locaties vindt en hoe tevreden u over uw woonlocatie bent.

74. ***Stel u bent op zoek naar een woning. Hoe belangrijk is dan de afstand tot:***
Het gaat om uw persoonlijke mening en niet om de mening van eventuele huisgenoten.

	zeer belangrijk	belangrijk	niet belangrijk /niet onbelangrijk	onbelangrijk	zeer onbelangrijk
uw belangrijkste werk/schoollocatie					
school van de kinderen					
winkels dagelijkse boodschappen (supermarkt, groenteboer, bakker, etc.)					
overige winkels (geen dagelijkse boodschappen)					
vrienden en/of familie					
horecavoorzieningen (restaurant, café, bar, discotheek)					
culturele of andere voorziening als toeschouwer (bioscoop, schouwburg,					
concert, museum, sportwedstrijd)					
sport−recreatieve voorzieningen als deelnemer (sporthal, sportpark, zwembad, speeltuin, etc.)					
overige georganiseerde activiteiten (kerk, politieke bijeenkomsten, hobbyclubs, etc.)					
groengebieden (park, bos, open gebied)					
treinstation					

75. ***Hoe tevreden bent u op dit moment bent over de afstand tot:***

	zeer tevreden	tevreden	niet tevreden/niet ontevreden	ontevreden	zeer ontevreden
uw belangrijkste werk/schoollocatie					
school van de kinderen					
winkels dagelijkse boodschappen (supermarkt, groenteboer, bakker, etc.)					
overige winkels (geen dagelijkse boodschappen)					
vrienden en/of familie					
horecavoorzieningen (restaurant, café, bar, discotheek)					
culturele of andere voorziening als toeschouwer (bioscoop, schouwburg,					
concert, museum, sportwedstrijd)					
sport−recreatieve voorzieningen als deelnemer (sporthal, sportpark, zwembad, speeltuin, etc.)					
overige georganiseerde activiteiten (kerk, politieke bijeenkomsten, hobbyclubs, etc.)					
groengebieden (park, bos, open gebied)					
treinstation					

76. ***Kunt u in onderstaande tabel aangeven welke locaties u als gevolg van een te lange reistijd minder vaak bezoekt dan u zou willen en/of met een ander vervoermiddel dan u zou willen? En wanneer dit het geval is, welk vervoermiddel uw voorkeur zou hebben***? (de vragen zijn alleen gesteld bij ontevredenheid over de afstand tot de betreffende locatie)

	minder vaak bezocht dan gewenst	ander vervoermiddel dan gewenst	gewenst vervoermiddel	
uw belangrijkste werk/schoollocatie	❍ ja ❍ nee	❍ ja ❍ nee	❍ auto ❍ trein ❍ bus ❍ motor/brommer /scooter	❍ fiets ❍ lopen ❍ anders
school van de kinderen	❍ ja ❍ nee	❍ ja ❍ nee	❍ auto ❍ trein ❍ bus ❍ motor/brommer /scooter	❍ fiets ❍ lopen ❍ anders
winkels dagelijkse boodschappen (supermarkt, groenteboer, bakker, etc.)	❍ ja ❍ nee	❍ ja ❍ nee	❍ auto ❍ trein ❍ bus ❍ motor/brommer /scooter	❍ fiets ❍ lopen ❍ anders
overige winkels (geen dagelijkse boodschappen)	❍ ja ❍ nee	❍ ja ❍ nee	❍ auto ❍ trein ❍ bus ❍ motor/brommer /scooter	❍ fiets ❍ lopen ❍ anders
vrienden en/of familie	❍ ja ❍ nee	❍ ja ❍ nee	❍ auto ❍ trein ❍ bus ❍ motor/brommer /scooter	❍ fiets ❍ lopen ❍ anders
horecavoorzieningen (restaurant, café, bar, discotheek)	❍ ja ❍ nee	❍ ja ❍ nee	❍ auto ❍ trein ❍ bus ❍ motor/brommer /scooter	❍ fiets ❍ lopen ❍ anders
culturele of andere voorziening als toeschouwer (bioscoop, schouwburg,	❍ ja ❍ nee	❍ ja ❍ nee	❍ auto ❍ trein ❍ bus ❍ motor/brommer /scooter	❍ fiets ❍ lopen ❍ anders
concert, museum, sportwedstrijd)	❍ ja ❍ nee	❍ ja ❍ nee	❍ auto ❍ trein ❍ bus ❍ motor/brommer /scooter	❍ fiets ❍ lopen ❍ anders
sport−recreatieve voorzieningen als deelnemer (sporthal, sportpark, zwembad,	❍ ja ❍ nee	❍ ja ❍ nee	❍ auto ❍ trein ❍ bus	❍ fiets ❍ lopen ❍ anders

speeltuin, etc.)			❍ motor/brommer /scooter	
overige georganiseerde activiteiten (kerk, politieke bijeenkomsten, hobbyclubs, etc.)	❍ ja ❍ nee	❍ ja ❍ nee	❍ auto ❍ trein ❍ bus ❍ motor/brommer /scooter	❍ fiets ❍ lopen ❍ anders
groengebieden (park, bos, open gebied)	❍ ja ❍ nee	❍ ja ❍ nee	❍ auto ❍ trein ❍ bus ❍ motor/brommer /scooter	❍ fiets ❍ lopen ❍ anders
treinstation	❍ ja ❍ nee	❍ ja ❍ nee	❍ auto ❍ trein ❍ bus ❍ motor/brommer /scooter	❍ fiets ❍ lopen ❍ anders

Stellingen over uw levensinstelling

De onderstaande stellingen gaan over hoe belangrijk het voor u is om een carrière, kinderen, een partner en een goed georganiseerd huis(houden) te hebben. De uitkomsten van deze vraag maken bijvoorbeeld duidelijk of mensen die hun carrière zeer belangrijk vinden, bereid zijn een langere woon−werkreistijd te hebben dan mensen die hun carrière minder belangrijk vinden.

− Hoewel de stellingen onderling soms niet veel van elkaar lijken te verschillen, zijn ze toch allemaal nodig om uw 'algemene' oordeel te kunnen berekenen.

− Ook als u op dit moment geen partner hebt of geen ouder bent, wordt u verzocht voor alle stellingen aan te geven in welke mate u het er mee eens bent.

− Het gaat om uw mening op dit moment. Als u bijvoorbeeld gepensioneerd bent, vindt u het op dit moment waarschijnlijk niet meer belangrijk om een succesvolle carrière te hebben, terwijl uw dat vroeger mogelijk wel belangrijk vond.

77. ***Wilt u aangeven in welke mate u het met onderstaande stellingen eens bent?***

	helemaal mee eens	mee eens	niet mee eens/niet mee oneens	mee oneens	helemaal mee oneens
De liefde en het plezier van het hebben van kinderen, zijn alle opofferingen die het ouderschap met zich meebrengt, waard					
Ik vind het belangrijk om het gevoel te hebben dat ik een goede ouder ben/zal zijn					
Het hele idee van het krijgen en opvoeden van kinderen spreekt me niet aan					
Mijn belangrijkste levensdoel is het hebben van een interessante en uitdagende baan/carrière					
Ik vind het belangrijk om een baan te hebben waarmee ik iets kan bereiken					
Ik vind het belangrijk om me succesvol te voelen in mijn werk/carrière					
Een succesvol(le) huwelijk/vaste relatie is het belangrijkste in mijn leven					
Getrouwd zijn/een vaste relatie hebben met een persoon waar ik van houd is belangrijker voor mij dan al het andere					
Ik verwacht dat de grootste voldoening in mijn leven voortvloeit uit mijn huwelijk/vaste relatie					
Het is belangrijk voor mij om een huis te hebben waar ik trots op kan zijn					
Ik vind het erg belangrijk om een comfortabel en aantrekkelijk huis te hebben					
Ik hecht veel waarde aan het hebben van een prettig huis					

Persoonlijke gegevens

U bent nu bijna aan het eind van de vragenlijst gekomen. Er volgen nog enkele vragen naar uw persoonlijke gegevens:

78. ***Wat is uw geboortejaar?***

79. ***Wat is uw geslacht?***
❍ Man
❍ Vrouw

80. ***Wat is uw hoogst voltooide opleiding?***
❍ lager onderwijs en/of lager beroepsonderwijs (o.a. basisonderwijs, lbo, mavo, mulo, vmbo)
❍ middelbaar onderwijs en/of middelbaar beroepsonderwijs (o.a. mbo, havo, vwo, mms, hbs)
❍ hoger beroepsonderwijs of universiteit

81. ***Wilt u aangeven in welke categorie uw persoonlijk netto maandinkomen ligt?***
❍ minder dan € 500,–
❍ € 500,– tot € 1000,–
❍ € 1000,– tot € 1500,–
❍ € 1500,– tot € 2000,–
❍ € 2000,– tot € 2500,–
❍ € 2500,– tot € 3000,–
❍ € 3000,– of meer
❍ weet ik niet
❍ wil ik niet zeggen

GPS–onderzoek
Tenslotte willen wij vragen of u bereid bent om mee te werken aan het vervolgonderzoek waarin het verplaatsingsgedrag van inwoners van Amersfoort, Veenendaal en Zeewolde gemeten zal worden met behulp van een GPS-ontvanger. Wij willen graag weten welke routes mensen volgen wanneer ze onderweg zijn naar bepaalde voorzieningen en hoe lang de werkelijke reistijden op verschillende routes zijn. Een GPS-ontvanger kan deze gegevens automatisch registreren door regelmatig de huidige positie te bepalen aan de hand van satellieten.

Wat wordt van u gevraagd?
De deelnemers zullen in januari, februari of maart een week lang een GPS-ontvanger om hun pols of in een tas met zich meedragen. Halverwege en aan het eind van de week wordt van u gevraagd om de data die in de GPS-ontvanger opgeslagen zijn, in uw computer te zetten. Hierna verschijnt een kaartje waarop u kunt zien waar u de afgelopen dagen bent geweest. De GPS-ontvangers worden bij u langsgebracht en opgehaald. Bij het langsbrengen zult u ook geinformeerd worden over de werking van de ontvanger. De verzamelde gegevens zullen anoniem en in overeenstemming met de wet op de privacy verwerkt worden. Wij hopen dat u mee wilt werken aan deze vernieuwende manier van onderzoek!

Onder de deelnemers aan dit onderzoek zullen 5 GPS-ontvangers verloot worden!!
Daarnaast is het voor alle deelnemers mogelijk om na afloop van het onderzoek een GPS-ontvanger voor de helft van de prijs te kopen (zolang de voorraad strekt).

82. ***Wilt u meewerken aan het GPS-onderzoek?***
❍ ja
❍ nee

83. ***Wilt u indien u mee wilt werken aan het GPS-onderzoek, hieronder uw naam, telefoonnummer en e-mailadres intypen zodat wij u kunnen benaderen voor het maken van een afspraak voor het langsbrengen van de GPS-ontvanger?***
Deze gegevens zullen uitsluitend gebruikt worden om u voor het GPS-onderzoek te benaderen.
Naam:
Telefoonnummer:
E−mailadres:

84. ***Heeft u nog op- of aanmerkingen naar aanleiding van deze vragenlijst?***

85. ***Indien u mee wilt doe aan verloting van de kadobonnen wilt u dan hieronder uw adresgegevens invullen?***
Deze gegevens zullen uitsluitend gebruikt worden voor het versturen van de cd/dvd−bonnen.
Naam:
Straat en huisnr:
Postcode:
Plaats:

Hartelijk dank voor uw medewerking aan dit onderzoek!!!

Wilt u op de hoogte blijven van de voorgang van het onderzoek?
Bezoek dan af en toe: www.verplaatsingsgedrag.nl

Evaluation GPS survey

Mogelijk heeft u in het afgelopen half jaar een aantal veranderingen meegemaakt die van invloed zijn op uw verplaatsingsgedrag.

1. ***Kunt u hieronder aangeven welke veranderingen u in het afgelopen half jaar heeft meegemaakt?***
❑ verhuizing naar een andere woning
❑ verandering van werklocatie
❑ verandering van werklocatie door partner
❑ u bent meer gaan werken, het totaal aantal uur is nu:
❑ u bent minder gaan werken, het totaal aantal uur is nu:
❑ uw partner is met u gaan samenwonen
❑ scheiding / u en uw partner zijn uit elkaar gegaan
❑ geboorte kind(eren)
❑ laatste kind(eren) is/zijn het huis uitgegaan
❑ het huishouden is over een (extra) auto komen te beschikken, het aantal auto's is nu:
❑ het huishouden is over minder auto's komen te beschikken, het aantal auto's is nu:
❑ een andere belangrijke verandering, namelijk:
❑ geen belangrijke veranderingen

De volgende vragen worden gesteld ter evaluatie van de in het onderzoek gebruikte GPS–methode voor het meten van verplaatsingsgedrag.

2. ***Vond u het belastend om de GPS–ontvanger de hele dag bij u te dragen?*** Indien u het belastend vond, kunt u dit dan toelichten?
❍ erg belastend, omdat ...
❍ enigszins belastend, omdat .....
❍ nee

3. ***Vond u het lastig er aan te denken om de GPS–ontvanger altijd mee te nemen?***
❍ ja, het aantal keer dat ik hem vergat is:
❍ ja, maar ik ben hem nooit vergeten
❍ nee

4. ***Vond u het belastend om de GPS–ontvanger 's avond te moeten opladen?*** Indien u het belastend vond, kunt u dit dan toelichten?
❍ erg belastend, omdat ...
❍ enigszins belastend, omdat .....
❍ nee

5. ***Vond u het lastig er elke avond aan te denken om de GPS–ontvanger op te laden?***
❍ ja, het aantal keer dat ik dit vergat is:
❍ ja, maar ik ben het nooit vergeten
❍ nee

6. ***Vond u het lastig om de door u gemaakte trips in de webapplicatie te controleren en aan te vullen?*** Indien u het lastig vond, kunt u dit dan toelichten?
❍ erg lastig, omdat ...
❍ enigszins lastig, omdat .....
❍ nee

7. ***Hoe lang was u ongeveer bezig met het controleren en aanpassen van uw gegevens in de webapplicatie?***
aantal minuten:

8. ***Hoe volledig denkt u dat u de door u gemaakte trips in de webapplicatie heeft kunnen controleren en aanpassen?***
❍ (vrijwel) volledig
❍ grotendeels wel
❍ gedeeltelijk wel/gedeeltelijk niet
❍ grotendeels niet
❍ helemaal niet

Tenslotte willen we u nog vragen om uw lengte en gewicht in te vullen. Deze gegevens gaan we gebruiken om de relatie tussen de inrichting van wijken en de hoeveelheid lichamelijk beweging van mensen te onderzoeken. Hiermee willen wij een bijdrage leveren aan de recente discussie over wijkinrichting, verplaatsingsgedrag en overgewicht. Wij beseffen dat uw lengte en gewicht heel persoonlijke informatie is en het verstrekken hiervan gevoelig kan liggen. In het belang van het onderzoek hopen wij dat u ons de juiste gegevens wilt geven. De door u verstrekte gegevens worden uiteraard strikt vertrouwelijk en anoniem behandeld en de uitkomsten worden zodanig gepresenteerd dat ze onmogelijk tot individuele personen zijn terug te voeren. Als u desondanks deze gegevens niet aan ons wilt doorgeven, kunt u de vragen overslaan door op ' verder' te klikken.

9. ***Hoe lang bent u en hoeveel kilo weegt u?***
lengte in cm:
gewicht in kg:

10. ***Heeft u nog opmerkingen of suggesties ter verbetering van de onderzoeksmethode?***

Curriculum vitae

Wendy Bohte was born on 20 September 1977 in Amsterdam. In 1995, she began studying Human Geography at Utrecht University, where she specialised in Urban Geography and attained her Master's degree in 2000. During her studies, she spent three months at the University of Oslo in 1997 and subsequently spent a further three months at Stockholm University studying Economic Geography. In 2001, she worked at the Ministry of Housing, Spatial Planning and the Environment as a member of the design studio 4DCITY. From 2002 to 2004, she worked as a researcher for the municipality of Zoetermeer, where she was involved in research projects on housing, travel, governance and the liveability and safety of neighbourhoods. In 2004 she took a PhD position at the Urban and Regional Development Section of the OTB Research Institute for the Built Environment at Delft University of Technology. She is currently working as a post-doc at the Faculty of Technology, Policy and Management of Delft University of Technology. Her research is part of the project 'Synchronising networks', a project that is part of the NWO's 'Sustainable Accessibility in the Randstad' program. The project focuses on how accessibility in the Randstad could be improved by synchronising the networks of passenger mobility, activity locations, and activity patterns in time, space and virtual space.

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Most Western national governments aim to influence individual travel patterns – at least to some degree – through the spatial planning of residential areas. Nevertheless, the extent to which the characteristics of the built environment influence travel behaviour remains the subject of debate among travel behaviour researchers. This thesis addresses the role of residential self-selection, an important issue within this debate. Households may not only adjust their travel behaviour to the built environment where they live, but they may also choose a residential location that corresponds to their travel-related attitudes. The empirical analysis in this thesis is based on data collected through an internet survey and a GPS-based survey, both of which were conducted among homeowners in three centrally located municipalities in the Netherlands. The study showed that residential self-selection has some limited effect on the relationship between distances to activity locations and travel mode use and daily kilometres travelled. The results also indicate that the inclusion of attitudes can help to detecting residential self-selection, provided that studies comply with several preconditions, such as the inclusion of the 'reversed' influence of behaviour on attitudes.

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