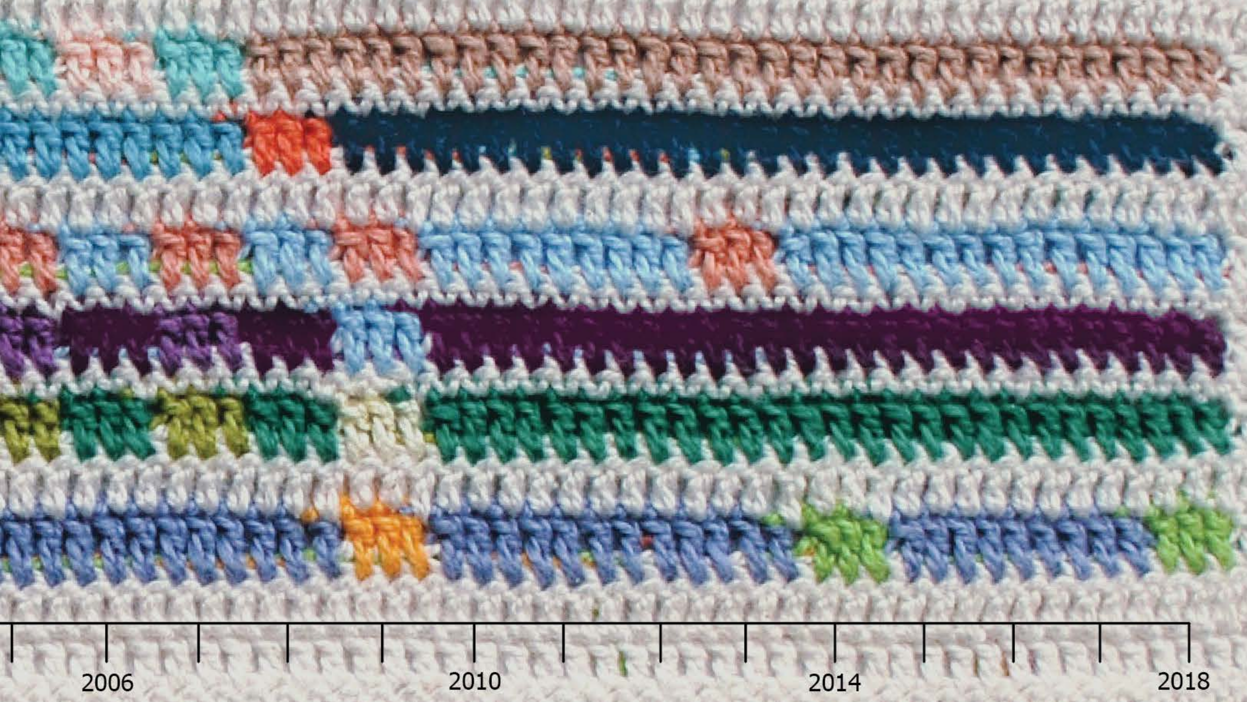
Effects of the built environment on dynamic repertoires of activity-travel behaviour



Effects of the Built Environment on Dynamic Repertoires of Activity-Travel Behaviour

Aida Paula Pontes de Aquino

/ Department of the Built Environment

bouwstenen 250

Effects of the built environment on dynamic repertoires of activity-travel behaviour

PROEFSCHRIFT

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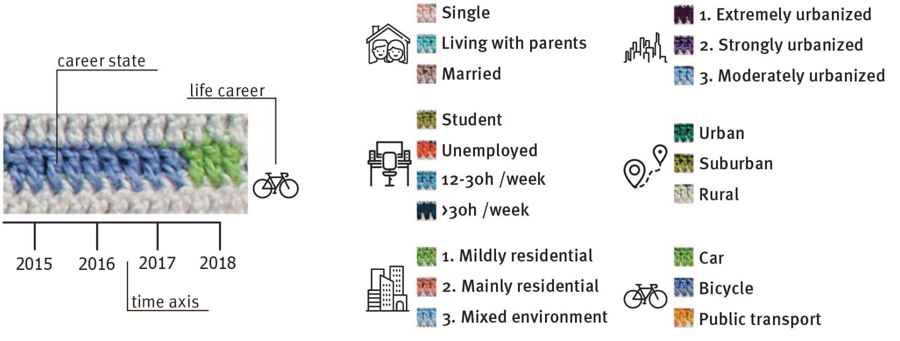
About the cover

The cover image is a visualization of the last 20 years of my life trajectory. It is a crocheted version of the visualization I use in this thesis to analyse data from the 350 respondents of my questionnaire. Each horizontal bar represents one life career studied in this thesis. The figure below explains how to read this visualization.



The use of the crochet technique to make the cover fully represents my PhD journey. During the years I've lived in Eindhoven, it was held in my home what we called the more than crochet group. Three friends asked me once to teach them how to crochet, and we began as a small group that after some months grew to evenings with more than 20 people at my home, having dinner and learning how to crochet. As we had weekly meetings, the reunion had a high importance for the life of those that were part of it. This cover is, thus, an homage to this group.

Crochet is a handicraft needle work, usually made by grandmothers. By the way, it helped me a lot to have conversations with elder women – and thus practice my poor Dutch – during some train trips.

Acknowledgements

The path undertaken to reach the end of this thesis was like a crochet project: after some lines stitched, it was necessary to undo many of the stitches to make it again correctly. In the end, some imperfections can still be seen, and the project is finalized with a different shape than expected. However, the stitches that were crocheted throughout this project matter less than the people who have joined me to make this project complete.

First of all, I would like to thank Professor Harry Timmermans, for the opportunity, inspiration and for always letting me choose my own way - this was always the best advice. You have taught me much.

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My fellows PhD students Fariya, Widi, Gamze, Sehnaz, Sareh, Elaheh, Soora, Dujuan, Feixiong, Oliver, Pauline, Marloes and all others. Thank you for our chat, coffees, and companionship inside and outside the Vertigo building. In particular, thank you Fariya for the conversations trying to find our ways throughout the PhD and our life trajectories.

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Alexey, Carol, Daniel, and Rubina, together with Anastasia and Nicole, you have been my family in the Netherlands. If there is a good reason why I went to the Netherlands do a PhD, the reason was to meet you.

Thanks for the More than Crochet people: Kristi, Lesly, Lale, Ioana, Gordon, Dominique, Guille, Karina, Francisco, Ale, Mei, Dominika, Ana Karla, Fernanda, Matias, John, and Nopi. One paragraph is not enough to explain the importance you had on my life, stitching, eating, and bringing warmth to my heart. The cold of the Netherlands was much milder with you filling my small living room and kitchen

Many parts of this thesis were written in Brazil. During those years I had the support of many friends. I would like to specially thank Pedro and Bea, for the help, but also making me forget the thesis when it was necessary. Also thanks to my friends from IAB and Unifacisa, specially Natália, Fabiano, and Mariana. My roommates in João Pessoa Laura, Iale, and Shiko, thank you for the loving daily routine. Finally, thanks to all researchers from LabRua, you are those who believed the most that it was going to work out (VDC!).

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Summary

Effect of the built environment on dynamic repertoires of activity-travel behaviour

Designing and shaping cities to trigger people to travel in a more sustainable way is an objective pursued for long in the fields of urban planning, urban design and transportation. To ground this design decision, the study of the relationship between urban form and (facets of) activity-travel patterns has received an overwhelming amount of attention in different fields of research. There are many papers and studies that have been published on this subject. Yet, these studies have resulted in conflicting outcomes: some studies claim to have found evidence of a significant relation between characteristics of urban form and particular aspects of travel behaviour, such as mode choice or distance travelled, while others report that this relationship is statistically insignificant.

On a different strand of work, studies on how life trajectory affects activity-travel behaviour demonstrate that people are less prone to change their travel behaviour after a certain stage of life. According to this research, it follows that urban planners should concentrate efforts on creating urban policies that target earlier stages of people's lives. Similarly, residential choice research demonstrates that for house choice, the characteristics of the house itself are usually more important than those of the urban form of the neighbourhood. Accessibility considerations, on average, play a much less important role.

Therefore, this thesis argues that there is a potential of examining the relationship between urban form and activity-travel behaviour in the larger context of a life trajectory approach. During a life course, individuals and households develop various careers: housing career, job career, mobility career, etc. Dynamic activity-travel patterns can be understood as short-term actions that should largely be consistent with these careers and their underlying plans, and that may be driven by a combination of these careers. This means that the study of the relationship between urban form and travel behaviour should be captured in this larger context – life events happening in people’s life might influence their choices of both residential location and activity-travel behaviour. According to this hypothesis, the built environment mediates the effects of life trajectory events on activity-travel behaviour.

To investigate this hypothesis, longitudinal data were collected about the life course of people and changes in their travel behaviour. Using a retrospective questionnaire, the survey covered the 20-year period from 1992 to 2011 and was carried out in the Rotterdam area, the Netherlands. Complementary, urban form data from different sources were also collected and processed using GIS software.

The direct and indirect effects of the relationships between life trajectory, built environment and activity-travel behaviour were analysed using Linear Mixed Models, Generalized Linear Models, and Generalized Structural Equation Models. Single-predictor regression and multivariate analyses were conducted for four different aspects of activity-travel behaviour: car use to seven different destinations, commuting mode choice, grocery shopping mode choice, and leisure shopping mode choice.

Overall, results support the hypothesis that the dynamics of the relationship between life trajectory, built environment and activity-travel behaviour can be understood as life trajectory affecting activity-travel behaviour with the built environment mediating this relationship. The role of the built environment is not prominent for commuting mode choice in our study, but it is clearly observed when one considers mode choice for groceries and shopping, or the overall car use for different activities. Such results call for the need of considering such indirect dynamics when studying activity-travel behaviour and inform urban planners about the effect of different urban designs.

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Introduction

1.1 Motivation

There is a worldwide concern about sustainability and how transport behaviour impacts the environment. In this context, a central aspiration related to travel behaviour is to seek solutions that reduce car use and increase the use of greener transport modes, such as walking, cycling, and public transportation. In this search for more sustainable transportation, different countries have put in place urban policies to encourage people to reduce the car use. In the USA, in spite of the existence of a strong culture prioritizing the use of the car, as a manifestation of the New Urbanism movement, several cities are introducing a bike network to foster a change in transport mode towards the bicycle: Different cities are also investing in public spaces to make the city more inviting for pedestrians, and putting in place systems to prioritize public transportation modes.

A similar path has been followed by some of the so-called developing countries – such as Brazil and other Latin American countries. Even though these countries have traditionally put considerably effort in fomenting car use and road infrastructure, some are nowadays seeking strategies to reduce car use, trying to implement public policies that would foment the growth of public transportation and bicycle networks. An example of such policies is the recent Brazilian Urban Mobility Law that came into force in 2012. This law sets the priority for pedestrian, bicycle, and public transportation over motorized transport modes in Brazilian city developments. European countries, although very diverse, often have efficient public transportation services compared to other countries. Nevertheless, they are largely concerned about reducing the impacts of urban structure imprints on our planet.

A common belief in the fields of urban planning, urban design and transportation is that the way we design and shape our cities plays a significant role in developing more sustainable travel behaviour (see for example Gehl, 2010). It is commonly believed that high-density cities, with mixed land uses, good public transportation services, and a good bicycle infrastructure induce people to drive less, walk and cycle more, and use more public transportation.

Based on this assumption, the study of the relationship between urban form and (facets of) activity-travel patterns has received an overwhelming amount of attention in different fields of research. Literally thousands of papers and studies have been published on this subject. Yet, this stream of research has led to conflicting outcomes: some studies claim to have found evidence of the significance of the relationship between characteristics of urban form and particular aspects of travel behaviour, such as mode choice or distance travelled, while others report that this relationship is statistically insignificant. There is no consensus about how and to what extent the built environment affects activity-travel behaviour. Some of the positive results can be attributed to questionable research design, which shows more signs of advocacy than of objective academic research. Another limitation of this stream of research in general is that the relationship between urban form and activity-travel behaviour is not embedded in the larger context of how people organise their lives.

This thesis argues that there is a potential and relevance in examining the subject matter in the larger context of a life trajectory approach. According to this premise, both the built environment and activity-travel behaviour are affected by life events that occur through individuals and households' life trajectory. Life events are the building blocks and cornerstones of how individuals shape their lives. During a life course, individuals and households develop various careers: housing career, work career, mobility career etc. To follow these careers, people take actions and decisions that are consistent with their underlying personal plans. People choose the place where they are going to live according to their needs – e.g. need for a bigger house for the family – and constraints – e.g. budget constraints. As residential choice research demonstrates, when choosing a house, the characteristics of the house itself are usually more important than those of the neighbourhood, and accessibility considerations, on average, play a much lesser role. Daily decisions regarding job location and transportation mode are made considering the effects on all these life domains. We argue that the relationship between the built environment and activity-travel behaviour should thus consider events happening in the life of people that might trigger changes not only in their residential location, but also in their activity-travel behaviour.

Therefore, this thesis resorts to a longitudinal analysis of the relationship between life trajectory, built environment and activity-travel behaviour. Collecting and examining longitudinal data about people's life careers allows us to better characterize and model how the relevant events for activity-travel behaviour unfold over life trajectories. Because the dynamics of a household career develop over years, a longitudinal analysis is necessary to understand typical trajectories and the interplay among different careers.

1.2 Research goals

The main goal of this thesis is to examine the relationship between the built environment and activity-travel behaviour considering people's life trajectory and adopting a longitudinal perspective. More specifically, our objectives are:

- Test our hypothesis on longitudinal data spanning decades of individuals' life;
- Characterize the dynamics of household, work status, and housing careers, as well as activity-travel behaviour of a diverse sample of individuals in the Netherlands;
- Develop a method for the analysis of the built environment considering buffers of 1km around respondents' dwellings, allowing for a more precise interpretation of the characteristics of the residential location than neighbourhood-based approaches;
- Evaluate the direct and indirect relationships between aspects of the life trajectory, the built environment and activity-travel behaviour.

Hence, this thesis contributes to answer research questions such as: What are the triggers for an individual to choose a transport mode? To what extent do aspects of the built environment, such as density and mixed land use affect people's transportation mode choice? If the choice of housing location is triggered by life trajectory aspects, such as household and work career, and these choices affect people's activity-travel behaviour, what is the role of the built environment in this context?

1.3 Thesis outline

The thesis is structured as follows: Chapter 2 discusses the relevant literature on the five key aspects of this thesis: studies on the relationship between the built environment and travel behaviour; studies on attitudes, lifestyle and self-selection; studies on housing career and lifecycle; studies that on the relationship between life trajectory, housing career and travel behaviour; and studies that integrate a dynamic perspective on those aspects. Based on a critical assessment of this literature, it also develops the conceptual framework underlying this study. It situates the relationship between urban form and travel behaviour in the proposed larger context: the life trajectory approach. This chapter shows how the different life careers are related to each other and to the relationship between the built environment and activity-travel behaviour.

Chapter 3 describes the data collection used to obtain data needed for the life trajectory and mobility aspects of the analyses. A 20-year retrospective paper-based questionnaire was designed and administered in 25 municipalities of the Rotterdam area. An overview of the data collected is presented, including a detailed descriptive analysis of the different careers encompassed in the life trajectories. The careers considered in this thesis are: household career, work career, housing career, and mobility career. Socio-demographic information of the respondents is also described in this chapter.

The data used about the built environment features for the analysis are detailed in Chapter 4. Three main aspects of the built environment were collected from different sources: density, land use and accessibility. Data were collected from different governmental sources and OpenStreetMaps, and the built environment characteristics were calculated at the respondent level. This chapter also provides a descriptive analysis of the longitudinal data computed for the respondents' housing career. As such, it provides a picture of the dynamics of the built environment over respondents' life trajectories.

Chapter 5 investigates the direct and indirect effects of the relationships between life trajectory, built environment and activity-travel behaviour. Generalized Structural Equation Models are used to perform a path analysis and examine such relationships. overall our results point at a mediating role for the built environment in the relationship between life trajectory, built environment and activity-travel behaviour. Although this mediating role is not seen for commuting behaviour, it is significant when considering respondents' car use for other trip destinations.

Finally, Chapter 6 discusses the major findings and contribution of this thesis, along with its limitations. Suggestions for future research are formulated.

2

Adding life trajectories to the study of the relationship between urban form and travel behaviour

2.1 Introduction

The analysis of the relationship between urban form and activity-travel patterns has been extensively studied during the past decades. Thousands of papers and studies must have been published on this subject in different fields of research, such as transportation, urban design, and urban planning. To date, however, there is no common view about if and how features of urban form affect the way people travel in cities.

Due to the lack of common results, researchers have also looked at other relationships that might affect people's travel behaviour, such as investigations on how attitudes and lifestyles affect travel behaviour and housing location. Researchers have argued that attitudes and lifestyles related to travel might affect travel and housing choices. The amount of research on this relationship incorporating attitudes and lifestyles is not sufficient yet to fully explain the triggers that affect people's activity-travel behaviour. Moreover, the exact meaning of the concept of lifestyle is still open for discussion.

The evolving line of research on the importance of lifestyles can be understood by the concern that evidence on the relationship between urban form and travel behaviour may not be valid and that the relationship is spurious. A particular lifestyle may be manifested in the choice of urban residential locations and in the use of the bicycle or public transportation to conduct activities. If this is the case, then any statistically significant relationship between urban form and travel behaviour has not meaning in term of causality but should be explained in terms of lifestyle.

Although we do not deny the relevance of lifestyle research, we argue that a more fundamental approach with the same intention of broadening the scope of analysis is the life trajectory approach. This approach emphasizes the notion that people's lives involve different life cycle domains and that life events and new opportunities affecting current routines that trigger people to reconsider their current routines are judged against the implications in all life domains. Moreover, there is a body of research studying how housing location is affected by the life trajectory of the household. Decisions to move to a new place are influenced by family context, and transportation attributes are less important than the house itself. Complementary to the examination of how lifecycle affects housing choices, studies on the effects of lifecycle and life trajectory on travel behaviour show that life trajectories are considerably connected to some aspects of travel behaviour.

The hypothesis put forward in this thesis is that the influence of life trajectory on activity-travel behaviour is a determinant one, and that urban form characteristics are a mediator in this relationship. If confirmed, this hypothesis can complement the current understanding of how people travel in the city and how results from previous studies can be reconciled, at least partially.

This chapter gives a critical review of the most important literature related to our hypothesis, and explains our conceptual framework.

2.2 Literature review

In this section, the body of research studied in this thesis is divided into five groups. First, the studies on the relationship between features of the urban form and aspects of activity-travel behaviour are discussed. Then, there is an overview of the studies about attitudes, lifestyle, and self-selection. Third, the housing career and lifecycle studies are examined. Next, we discuss studies on the relationship between life trajectory, housing career and travel behaviour. Finally, we present studies that integrate a dynamic perspective when investigating the relationship between life trajectory and activity-travel behaviour.

2.2.1 Urban form and travel behaviour

An examination of the relevant literature suggests that the definition of urban form varies widely in the literature on the relationship between urban form and travel. According to the dominant view in urban design and urban planning, form is a term used specifically for morphology. It refers primarily to the urban design literature with a focus on different forms (grid, radial, etc.) for the design of cities, neighbourhoods and transportation systems. In contrast, urban function refers to the set of functions available in a neighbourhood or within some distance or travel time band.

This distinction between urban form and urban function is important from the perspective of interpreting the results of analyses. A focus on urban form implicitly involves a test of the hypothesis that different morphologies will induce particular behaviours. This seems a rather indirect relationship. In contrast, a focus on urban functions implies examining a more direct relationship in the sense that activity participation and travel behaviour by definition involve activity locations and therefore urban functions.

Studies on urban form

Considering this distinction, a number of studies has examined the influence of urban form on travel behaviour. Most of these studies analysed the difference between neighbourhoods (or cities) according to the characteristics of the street network. Usually this difference is related to the question whether the neighbourhood had either a grid-like or a cul-de-sac street network. In a few cases, the research included neighbourhoods that had a mix of these two characteristics (e.g. Crane & Crepeau 1998; Schwanen & Mokhtarian 2005).

Some studies found a significant relationship between urban form and travel behaviour. Cervero and Radisch (1996) concluded that pedestrian-oriented design and compact neighbourhoods in the San Francisco area, USA, encourage people to drive less and walk or ride transit more. Urban form is also an important tool to slow down the level of motorization in the study of four neighbourhoods in Shanghai (Pan et al. 2009). However, this study concluded that there are other triggers, such as income, affecting travel behaviour.

Other researchers found a weak relationship between urban form of neighbourhoods and travel behaviour in Northern California (Handy et al. 2005; Schwanen & Mokhtarian 2005; Cao et al. 2006; Cao et al. 2010). Often, these studies found a stronger influence of urban form on non-motorized and public transportation travel modes. Crane and Crepeau (1998) found no significant effect on travel mode when controlling for land uses and densities around the trip origin, trip costs and traveller characteristics. Boarnet and Crane (2001) did not find a clear relationship between car trips and urban form within small or larger areas of study. Moreover, some of these studies concluded that attitudes, lifestyle and residential self-selection might exert a stronger influence on travel behaviour than urban form.

Snellen et al. (2001; 2002) concluded that the effect of urban form on activity-travel behaviour is negligible. These studies analysed urban form at the city and at the neighbourhood level. Nine cities in the Netherlands were chosen according to two components of urban form: the shape of the cities, and the street network for motorized transportation. Shape of the cities was considered as lobe city, poly-nuclear city or grid city; and the transportation network as radial, ring, (shifted) grid, or linear networks. Within the cities, 19 neighbourhoods where analysed according to the following characteristics of urban form: location in relation to the city centre, location vis-à-vis the main train station, and location with respect to a services sub-centre at the district level (when present). Authors arrived at the conclusion that "individuals and households tend to organize their daily activity-travel patterns according to their personal preferences and ability of adjustment", and that urban form exerts no significant influence on that.

Studies on urban function

Considering not urban form, but function, most studies have examined the influence of variables such as density, mixed land use, and distance to bus and train stations, and activity-travel behaviour. Nearly all papers that analysed urban function considered more than one variable. Density and (mixed) land-use characteristics usually prevail in these studies, while transport network and accessibility were less often investigated.

Some studies found a significant relationship between aspects of urban function and activity-travel behaviour. Frank and Pivo (1994) concluded that both density and mixed land use have an effect on mode choice when controlling for non-urban factors. Cervero (1996) found that density has a stronger influence on motorized transport modes while land use exerts more influence on non-motorized commuting. Cervero and Kockelman (1997) found evidence of a weak relationship between urban functions and travel demand. Maat and Timmermans (2009) found that work locations with high density reduce commuting and that the work location has more effect on commuting mode choice than the residential environment. Trip mode choice was found to be positively affected by the built environment by Lee et al. (2012). Akar et al. (2016) pointed out that distance from urban areas and less dense built environments influence people to travel longer distances. Residential density appear to have the potential to change walking behaviour in the study by Kamruzzaman et al. (2016). Other studies also link density, mixed-land use and shorter commuting distances, lower travel time and less car use (Banister et al. 1997; Newman & Kenworthy 1999; Stead 2001).

Other analyses suggest that attitudes related to travel exert a stronger influence on travel behaviour than urban function, although urban function still plays an important role in travel distance and transport mode choice (Handy 1996a; Kitamura et al. 1997).

Another group of studies found no significant or weak influence of urban function on activity-travel behaviour. Maat et al. (2005) pointed out that high density and mixed land-use do not induce people to travel less or to travel in a more sustainable way. Krizek (2003b) found that change in urban function does not trigger changes in overall modal split, what leads him to support the self-selection theory. According to this theory, "a household with a predisposition toward a certain type of travel 'self-selects' a residential location enabling the pursuit of that preferred type of travel" (Schwanen & Mokhtarian 2005). We feel that this definition puts too much emphasis on preferences and ignores that many people cannot afford what they prefer or choose to spend their disposable income on expense categories other than travel mode. Consequently, their choice is constrained by their potential action space dictated by the available transport modes they can afford.

Van Acker and contributors used structural equation modelling to analyse data from the Flemish Regional Travel Survey in 2000-2001 (Van Acker et al. 2007; Van Acker & Witlox 2010). In earlier work, they found that the effect of land use on travel behaviour was limited when compared to the socio-economic characteristics. Later, they concluded that characteristics of urban function, such as high density and mixed-use neighbourhood, are related to lower car ownership and less car use.

Besides density and land use, two other characteristics of urban function that received attention are transport network and accessibility. Naess and Sandberg (1996) studied the interdependencies between workplace location, modal split, and energy use in Oslo, Norway. They concluded that public transportation facilities and parking conditions directly affect car travel. Handy (1996b) analysed how accessibility influences travel behaviour for non-work travel in the San Francisco Bay Area, USA. Handy defined accessibility as a reflection of the distribution of potential destinations around a place and the character of the activity found there. Her study suggests that higher accessibility is associated with shorter trips, a greater range of destinations, higher trip frequencies, and a greater number of walking trips. Miranda-Moreno et al. (2011) observed that even an increase in public transportation accessibility, as well as population density and land use mix, has limited effect in reducing trip distances. Vale and Pereira (2016) found that accessibility has a mediating role between built environment and walking behaviour in Santarém, Portugal.

This overview of exemplary studies in the literature shows that with some exceptions, the majority of studies on urban form and function did not find strong relationships between these urban aspects and facets of travel behaviour. Moreover, to the extent significant statistical relations were found, the question is whether these relationships can be interpreted as a causal effect of the built environment on travel behaviour. The design of most study does not allow rigorous interpretation. As discussed above, some studies cast doubt on such causality. Hence, the discussion of self-selection became prevalent in this line of research. In turn, this triggered research that used a broader perspective to examine the relationship between urban form/function and activity-travel patterns. In particular, the inclusion of attitudes and lifestyles in the analyses has been advocated. In the following, we examine research using these approaches.

Irrespective of this classification between urban form and urban function, it is relevant to mention the meta-analysis work from Ewing & Cervero (2010), that used the well-known classification of the "five D's": density, diversity, design, destination accessibility, and distance to transit, thus not making a distinction between urban form and function. The authors summarized around 200 results in the relationship between the built environment and travel, aiming to update their earlier work (Ewing & Cervero 2001), and to quantify effect sizes using the elasticity as a measure of association.

The contribution of this work is the systematic comparison of a large body of previous studies of the relationship between built environment and travel variables. The relationship between each of the built environmental variables isolated and travel are inelastic. Nevertheless, when combined, the D's variables can have a sizable effect on travel behaviour. Some results are closely related to the scope of this thesis: there is a strong association between destination accessibility and between distance to downtown to Vehicle Miles Travelled, positive and negative respectively. Mode share and likelihood of walk trips are related to diversity. This thesis complements the results by examining the role of built environmental variables in mediating the effect of life trajectory variables on travel behaviour.

2.2.2 Attitudes, life-style, and self-selection

Studies incorporating attitudes and lifestyle have aimed understanding to which extent travel-related predispositions influence travel behaviour. This represents an attempt to explain (part of) the unexplained variance in activity-travel patterns after including characteristics of the built environment and socio-demographics. More importantly, the inclusion of these variables may also change conclusions about the importance of the built environment because of interdependencies. Various types of personalities, lifestyles and travel attitudes have been studied in the literature.

Salomon and Ben-Akiva (1983) argued that people in a similar lifestyle group share preferences for the choice of transport mode and destination for shopping trips. If their argument is accepted, it means that if individuals belonging to different lifestyle groups live in the same neighbourhood and lifestyle is not incorporated into the analysis, then the strength of the relationship between neighbourhood characteristic and transport mode/destination choice will be reduced.

Several studies suggest that attitudes towards transportation better explain people's travel behaviour than the built environment (Kitamura et al. 1997; Bagley & Mokhtarian 1999; Bagley & Mokhtarian 2002; Cao & Mokhtarian 2005; Handy et al. 2005; Heinen et al. 2013; Hong et al. 2014; Larrañaga et al. 2014; Maldonado-Hinarejos et al. 2014; Paulssen et al. 2014). Most of these studies claim that attitudes exert a stronger influence or may have a more direct effect than urban form.

A common way to collect data on attitudes and lifestyles is to ask respondents to rate statements related to attitudes toward travel and way of life. To measure attitudes related do travel, Mokhtarian and co-workers (Kitamura et al. 1997; Bagley & Mokhtarian 2002; Schwanen & Mokhtarian 2005) asked respondents to scale 39 statements related to attitudes toward private automobile, ridesharing, public transportation, congestion and air quality, time use, housing preferences, and economic policies related to transportation. To measure lifestyle, respondents should select activities and interests from a list of 100 types. From the data collected, different lifestyles such as culture-lover, homebody, relaxer and pro-environment, pro-transit, and workaholic attitudes were derived.

Similarly, Handy, Mokhtarian and Cao (Handy et al. 2005; Cao et al. 2006; Cao et al. 2010) asked respondents whether they agreed or disagreed with a series of 32 statements. After using factor analysis, six attitudes related to travel were identified: pro-bike, pro-travel minimizing, pro-transit, safety of car, and car dependency. Van Acker (2010) analysed lifestyles through three different aspects of leisure: holiday/travel, literary interests, and recreational activities. The survey resulted in 136 binary variables representing lifestyle activities which, after using two order factor analysis, were reduced to five lifestyles: culture-lover; friends- and-trends; home-oriented-but-active-family; active; and home-oriented-traditional-family. Afterwards, Van Acker et al. (2014), using a structural equation model, supports residential self-selection with results pointing that residential and travel attitudes have a large effect on selecting the land use characteristics of the housing. In different experiments, these lifestyles and attitudes were found to explain some of the variability of people's travel behaviour.

Scheiner and Holz-Rau (2007) criticised the studies focused on lifestyle and attitudes as determinant to travel behaviour, as these do not consider the life situation of individuals. They elaborate that lifestyle and attitudes might be a mediator between an individual's life situation and travel behaviour, and not the main trigger in this relationship. As expected, they find that travel choices of individuals are more affected by their life situation than by their lifestyle, although the latter plays an important role.

Predisposition to certain travel behaviour was also argued to influence people's choice for their housing location (Bagley & Mokhtarian 1999; Wee et al. 2002; Walker & Li 2006). People might choose the place where they are going to live according to their already established travel patterns. This is called the self-selection theory. Chatman (2009) argues, "Transit-seeking households are more likely to buy or rent homes near a stop on the line to work; people who shop a lot by car are more likely to find a place to live near a highway on-ramp; households who like to walk to the park choose neighbourhoods with good parks within walking distances." Interestingly, this view has been mainly expressed by transportation researchers, who often used a limited research design. In contrast, the residential choice literature, which tends to differentiate between housing attributes, attributes of the neighbourhood (functionally and socially) and relative location to a wide set of activity locations (accessibility) has repeatedly shown that accessibility is the least influential factor (Clark & Onaka 1983; Giuliano & Small 1993; Zondag & Pieters 2005). Of course, this finding does not rule out that for certain segments of the population the relative importance of factors differs and that particular segments are heavily constrained in their choice of residential location. However, particularly in developed countries, where most of this research took place, accessibility is not a main concern for the majority of people, relative to non-transport related factors.

Incorporating attitudes and lifestyles has the conceptual and methodological advantage of including more behavioural terms in the analysis. It is however a broad concept, and it is not readily evident why, for example, political preferences are related to travel behaviour. Of course, including lifestyle as an additional variable will likely pick up some of the unexplained variance, but that does not necessarily mean that the understanding of the relationship between urban form and travel behaviour also improves.

In part, this depends on the measurement of lifestyle. Some studies in transportation have chosen, as in marketing research, a rather broad set of variables measuring lifestyle. When the study defines lifestyles (and/or attitudes) that are evidently related to travel, such as pro-transit, pro-bike, pro-drive alone, etc., it is realistic to assume that a person who has pro-bike attitude will bike more often (although attitudes do not necessarily show strong links with actual behaviour) than another person that has a pro-drive alone attitude. But for other chosen attitudes, such as work-driven attitudes, there is only an unclear relationship between activity-travel behaviour and the attitude in question.

The same issue occurs with the analysed lifestyle characteristics: it is not immediately clear why and how culture-lover, homebody, calm and adventure lifestyles cause particular activity-travel patterns. Thus, the resulting correlation is of limited use to the understanding the underlying processes that trigger activity-travel behaviour.

2.2.3 Housing career and lifecycle studies

Several studies have provided evidence on how lifecycle events affect the housing career – triggers to make people move to a different house and how they choose the different places. Also, a number of researchers have encompassed the relationship between life trajectory events, especially housing career events, and activity-travel behaviour. Careers are the consistent paths formed by the stages or statuses people have and take over time according to different aspects of their lives (Mulder 1993). During a lifetime, people develop various careers in different aspects of life: education, work, family, house, mobility, and others.

Studies on life trajectories examine the different careers people go through in their life trajectory and how these affect housing choice. Research on housing careers shows that the decision to move to a new place and how the house choice is made is influenced by the family context, such as the place where parents live (Courgeau 1985; Mulder 2007) and place of birth (Feijten et al. 2008). Household composition is also a key factor affecting moving and house choice, especially for people starting a life together, getting married, being influenced by partners, and having children (Doling 1976; Timmermans et al. 1992; Deurloo et al. 1994; Feijten & Mulder 2002; Feijten & Mulder 2005; Smits & Mulder 2008).

Key events in the different life careers influence both the move to a new residential place, the choice of the house, and first-time homeownership. Marriage and the birth of a child may trigger housing moves to a different location (Courgeau 1985; Deurloo et al. 1994). The choice of the house location is also affected by the job location and income (Van Ham et al. 2001; Clark et al. 2003), not only of the individual concerned but also of spouses (Borgers & Timmermans 1993; Timmermans et al. 1992).

Similar effects of key events have been found for first-time homeownership. Because the spatial distribution of rented versus owner housing is not uniform, spatial effects may be observed. Deurloo et al. (1994), for example, concluded that the main triggers for a move into homeownership are the transition from couple to family and a significant positive income change. Family-related reasons were also mentioned by Feijten and Mulder (2002) as a decisive factor for the change to a long-stay dwelling. Smits and Mulder (2008) found that the likelihood of becoming a first-time homeowner was greater for singles, cohabiters and those starting cohabitation than for married people.

Although these studies do not consider a change in travel behaviour, they show that several other aspects besides travel behaviour and the housing place in itself are playing a role in the decision to move and on the choice of a residential location.

2.2.4 Life trajectory, housing career and travel behaviour

Regarding the relationship between both life trajectory and housing career and travel behaviour, Molin and Timmermans (2003) showed that the influence of transport attributes on choosing a house is not as strong as one might think. Borgers and Timmermans (1993) also stressed that transport facilities do influence residential choice behaviour, but are less important than the housing characteristics. These studies, however, rely on cross-sectional data. Thus, they lack a broader understanding of changes of transport modes over the life course.

From a longitudinal perspective, research has provided some evidence that activity-travel behaviour may be affected by the life trajectory. Beige and Axhausen (2006) concluded that residential mobility is influenced by the ownership of different mobility tools and vice-versa. Also related to mobility tools, Clark et al. (2016) found that household composition has a strong impact on car ownership: a child in the household increases car ownership while younger households tend to own less cars. Clarket al. (2016) advocates thus that life events should be considered in both conceptualisations of travel behaviour change and in public policies. In agreement with Clark et al. (2016), Scheiner and Holz-Rau (2013) reported that travel mode use is affected by relocation and household changes in data collected in Cologne, Germany. Beige (2008) pointed out that spatial changes and changes in mobility tools are considerably connected to one another.

In the Netherlands – the country where our data is also collected – Verhoeven and collaborators used retrospective data and Bayesian Belief Networks, and found that life trajectories are related to changes in car availability and transport mode choice decisions (Verhoeven et al. 2005; Verhoeven et al. 2006; Verhoeven et al. 2007). Similarly, Oakil et al. (2011; 2014) found that car ownership is strongly related to household formation and birth of a child. Interestingly, their results found no effect of residential mobility on car use. Because residential mobility tends to imply a change in the characteristics of the built environment, it suggests that the built environment does not play a direct key role in shaping travel behaviour, at least in their data. Once people possess certain modes, they tend to use them regardless of where they live, subject to space-time constraints.

Studies from Sharmeen and collaborators focused on the effects of social events on activity-travel behaviour through a life trajectory approach. Some of their studies seek to test the path dependency effects of mode choice and travel behaviour for social interaction (Sharmeen et al. 2013, 2014a, 2014b) Using an event-based retrospective questionnaire, data was collected from 703 respondents in September 2011 in the Netherlands. Their studies argued that the dynamics of life-cycle events, social network and activity-travel needs are interrelated and should be modelled in an integral manner.

Few studies found no or weak relationship between life course events and residential changes or travel behaviour changes. Using German longitudinal panel data, (Prillwitz & Lanzendorf 2006) showed that not every residential change causes direct impact on travel behaviour.

From a long-term dynamic perspective, studies considering how changes of urban form affect activity-travel behaviour are scarce. As it is assumed that life-cycle events are triggers of long-term dynamics, it is relevant to this study to draw attention to those works that studied long term dynamics, even if only a few of them are mainly related to the urban form/urban function characteristics. In the following, we review relevant studies that employed longitudinal analyses involving urban form/urban function and activity-travel behaviour.

Both Aditjandra et al. (2012) and Jahanshahi & Jin (2016) used Structural Equation Modelling to investigate indirect effects of the built environment on activity-travel behaviour. Jahanshani and Jin (2016) used a latent variable representing built environment characteristics of a sample of UK residents and found that built environment characteristics have an important influence on the distances travelled. Also in the UK, Aditjandra et al. (2012) concluded that neighbourhood variables affect changes in driving behaviour indirectly through their influences on changes in car ownership. Both studies used longitudinal data to model the dynamics of activity-travel behaviour choices.

Together, these limited results suggest that life career events both directly and indirectly affect activity-travel behaviour. This may imply that needs and constraints of individuals and households have a bigger influence than urban form characteristics on housing choice, re-location decision, and activity-travel behaviour. One consideration is that, to our knowledge, no study using longitudinal data has modelled the outcome variable as the (categorical) travel mode chosen for a given activity. Usually, the total travel distance, distance travelled by car, or travel time are considered (as numerical variables).

2.3 The life trajectory approach as a larger conceptual framework

Considering that (i) there is a lack of consensus in the literature about whether urban form characteristics affect activity-travel behaviour, and that (ii) the influence of transport facilities and accessibility is relatively weak in the decision process of housing location, we believe that previous studies have often adopted a too narrow perspective when looking for an influence of urban form on activity-travel behaviour. We argue that the relationship between urban form and activity-travel behaviour should be seen within a larger context: considering people's life trajectory.

People have certain goals in life they wish to pursue or to achieve. They may wish to have a family, make sufficient money, travel, have friends, play a role in society, entertain and be entertained, have an inspiring job, live in a nice house, etc. They have certain needs, desires, aspirations and expectations. In trying to realise these aspirations, people will go through a life trajectory, or life course, which is composed of multiple careers individuals have in their lives and their developmental implications (Elder 1998).

The realisation of these aspirations involves activities. To some extent these activities involve spatial decisions in the sense that the facilities to conduct the activities are unequally spatially distributed and this involves travel. The built environment offers opportunities and at the same time poses constraints. The availability of a bus stop close to one's house means that an individual can easily decide to use public transport. The non-availability of a bus stop at close range means that public transport is not a realistic option. Available budgets also represent constraints. In the beginning of careers, when individuals tend to have less money, they will face more constraints in terms of affordable housing, availability of car(s), etc. Later during the life course, they may have more to spend and thus are less constrained in where to live, choice of transport mode, activities to conduct and how much to spend on these activities.

During a life career major events occur, such as marriage, birth of child, change of job location, etc. When an event happens, we assume that people enter a process of reconsideration of their current behaviour and if necessary adapt to the new life context (Verhoeven et al. 2005). This adjustment is a function of the relative importance of the various careers, viewed from a longitudinal perspective. For example, consider the job search process. If an individual does not truly need a new job and receives an offer that would only make a marginal difference, it is unlikely that it will be accepted. If, however, this is a dream job, probably everything else (house, social network, travel etc.) will be ignored and the opportunity will be taken. Analogously, we assume that all major decisions in a life trajectory will be implicitly or explicitly evaluated in terms of the multiple careers, of the different household members and a decision, not necessarily optimal, will be made, given the constraints faced by the individual and the household. In the meantime, individuals and households will cope the best way they can with the situation and organize their daily activities accordingly. Lifting constraints may cause shifting behaviour. For example, if the office is relocated from the middle of the city to the main train station, the commute time will be reduced. Consequently, using the same budget, this may open up new opportunities for more preferred housing further away from work. If the relative importance of housing for the quality of life is higher than that of other facets, the reduced travel time will likely be used to realize housing aspirations rather than reducing travel time.

Different modalities in the relevant processes also play an important role in this context. The first housing choice of many individuals is typically made when they do not have much money, perhaps are still single, may have a temporary job or a first job in the job career etc. Hence, the choice may be heavily constrained, and may be made considering that it is very likely that a housing move will follow (soon). In contrast, the second or third house in many cases will be more permanent. Even though the housing decision may have been made such as to maximize household utility, characteristics of the neighbourhood will change: economies of scale may imply that certain types of stores will disappear; the social composition may change, often small design aspects are changed over time as the neighbourhood needs revitalisation and maintenance. It does imply however the existence of inertia and different generations of movers, characterised by different preferences and/or constraints. Consequently, the strength of the relationship between urban form and travel behaviour may be less than one might expect or planners would like to believe.

Due to such constraints, exogenous change, and events, individuals and household will experience discrepancies between aspirations and the actual situation, and they will need to cope with such discrepancies. Over time, the stress to realize their aspirations and/or to cope with organising their daily activities in time and space due to a busier agenda or increasing travel time may increase. They will try to deal with these situations, and enforce relatively easy-to-made changes (e.g. departing earlier, less free time) until some more dramatic change is required. These dynamics take place against the background of the same attributes of the built environment, especially at the level of basic urban form indicators. Thus, activity-travel patterns and housing careers are unfolding; the built environment is merely the décor.

Our proposed conceptual framework, depicted in Figure 2.1, captures the relationship between urban form and activity-travel patterns in this larger context, considering events that occur during people's life trajectory. These events can directly affect people's activity-travel behaviour and their choice of housing location. For example, a change in work location can lead to increasing travelling time and distance as well as a change in mode choice. With the increasing travel time, this person may consider changing the housing location closer to work. The changing house location, in turn, may trigger this person to reconsider his common travel patterns to suit the distances for their main destinations from the new place of residence. At the same time, people might choose the place they want to live according to their already established travel patterns.

The choice of the housing location can be also influenced by the urban form characteristics. People chose the place where they want to live according to the characteristics of the house, the neighbourhood and relative location vis-à-vis various kinds of facilities, family, etc. Thus, in this example, urban form has a mediating role in people's activity-travel behaviour.

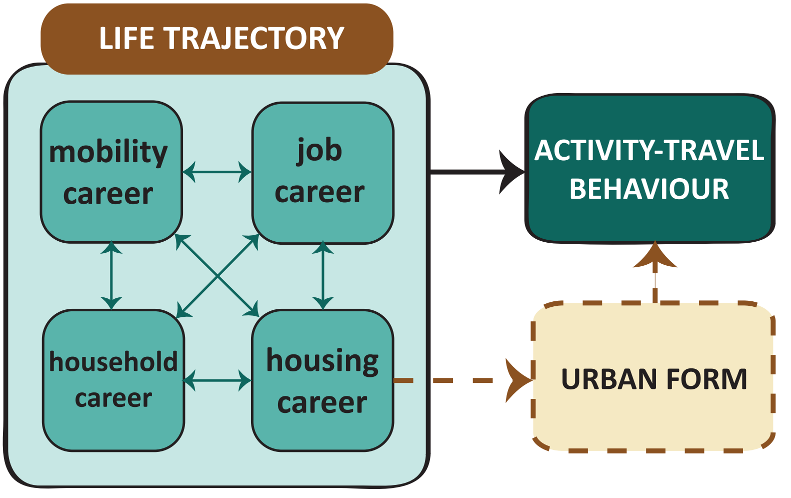


Figure 2.1 | Conceptual framework

With this framework it is possible to test whether there is a direct relationship between urban form characteristics and activity-travel behaviour or that any positive relationship found may be a spurious relationship that occurs because these two variables are related to life trajectory events.

2.4 Conclusions

In this chapter we have reviewed the existing literature on urban form and travel behaviour, attitudes/life style, life trajectory, and housing career. Based on this review, we have advocated the use of a life trajectory approach to analyse the relationship between urban form characteristics and activity-travel behaviour. We have also proposed a conceptual framework with which it is possible to capture the two factors we consider to be influencing activity-travel patterns.

It is important to note that the proposed perspective will not necessarily lead to different conclusions regarding the influence of the built environment on travel behaviour. In fact, because the currently prevailing narrow approaches may be more sensitive to confounding, it is more likely that this broader approach will find even less evidence of a strong impact. Results will also depend on the area under investigation. In countries and cities with more uneven spatial distributions (less equity) and more heterogeneous travel behaviour, due to constraints and/or higher cultural diversity, stronger relationships may be expected. In contrast, less variability in antecedent conditions is expected to lead to weaker relationships.

It should also be articulated that the relative lack of evidence that the built environment exerts a strong influence on travel behaviour does not mean that we should not try to plan, design and develop our cities and transportation systems in a sustainable manner. The reason is that the discussed relationships are non-symmetrical. The availability of public transport services or mixed land uses does not necessarily imply that individuals and households will use them. However, the lack of or non-availability of such services and mixed land use does imply that individual and household cannot choose them, implying that if for whatever reason constraints become to over-rule preferences, for example due to increasing fuel prices or scarce resources, we have created urban systems that will eventually breakdown or that will lead to relatively high social exclusion levels.

In the next chapter we describe our instrument to collect longitudinal data to test our hypothesis.

3

Retrospective life trajectory data

3.1 Introduction

The previous chapter argued that studies considering life trajectories can offer a new perspective to think about the relationship between urban form and activity-travel behaviour. To examine the effects of life trajectories on activity-travel behaviour, it is necessary to collect longitudinal data about the life course of people and changes in their travel behaviour. In order to collect this type of data, this project used a retrospective survey, which covered the 20-year period from 1992 to 2011 and was carried out in the Rotterdam area, the Netherlands. A paper-based questionnaire was designed for the survey, which consists of four parts: personal form (demographic characteristics), life calendar, housing career and future events.

This chapter starts detailing the design and administration of the questionnaire used to collect the data (Section 3.2). After this, it presents an overall description of the data collected (Section 3.3), including a descriptive analysis of the different careers embedded in the life trajectory (Sections 3.4, 3.5, 3.7, and 0).

3.2 Questionnaire design and application

As mentioned before, our goal is to collect longitudinal data about different careers of a life trajectory. Ideally, one should use panel data do analyse longitudinal changes. However, to the best of our knowledge, there is no available panel data that condenses the information needed to test our hypotheses. Besides the panel data, two other methods could be used to obtain retrospective data: repeated cross-section surveys and retrospective surveys. Together with panel data, all three methods pose advantages and disadvantages described by Behrens and Del Mistro (2010).

In our case, the method that appears most suitable is the retrospective survey. The advantages of the retrospective surveys in comparison to repeated cross-section surveys is their ability to explain intra-personal change and the requirement of smaller sample sizes. Nonetheless, retrospective surveys have the disadvantage of having responses that are potentially incomplete or inaccurate due to memory issues, especially when the interval between the occurrence of the event and the recollection time is long.

In spite of its disadvantages, previous studies (Beige & Axhausen 2006; Verhoeven et al. 2007; Behrens & Del Mistro 2010) suggest that retrospective surveys can provide trustworthy information about important events in the past and have a potential as a way of analysing changing personal travel behaviour. Behrens and Del Mistro (2010) recommended attention to the use of recall aids, which will be further explained while describing the design of the questionnaire used to collect our data (Section 3.2.2).

3.2.1 Overview of the questionnaire

The questionnaire was divided in an introduction followed by four parts: personal form (demographic characteristics), life calendar, housing career and future events. In the following, we describe the main features of each part of the questionnaire. The full questionnaire is included in Appendix A.

The questionnaire starts with an introduction that presents the research, its goals and the reasons to conduct the survey. This is followed by an overview explanation of the parts of the questionnaire and recommendations on how to answer the questions – especially those related to past events.

Next, the personal form asks for demographic characteristics of the respondent. Questions about age, gender, nationality, education, work status and income for the respondent and his/her partner were included in this part of the form (Figure 3.1).

The second part of the questionnaire consists of a life calendar addressing the years between 1992 and 2011. The calendar is a grid where the respondent can draw when events started and finished over the years, both for him/herself and for a partner. Changes in the following careers are asked: Housing, household, work, and mobility careers. This part is preceded by a detailed explanation and an example of how to fill the life calendar. Figure 3.2 shows an extract from the example page of the life calendar.

In the housing career section of the life calendar, the postcode of the different places where the respondent lived during the study period is asked. The section about the household career asks how many people were living in the household and when five different life events happened: started living together, marriage/divorce, birth of a

Toelichting bij het formulier Persoons Gegevens

In dit gedeelte verzoeken wij uw persoons gegevens in te vullen zoals geslacht, geboortedatum, nationaliteit en opleiding.

1) Bent u...
Man Vrouw

2) In welke jaar bent u geboren?

3) Wat is uw nationaliteit?

4) Wat is uw hoogst genoten opleiding?
- Geen/onbekend
- BO/LO
- LBO/VGLO/LAVO/MAVO/MULO
- HAVO/MMS/HBS
- Atheneum/gymnasium
- MBO
- HBO
- Universiteit
- Overig:

1) Is uw partner...
Man Vrouw

2) In welke jaar is uw partner geboren?

3) Wat is de nationaliteit van uw partner?

4) Wat is de hoogst genoten opleiding van uw partner?
- Geen/onbekend
- BO/LO
- LBO/VGLO/LAVO/MAVO/MULO
- HAVO/MMS/HBS
- Atheneum/gymnasium
- MBO
- HBO
- Universiteit
- Overig:

Figure 3.1 | Extract from the personal form of the questionnaire

child, child leaving home, and death in the family. Changes in work status, working places, and income are inquired in the working career section. The last section, the mobility situation, demands information about the availability and use of different transportation modes.

The housing career is the third part of the questionnaire and has four sections, all of which ask information about up to five different houses: the present and the past four most recent houses where the respondents has lived in the study period. The first section centres on the house itself: it asks information about the building characteristics and the postcode. The second section focuses on the neighbourhood, asking questions about the characteristics of the neighbourhood and the respondents' satisfaction with it. The next section concentrates on the accessibility, enquiring about the travel time, transport mode, and travel satisfaction for seven destinations: work/study, grocery shops, non-grocery shops, restaurants and cafes, parks, cultural centres, and sport and

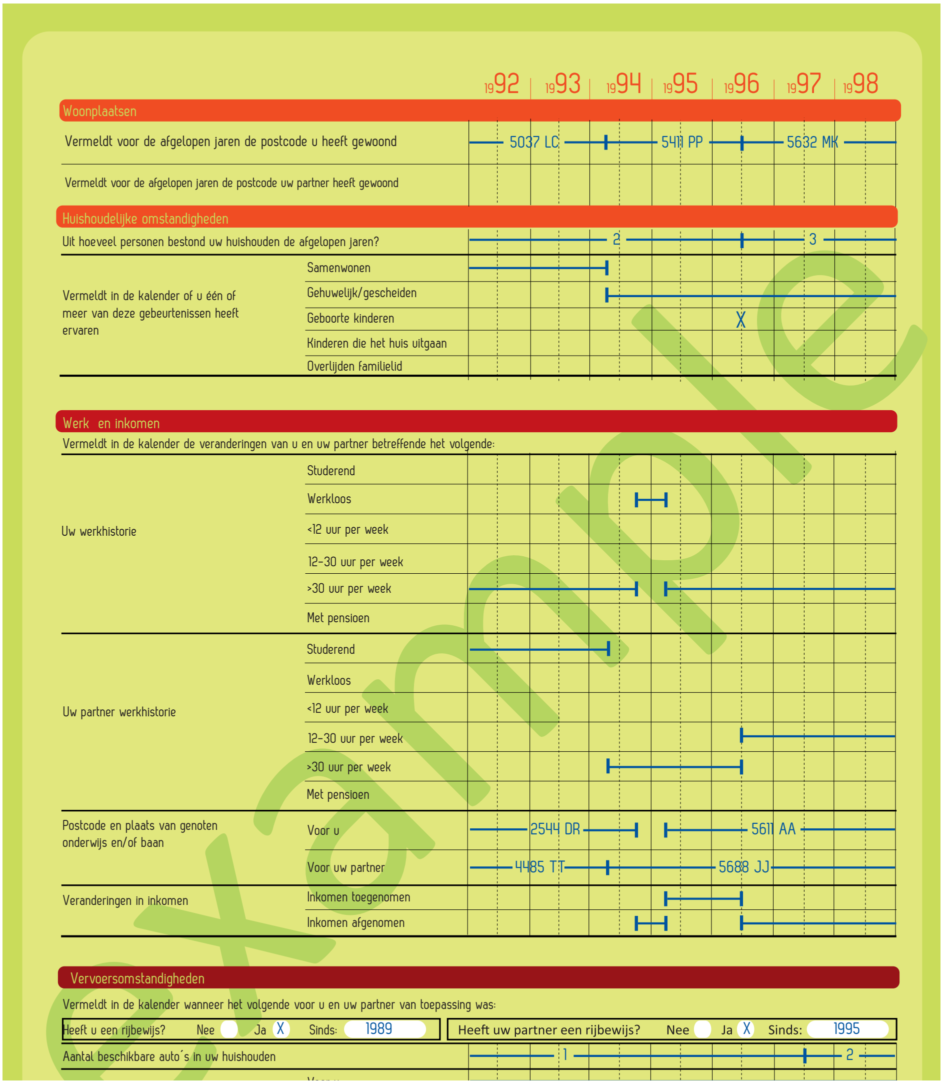
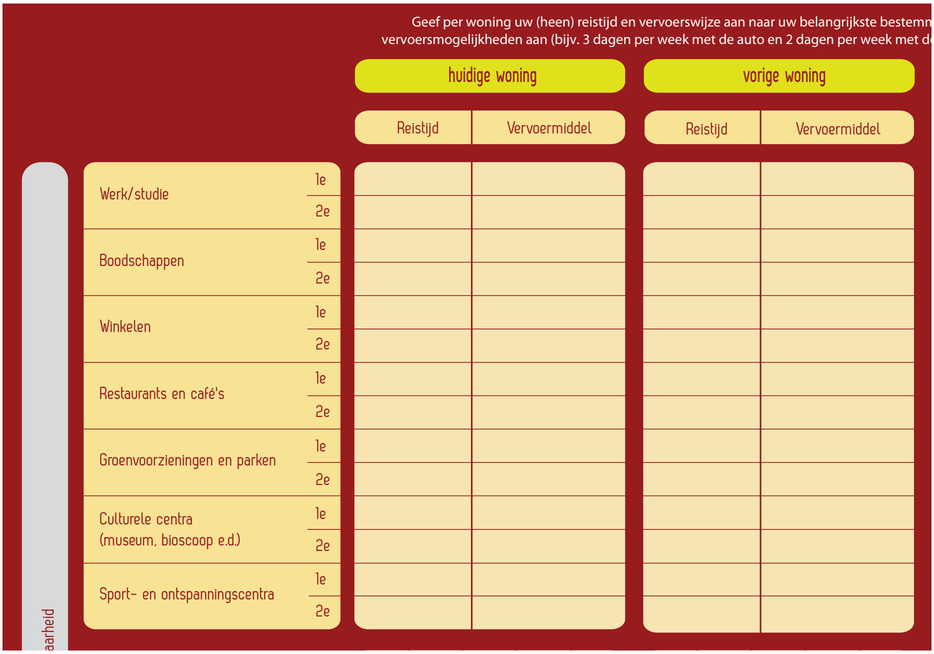


Figure 3.2 | Extract from the filled in example of the life calendar part of the questionnaire

leisure centres. The fourth section requests information about the reasons to move and whether the housing was the favoured choice when deciding to move. The housing career part is preceded by a detailed explanation on how to fill in this part. Figure 3.3 shows an extract of the accessibility section in the housing career part of the questionnaire. The last part of the questionnaire contains questions about future events and about planning for changes in the housing and mobility careers.



Geef per woning uw (heen) reistijd en vervoerswijze aan naar uw belangrijkste bestemn
vervoersmogelijkheden aan (bijv. 3 dagen per week met de auto en 2 dagen per week met d

		huidige woning		vorige woning	
		Reistijd	Vervoermiddel	Reistijd	Vervoermiddel
Werk/studie	1e				
	2e				
Boodschappen	1e				
	2e				
Winkelen	1e				
	2e				
Restaurants en café's	1e				
	2e				
Groenvoorzieningen en parken	1e				
	2e				
Culturele centra (museum, bioscoop e.d.)	1e				
	2e				
Sport- en ontspanningscentra	1e				
	2e				

aarheid

Figure 3.3 | Extract from the accessibility section of the housing part of the questionnaire

3.2.2 Questionnaire design

Retrospective data collection poses the problem of memory issues: details of events further in the past are harder to remember in comparison to those of more recent events. This raises the problem of several types of errors that may affect the reliability of the data collected. Even for recent events, some of them are easier to remember than others. For example, dates are in general the most difficult for people to remember while aspects such as where and with whom are easier to remember (De Leeuw et al. 2008). Usually, an event that is highly related to an emotion is easier to remember and thus the respondents can more easily recall with temporal coincidence. Because of this, our questionnaire was designed in a way respondents would remember first places, e.g. residences, and personal changes, e.g. getting married or having a child, and then work change or having a car. Only after that, detailed information such as distance, frequencies, and their evaluation of the neighbourhood were asked. Using this structure, we aim to facilitate that respondents remember how daily routines used to be at a certain stage of life by remembering himself/herself at the place they were living at that time.

The question of whether the questionnaire would be paper or web based was mainly answered by the memory issues a retrospective data collection induces. Giving time for people to answer is a way to help respondents remember past events. This is a major reason for our choice of a paper-based questionnaire. We also encouraged people to look at documents if they had doubts about dates of events. The paper-based questionnaire also allowed people to easily go back and forward to relate the events - specially in this case where you have different pages that are related to each other and may help to fill in certain questions.

The design of the questionnaire - its visual design - is one important tool to enhance the apprehension of the questionnaire and thus improve the answers of respondents (De Leeuw 2005). In the questionnaire developed for this study, the design was carefully addressed aiming at reducing item nonresponse rates. To achieve a better design, Dillman (2005) defines 12 rules that can be checked. Among these 12 rules, those pertinent to our case were applied in our questionnaire design. Figure 3.4 shows some of these rules reflected in the questionnaire design. Some of the rules are not applicable to our questionnaire, such as agency-only information box and the use of codes for some questions.

Due to the length of the questionnaire, it was also decided to give different colours to each part. This helps respondents to feel that the answering process is moving forward and is thus make this process less tedious.

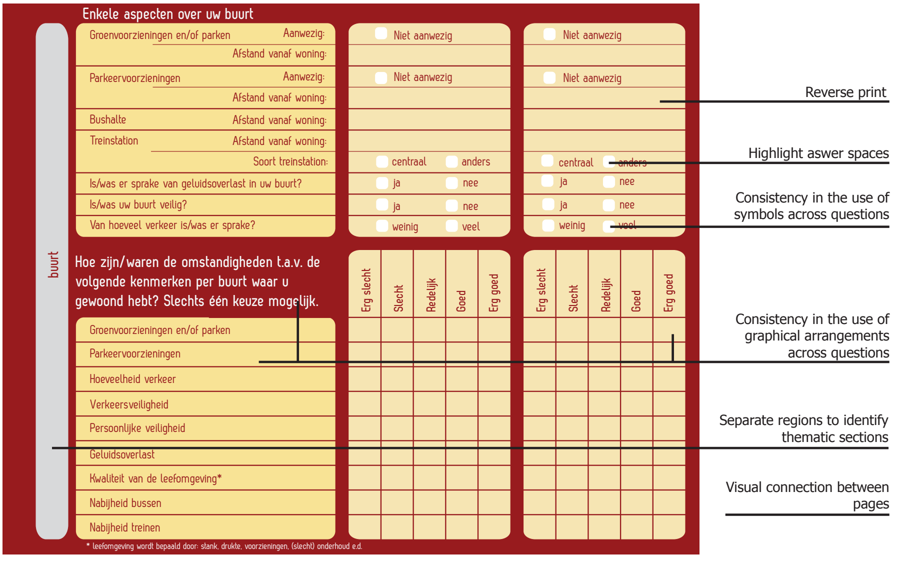


Figure 3.4 | Rules from Dillman (2005) applied in the questionnaire

3.2.3 Pilot study

To check whether the questionnaire was suitable, understandable, and without major issues, we performed a pilot data collection. In August 2011, the questionnaire was distributed among 28 people recruited among friends and friends of friends. It was decided that respondents should be people living in the Netherlands for at least 20 years. This was done so as to ensure the questionnaire would suit the longitudinal data, as data coming from other countries would not be used.

Overall, people answering the pilot questionnaire did not have major issues. However, it was detected that we were not capturing one important element of our analysis: the postcode of the houses. This was due to a wrong question formulation. Therefore, we changed the design of this question to make sure the respondents would not skip it: it was put in a separated box with bigger font letters, with a direct question,

Figure 3.5 | Pages 9 and 10 of the questionnaire before the pilot study

Figure 3.6 | Pages 9 and 10 of the questionnaire after the pilot study

and a reminder that this question is an important one. This change is aligned with one rule from Leeuw (2005), which prescribes to make hidden questions more visible. Figure 3.5 and Figure 3.6 show this part of the questionnaire before and after the pilot, respectively.

3.2.4 Questionnaire administration

The administration of the questionnaire was organized and managed by a specialized company, called TNS Nipo. The company received the final questionnaire design, printed the questionnaires and distributed them to respondents in the study area we determined.

The Rotterdam area was defined as our study area for two reasons. First, it is one of the most diverse areas in the Netherlands in terms of different urban forms. A second reason for this choice is related to the research group in which this project was conducted: our data collection will also be used in a larger project that will consider the same region.

Due to the choice of study area, a requirement to answer the questionnaire used in this project was to be living in the Rotterdam area. All present dwellings of the respondents are, therefore, located in the city of Rotterdam or in its surroundings. We received three questionnaires with respondents living in other cities, but these questionnaires were discarded for the analysis.

The data were collected in October 2011, and resulted in 350 completed questionnaires. These questionnaires were manually digitalized and put into SPSS files.

3.3 Sample characteristics

We received a total of 350 questionnaires back. The final sample consisted of slightly more women than men. About 70% of the respondents have a partner. Figure 3.7 shows the distribution of respondents by age category. The average age is 43.2 (standard deviation 17.1). The nationality of the respondents is mainly Dutch. Figure 3.8 presents the distribution of work status for the respondents. The majority of respondents is working (56.0%). There is a large representation of retired people, housewives/housemen, and unemployed people (26.9%, 8.3% and 3.7%, respectively).

Comparing our sample with the census data from CBS (2010), we observe that the distribution of women and men, and unemployment rate are similar for our sample and for the CBS data for the Rotterdam region. There are more relevant differences

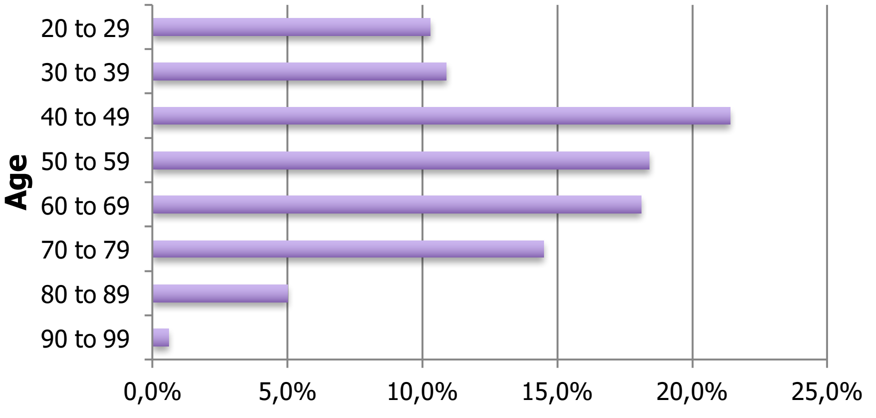


Figure 3.7 | Respondents' age

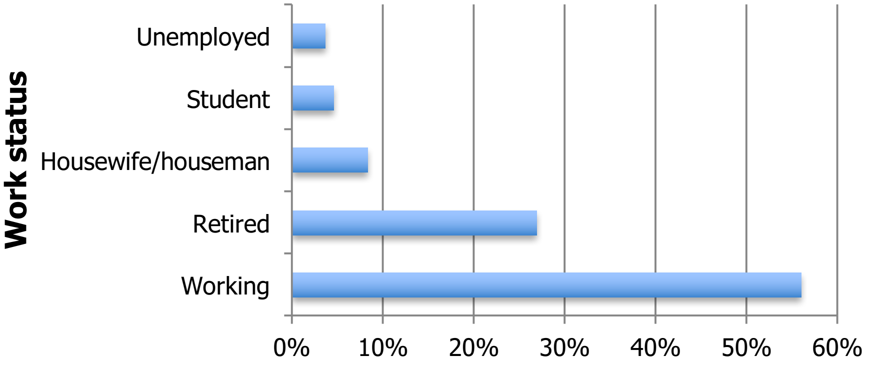


Figure 3.8 | Respondent's work status

comparing age, nationality and percentage of retired people in our sample and official data. Our sample has a higher representation of 40-79 years old people, and a lower representation of 20-39 years old people. Retired people are also overrepresented in our sample: the proportion of retired people in our sample is two times higher than in the official statistics. Both of these differences might be explained by the fact that these people are usually more available to answer this type of survey. Finally, non-Dutch people are absent in our sample: while the Rotterdam area has 7.56% of non-Dutch inhabitants according to CBS (2010).

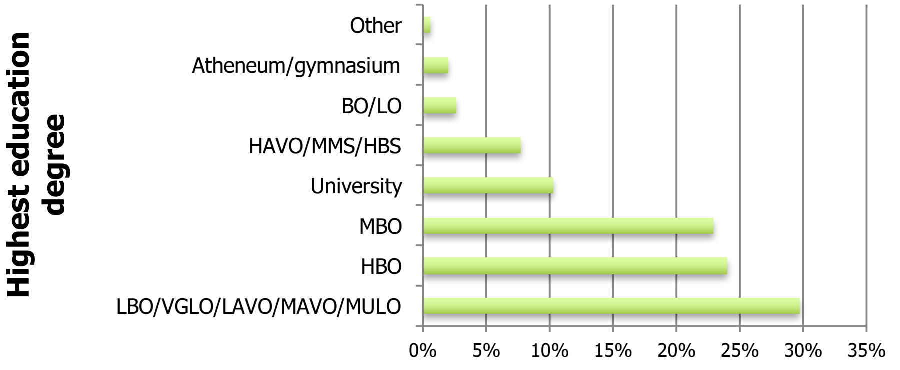


Figure 3.9 | Respondent's highest education degree

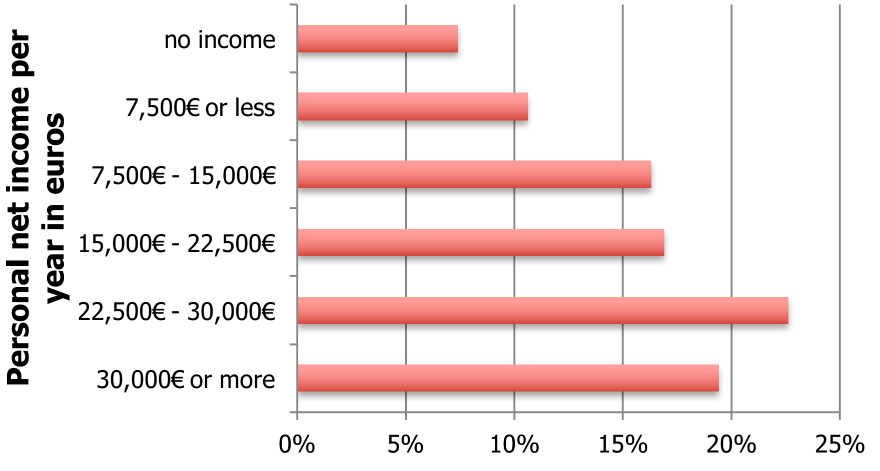


Figure 3.10 | Personal net income by year

Most of the respondents' highest educational level is college (MBO and HBO) and high school (HAVO/MMS/HBS and LBO/VGLO/LAVO/MAVO/MULO), accounting for 46.9% and 37.4% respectively. No more than 10.3% of the respondents have a university degree (Figure 3.9). Respondents with higher education are overrepresented and respondents with a lower education are thus underrepresented in our sample, compared to CBS data. Finally, the annual income distribution by year is shown in Figure 3.10.

Overall, our sample deviates from the overall Rotterdam population according to census data with respect to its proportion of retired and highly educated respondents. This calls for the weighting of sample cases if one is to generalize unbiased statistic estimates of the population from our sample. Nevertheless, in the remainder of this thesis we opt to work directly with unweighted sample statistics. This decision in grounded on the observations that (i) most of our descriptive analysis are longitudinal, and investigate how the characteristics of respondents change over their age, instead of generalizing averages or other summaries at cross-sectional points, and (ii) the central point of our regression analyses is the evaluation of the significance of relationships between variables in models that account for the interaction of group characteristics and the independent variable of choice.

The following sections describe sample characteristics by career. Four life careers are studied in this project: housing career, work career, mobility career, and household career.

3.4 Housing career

Respondents were asked to inform in the calendar the different places where they lived during the last 20 years. A large fraction of the respondents (36.0%) had two houses in the last 20 years, and 78.3% of them had between one and three houses during the same time. The percentage of respondents that had lived in four or five houses drops to 9.1% and 9.7%, respectively. Six respondents (1.71% of respondents) reported more than five housing places in the life calendar, however only the information about the last five houses was detailed. Figure 3.11 displays the percentage of respondents who provided information about different houses.

Results show a tendency to move from an apartment to a house; the proportion of respondents living in houses increases as respondents reach more recent stages of their lives. As expected, the percentage of student houses steadily decreases as respondents move houses (Figure 3.12).

The question about reasons to move to a different house was a multiple choice one with 13 options for each of the houses. Respondents could check all reasons that apply. The different reasons to move to the house were identified based on a review of the relevant literature and feedback received in the pilot application of the questionnaire. The included reasons are: better/nicer house, family reasons, close to work, close to the city centre, good public transportation, close to cultural facilities,

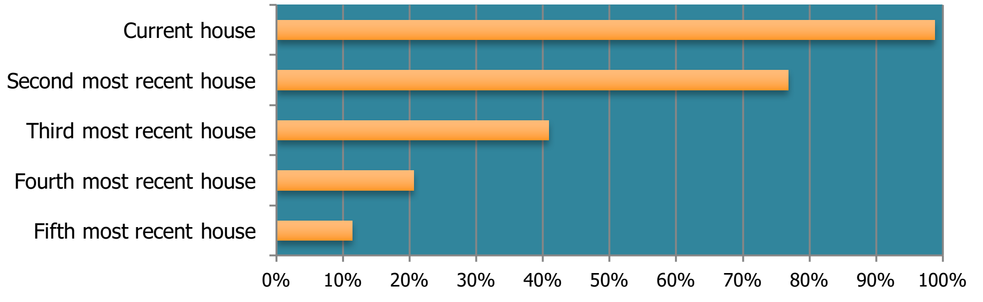


Figure 3.11 | Percentage of respondents who provided data about past houses

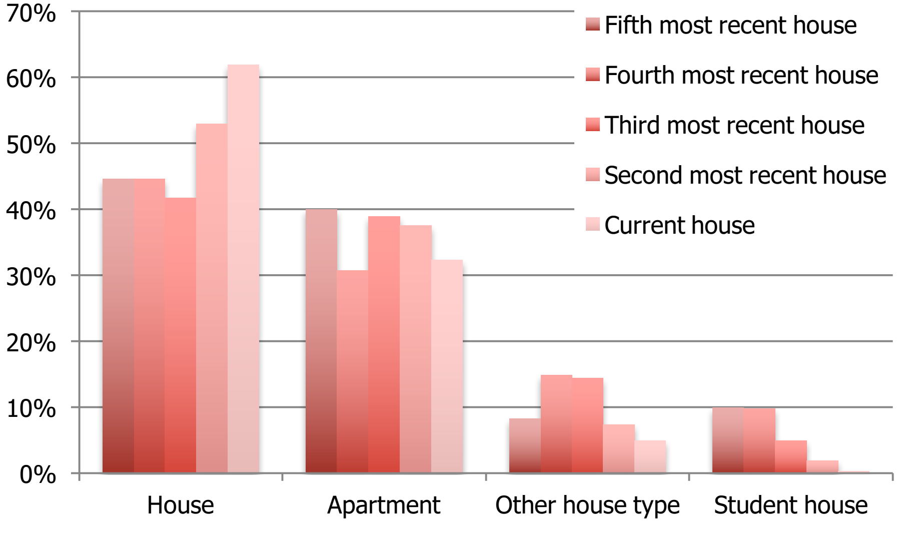


Figure 3.12 | Houses' types over the years

close to green areas and parks, good school, house-related reasons, quality of the living environment, work-related reasons, close to family and friends, and other reasons.

Investigating the reasons why people chose the places where they were going to live, the characteristics of the house and of the neighbourhood are the most often cited (Figure 3.13). The proportion of respondents that cited reasons related to work or accessibility were remarkably low comparing to 'a better/nicer house' or 'quality of the living environment'. During life, it seems that the quality of the house and the living environment become more important aspects. A likely explanation is that at earlier stages of life or family composition, households face more constraints. For example, money, urgency, and availability constraints. Afterwards, moving to a better house seems the natural path to undertake. On earlier stages of life reasons related to family and 'other reasons' are the most cited ones. Often the 'other reasons' where related to living together or marriage.

3.5 Working career

Most frequently, respondents declared that they were working 30 hours or more per week at the time of the survey: 37.7% of respondents chose this option. The second most common work status is being a student. The fraction of unemployed people was 11.7%, slightly higher than the average at the Rotterdam region. This can be explained by the fact that unemployed people have more time to fill in the questionnaire (See also Section 3.3). Also note that respondents that identified themselves as housewife or houseman are in this category (Figure 3.14). Indeed, Figure 3.8 shows that taking together retired people and housewife/houseman they account for the same number of

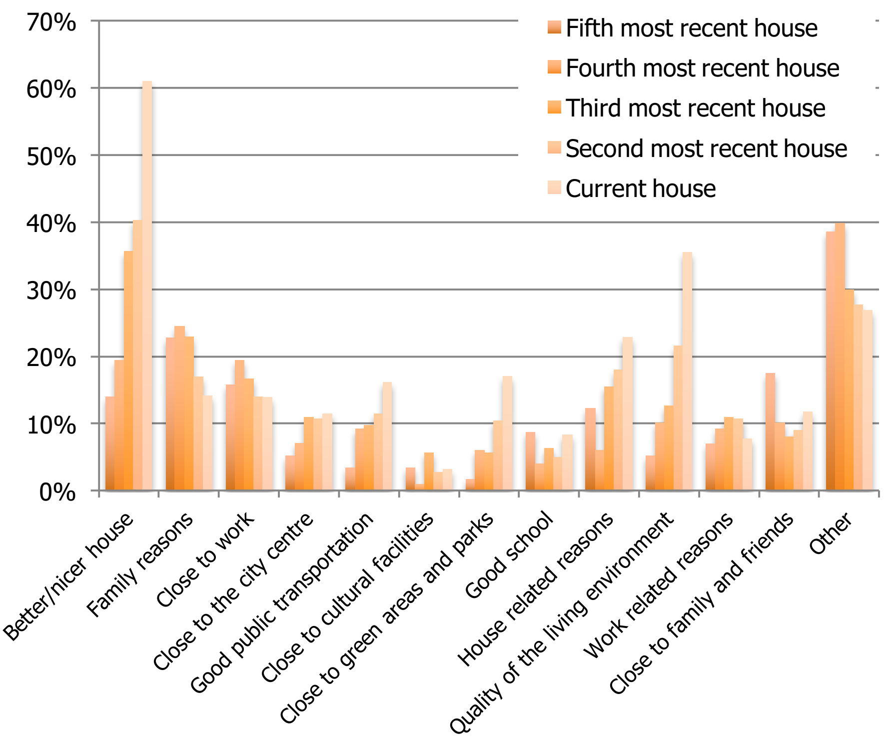


Figure 3.13 | Reasons to choose the different housing locations

respondents.

To analyse the work career trajectory, we resort to the changes in the work status informed through the life calendar part of the questionnaire. Eight different work statuses were possible: unknown, student, unemployed, <12h/week, 12-30h/week, >30h/week, retired, and missing. Figure 3.15 shows the example of a work career trajectory for ten respondents distributed by the calendar year. The same sample of ten respondents were used in the example shown in Figure 3.16, where the work career trajectory is shown based on the age the respondent had when the event occurred.

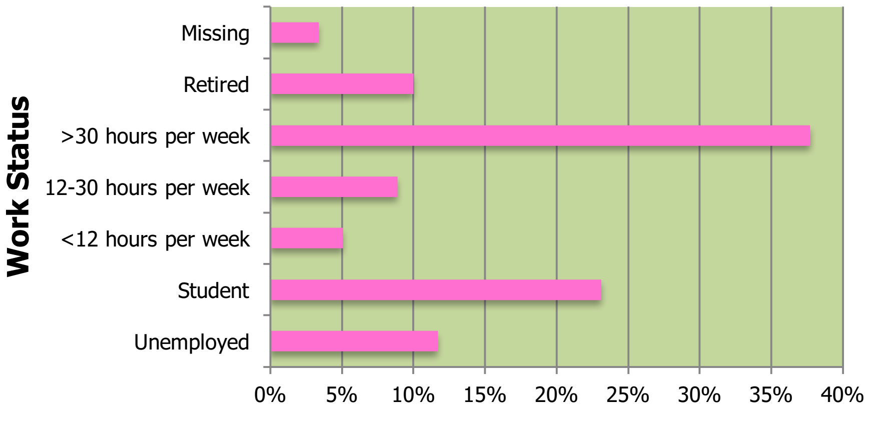


Figure 3.14 | Respondents' work statuses

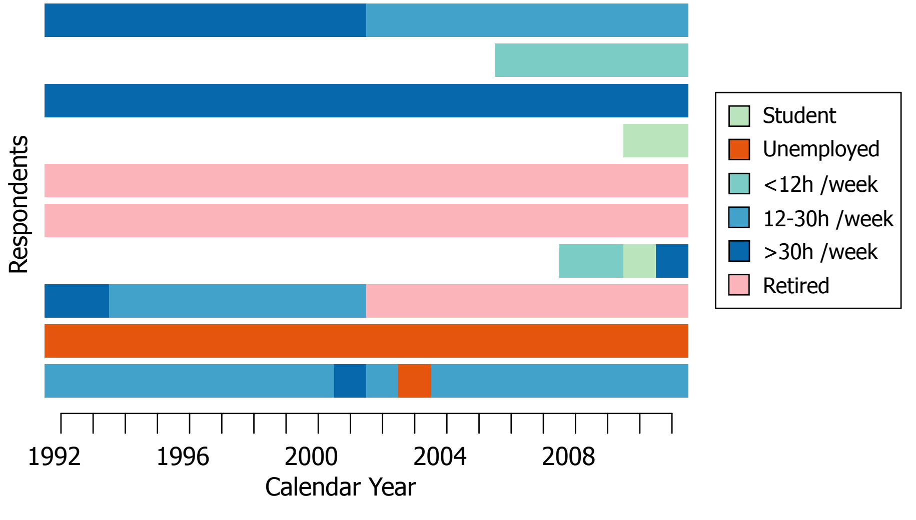


Figure 3.15 | Example of the work career trajectory distributed by year informed for ten respondents

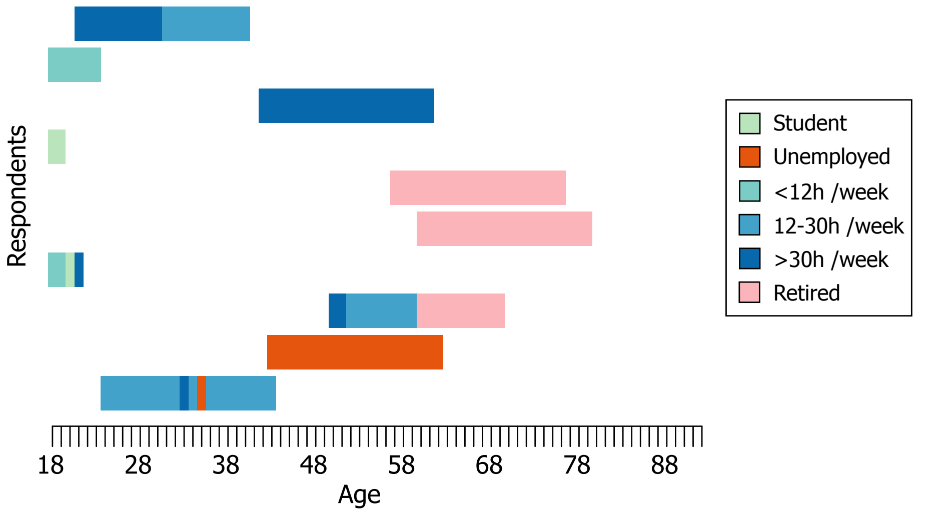


Figure 3.16 | Example of the work career trajectory distributed by age for ten respondents

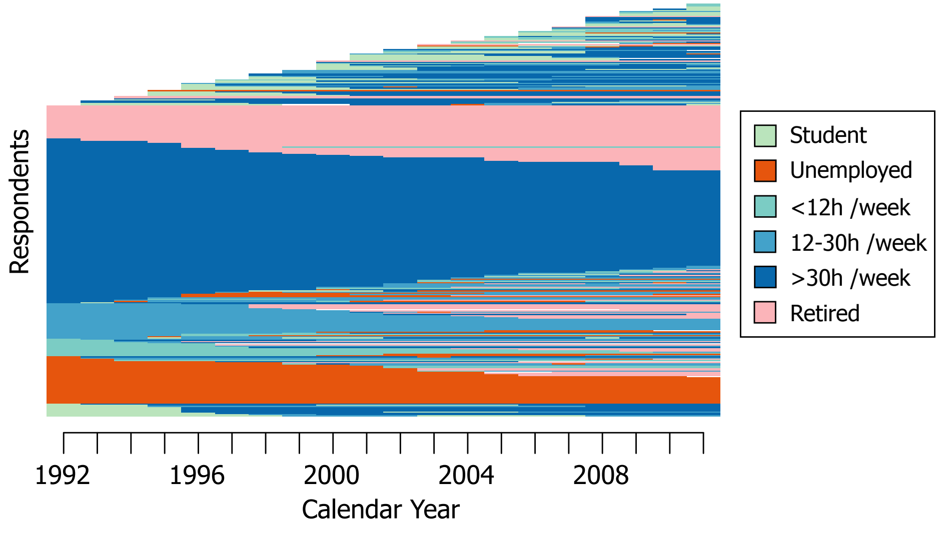


Figure 3.17 | Work career trajectories distributed by the year informed

Among all respondents, 45% had only one work status throughout the study period, with the most frequent being >30h/week followed by retired, unemployed, and 12-30h/week. 32% of the respondents had only one change in work status. The

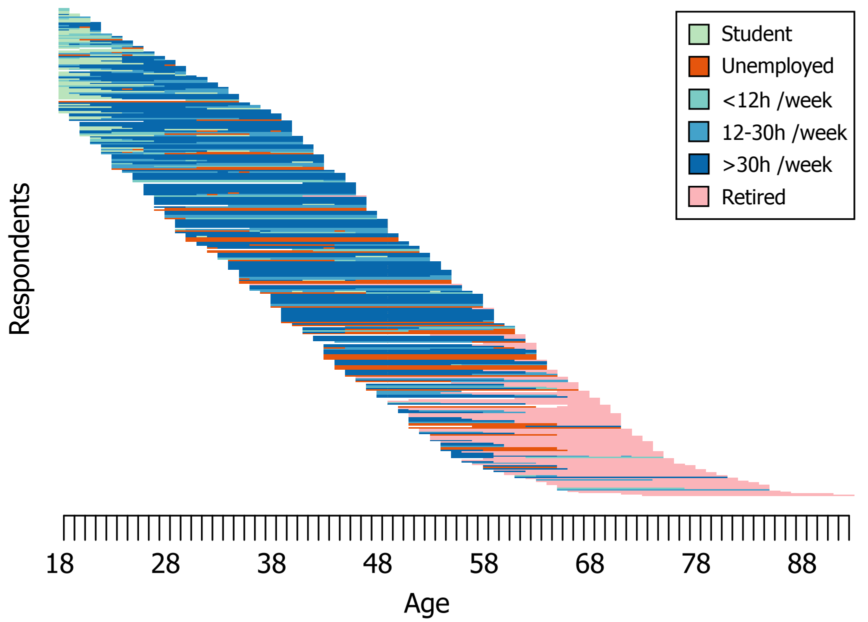


Figure 3.18 | Work career trajectories distributed by the age the event occurred

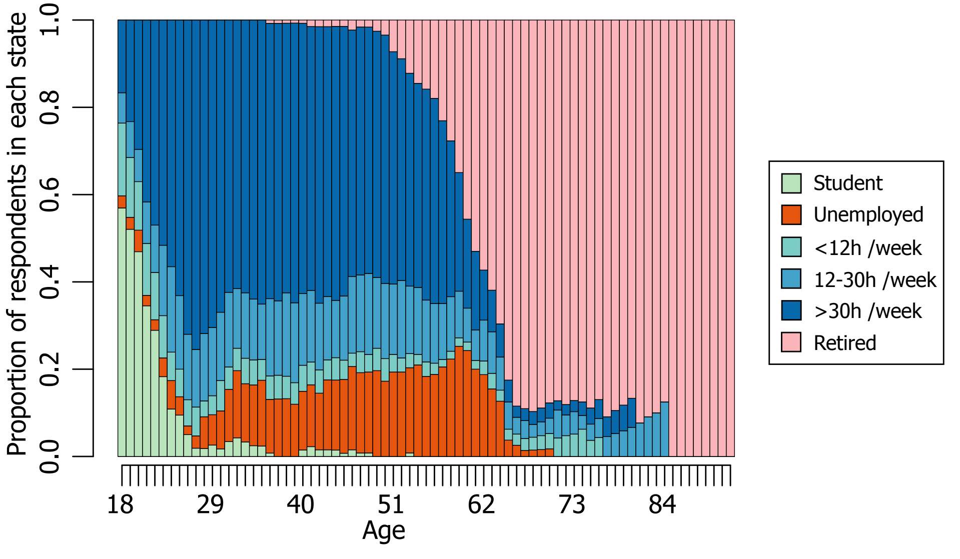


Figure 3.19 | Proportion of respondents' stages according to their age

remainder of the respondents had an average of 4 work statuses. The most frequent changes on work career are: students to >30h/week (13% of respondents reported this change), >30h/week to retired (related to 8% of respondents), and >30h/week to 12-30h/week (7% of respondents). Figure 3.17 and Figure 3.18 show the work career trajectories for all respondents by the calendar year and by the age when the event happened, respectively.

Finally, we analysed the proportion of respondent's stages according to their age (Figure 3.19). Until the age of 20, the majority of respondents were students. In the age range between 20 and 60, the majority of respondents were working more than 30 hours per week, and above 60 years old most of respondents were retired.

3.6 Household career

The household career was derived from the life calendar section of the questionnaire. Besides the changes in the amount of people living in the household, the questionnaire asked about the occurrence of five different life events during the years of the questionnaire. The events considered were: living together, marriage/divorce, birth of a child, children leaving home and death of a family member.

The birth of a child was the event that happened the most: 146 times, and to 84 respondents. The second event that happened the most was marriage/divorce, which happened to 108 respondents. Living together and children leaving home were the third most common type of event; both happened to 86 respondents.

The number of death events of a family member was surprisingly high, occurring at least once for 64 respondents. We suspect that the respondents did not

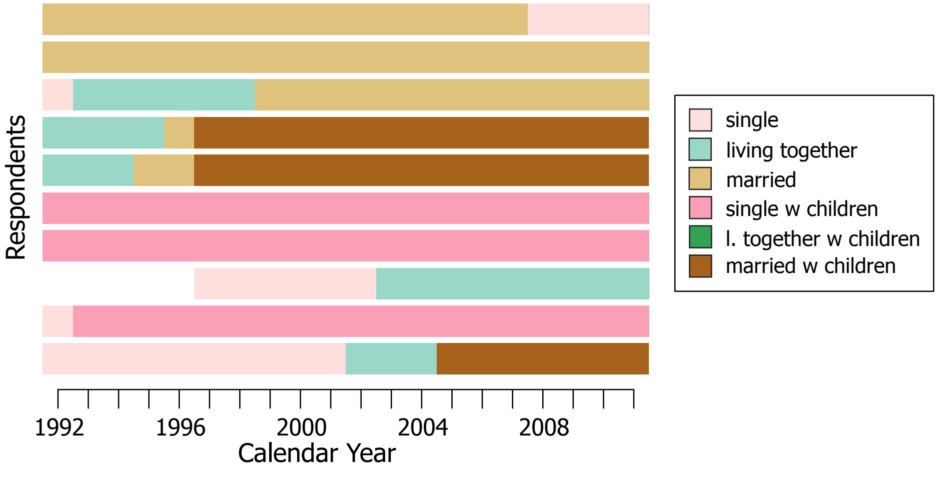


Figure 3.20 | Example of the household career distribution by year informed for ten respondents

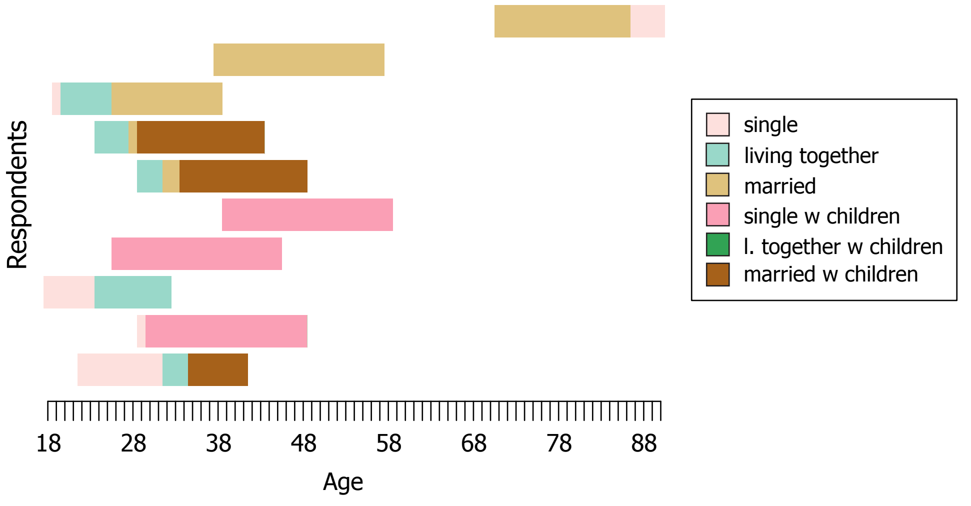


Figure 3.21 | Example of the Household Career Distribution by Age for Ten Respondents

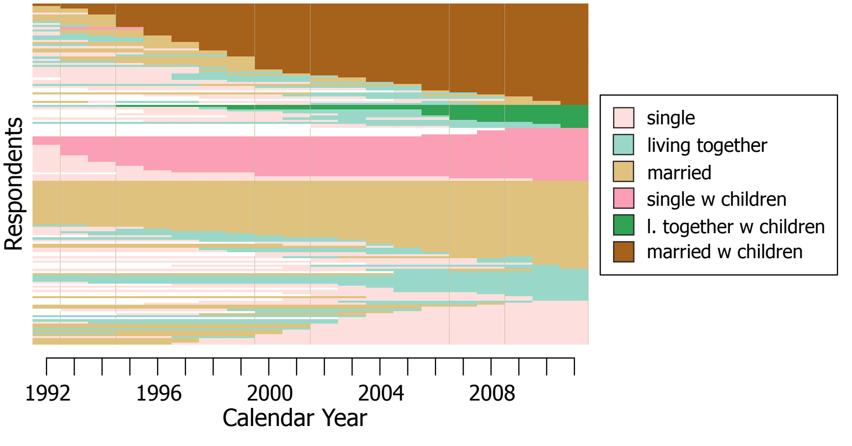


Figure 3.22 | Distribution of the household career per year informed

consider the family as the close family. All results are consistent with the average age of the respondents. Figure 3.20 shows an example of the household career trajectory for ten respondents distributed by the year informed in the questionnaire. The same sample of ten respondents were used in the example shown in Figure 3.21, where the household career trajectory is shown based on the age the respondent had when events occurred.

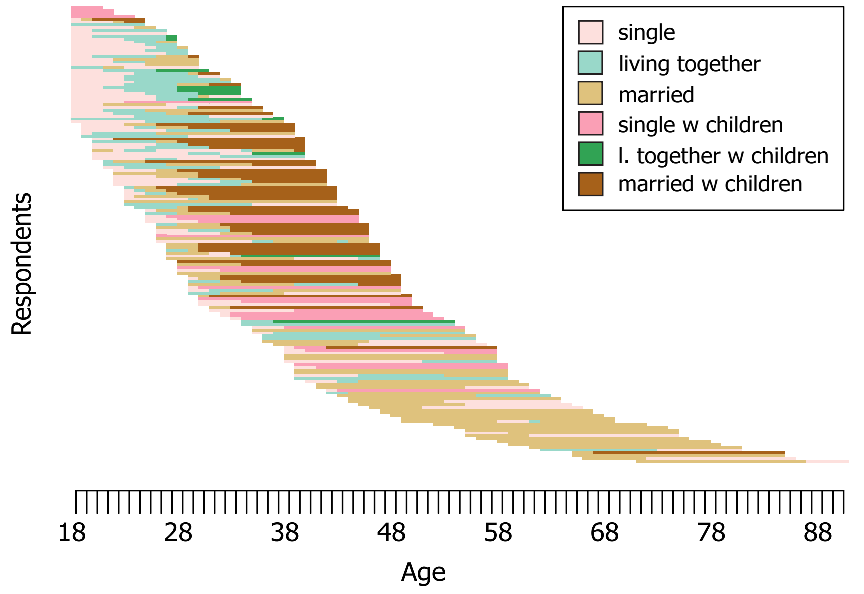


Figure 3.23 | Distribution of the household career according to the respondents' age

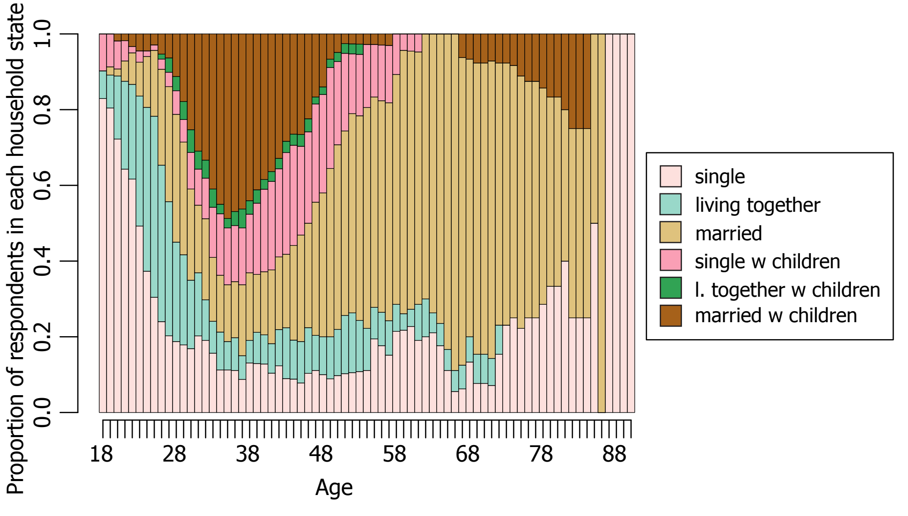


Figure 3.24 | Proportion of household events according to their age

Figure 3.22 and Figure 3.23 show the household career trajectories for all respondents distributed by the year informed and by the age when the event happened, respectively. Among all respondents, 22% experienced only one household event. As mentioned before, the most frequent one was the birth of a child. 34% had two different life events and 35% of respondents had three life events during the period asked in the questionnaire. The remainder of respondents had 4 or more different life events.

Looking at the distribution of household status categories over the years, taking into consideration the age the respondents had at the time the event happened (Figure 3.24), we observe that between the age of 20 and 30, there is a decrease of single people while the percentage of married people increases. The appearance of children in the household also increases gradually until 35 years old when it starts decreasing. The percentage of the statuses living together and living together with children remains relatively constant during all age ranges. It is likely that our data underestimates the number of households with children due to the fact that we can only account for a child in a house if the child either was born or left the house during the period considered by the questionnaire. We can only infer that there was a child if there was an event related to this child reported in the questionnaire.

3.7 Activity-travel behaviour

Differently from the work career trajectory, the information needed to analyse the mobility career trajectory was extracted from the housing career part of the questionnaire. The information leveraged was the main transport mode of respondents in each house for seven different destinations: commuting, grocery shopping, shops in general, restaurants, green areas, sports, and culture. Four variables were derived from these seven transport modes: the first three are the commuting, grocery shopping and shopping transport mode; the fourth is the prevalence of car use among the seven trip destinations. In the following, we describe each of these variables in turn.

3.7.1 Commuting mode choice

The first mobility career variable is the main commuting transport mode used by respondents, which we name commuting mode choice. This was an open question in the questionnaire from which we derive the following set of categories: car, bicycle, public transport, walking, and other. The 'other' category includes the responses that could not be associated with any of the main categories, most of which are motorbikes and scooters.

Results show that across all life trajectories in our sample, there is a clear tendency for respondents to predominantly use the car. The use of public

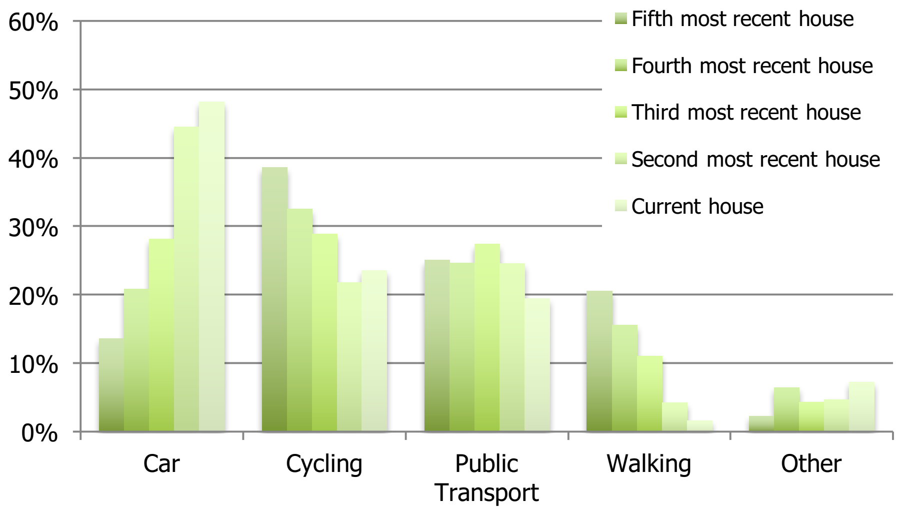


Figure 3.25 | Changes in commuting transport mode over the houses

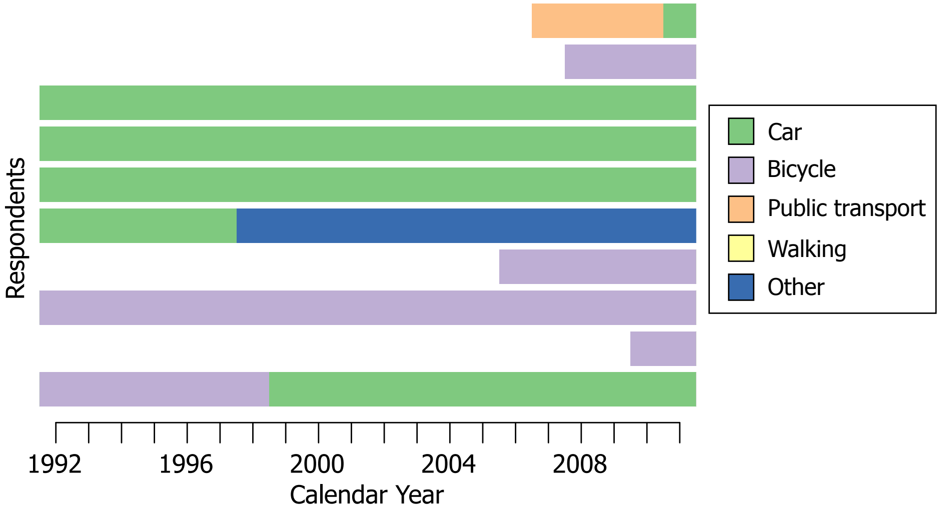


Figure 3.26 | Example of the commuting mode choice distribution by year informed for ten respondents

transportation, cycling and walking tends to decrease in later stages of life. Figure 3.25 shows the frequency with which each transport mode is used for commuting for the five

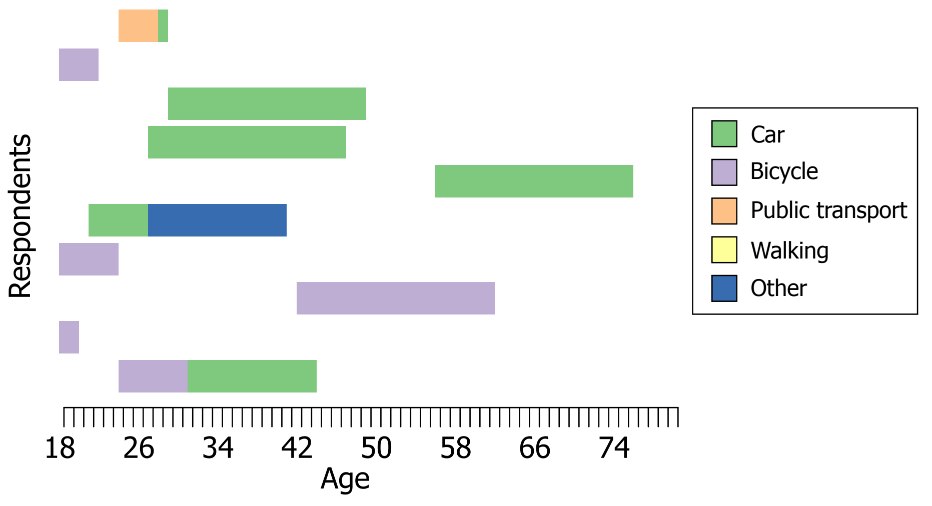


Figure 3.27 | Example of the commuting mode choice trajectory distributed by age for ten respondents

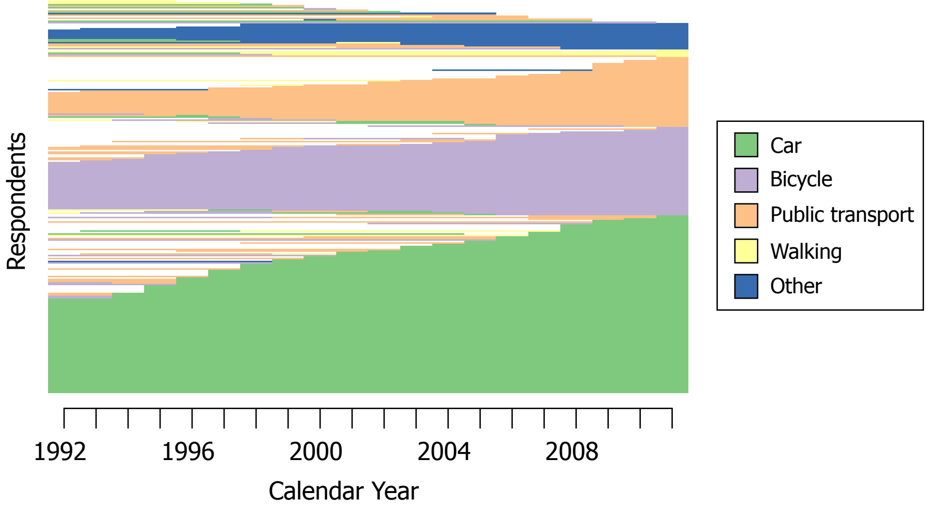


Figure 3.28 | Distribution of the commuting mode choice per year informed

houses of respondents. Figure 3.26 shows the example of the mobility career trajectory from the commuting transport mode standpoint for ten respondents considering the year informed in the questionnaire. The trajectories for the same sample of ten respondents are shown in Figure 3.27 with the age of the respondent as reference.

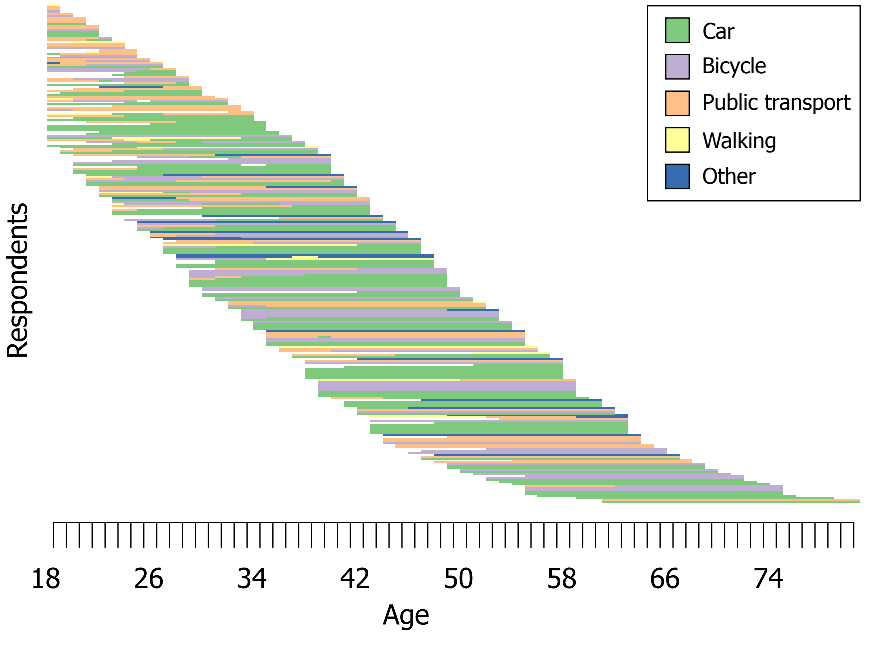


Figure 3.29 | Distribution of the commuting mode choice per age

Figure 3.28 and Figure 3.29 show the commuting mode choice trajectories for all respondents distributed by the calendar year and by the age when the event happened, respectively. Among all respondents, 56% have a single commuting transport mode over our study period. 34% of respondents used two different transport modes. The remainder had three commuting mode statuses, with the exception of one respondent that had four. The most frequent changes in the mobility career are: from public transportation to car (9% of respondents reported this change); and from public transportation to bicycle, bicycle to public transportation, and bicycle to car (7% of respondents).

Looking at the distribution of mobility statuses over the years, Figure 3.30, walking explicitly decreases with age. The proportion of respondents cycling is relatively constant over different ages, but diminishes drastically around 70 years old, which might be related to less physical vigour at this age. Public transportation decreases until reaching about 60 years old, showing a considerable increase after this age. Car usage increases from 18 to a peak in the 30s, and from the 60s onwards.

For the commuting travel time, respondents also provided us with information about their travel time to work in different houses. Individually, some respondents decrease their travel time, while others increase. Figure 3.31 displays the distribution of travel time reported for the different houses: there is a trend towards moving from very short (0-15) to short (16-30) travel times as one progresses from least recent to more recent houses.

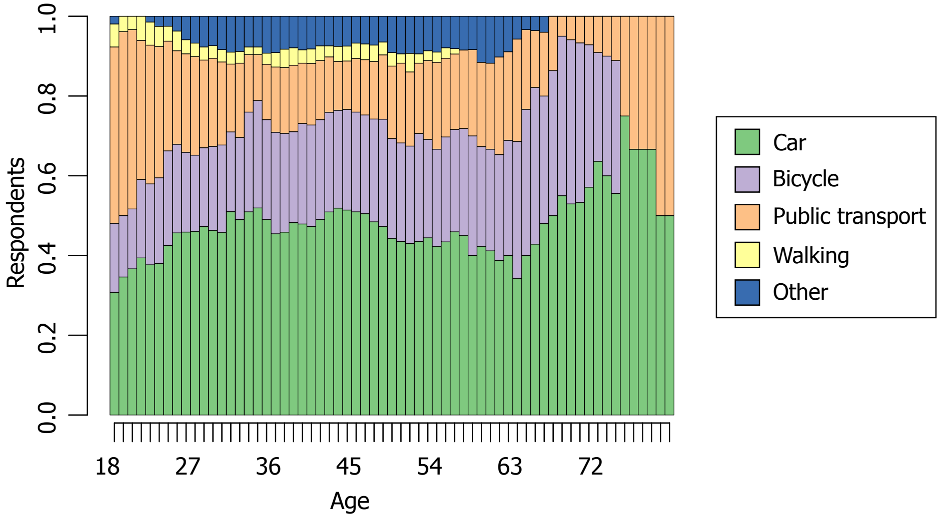


Figure 3.30 | Proportion of commuting transport mode used according to their age

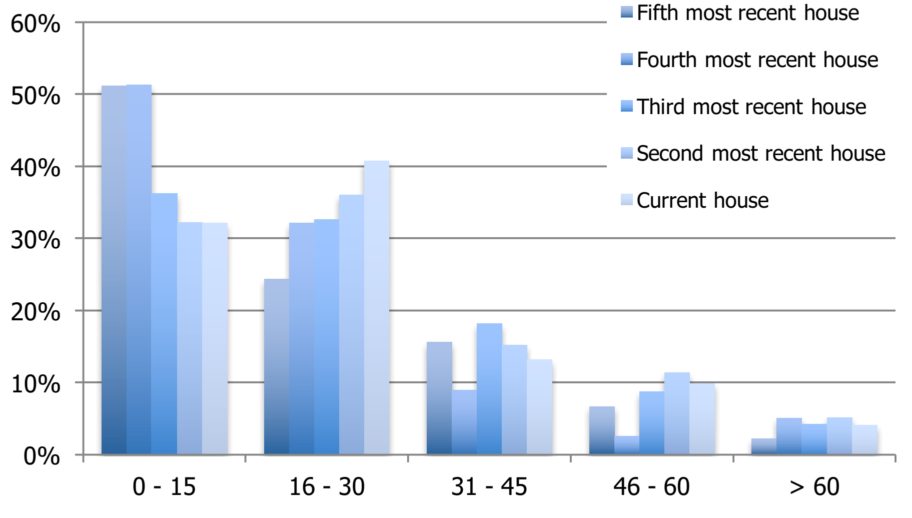


Figure 3.31 | Changes in travel time to commute (in minutes) over the houses

3.7.2 Grocery shopping mode choice

The distribution of respondents using each transport mode for grocery shopping over time has a notably different distribution compared to commuting mode choice. Figure 3.32 shows the frequency of grocery shopping mode choice for respondents at each age. There is substantially less use of public transport to go to the grocery store than for commuting. Walking is much more frequent, and seems to become a bit more frequent for respondents in their 50s and later. There is not a clear trend for the increase or decrease of car use for grocery shopping as respondents get older. Similarly, to commuting, respondents use the bicycle for grocery shopping less frequently at more advanced ages. Figure 3.33 shows that there is no clear trend in the grocery shopping mode choices over calendar years. The dynamics observed in Figure 3.32 seem to be related to respondents' age, and not to any exogenous time-dependent trend.

Regarding the number of transport modes used for groceries in their trajectory, 74% (254) of respondents that informed at least a mode choice (341) used a single transport mode. Another 18% (60) used two modes, and the maximum number of different modes was four.

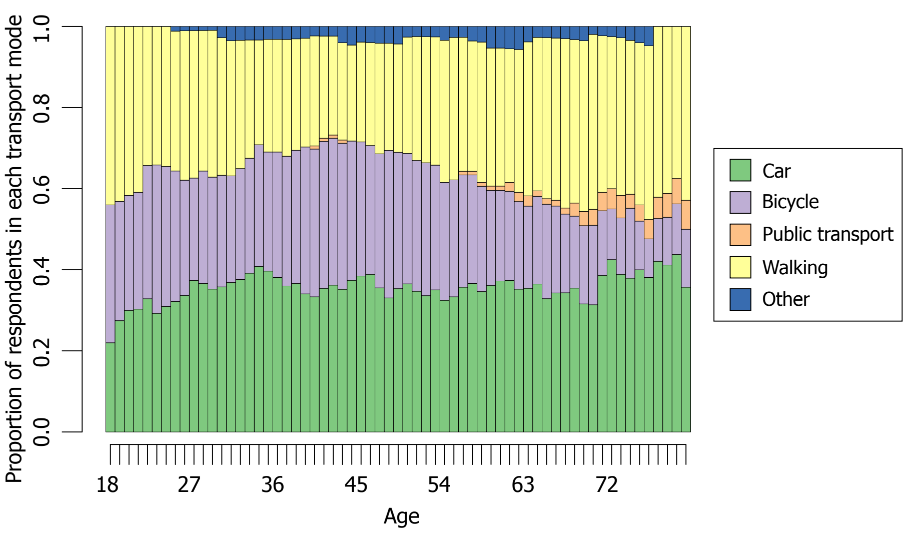


Figure 3.32 | Proportion of grocery shopping transport mode used according to their age

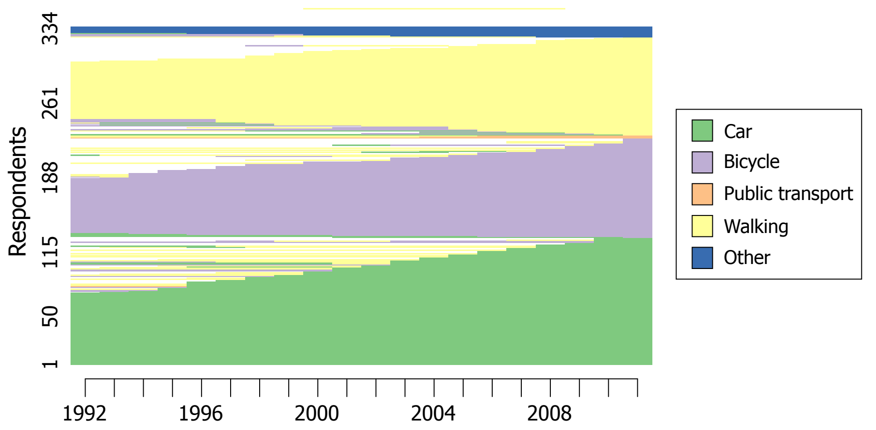


Figure 3.33 | Distribution of the grocery shopping mode choice per year informed

3.7.3 Shopping transport mode choice

Figure 3.34 and 3.35 show the distribution of transport mode choices for respondents at different ages and over calendar years. The transport mode choice for shopping shows a third pattern compared to commuting and grocery shopping, although there are similarities with both. There is a steady increase in the frequency with which

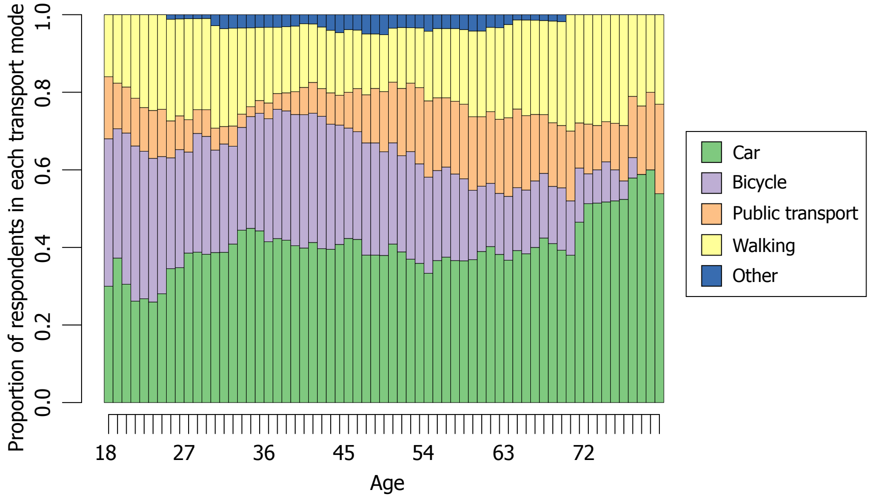


Figure 3.34 | Proportion of leisure shopping transport mode used according to their age

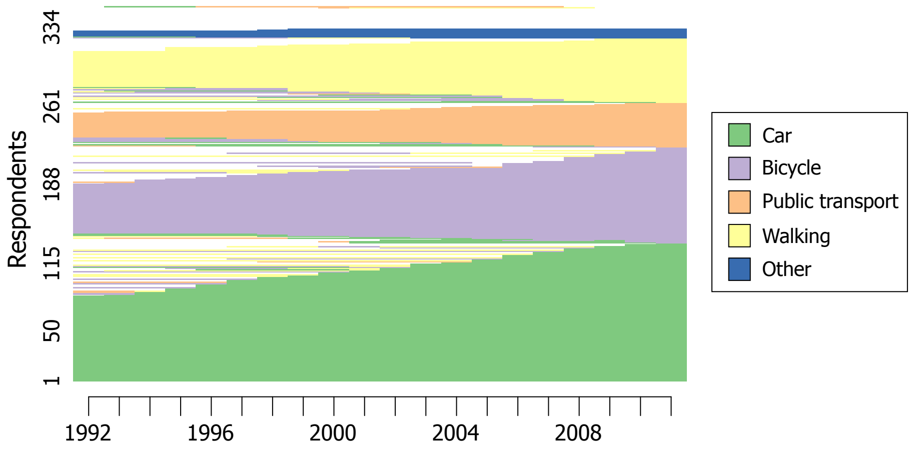


Figure 3.35 | Distribution of the leisure shopping mode choice per year informed

respondents use the car for shopping as they get older. In the same way, the use of public transport also increases. Both increases seem to happen at the expense of a less frequent use of the bicycle.

The majority of respondents (257, or 78%) that provided data about their shopping mode choice used a single transport mode during the whole trajectory informed in the questionnaire. A total of 16% of the respondents had two different transport modes during their trajectory, and the remainder had three or four transport modes.

3.7.4 Car use

Our fourth variable used to characterize the mobility career of respondents is an aggregation of their mode choices for all seven destinations informed through the questionnaire: commuting, grocery shopping, leisure shopping, restaurants and cafés, green spaces, cultural centres, and sport centres. This variable is a continuous one that measures for which proportion of the seven mode choices the answer of a respondent was the car. This variable is named *car use*. It does not measure the proportion of trips made using the car. It does, however, measure the prevalence of the car as a choice for the different routine trips made by respondents.

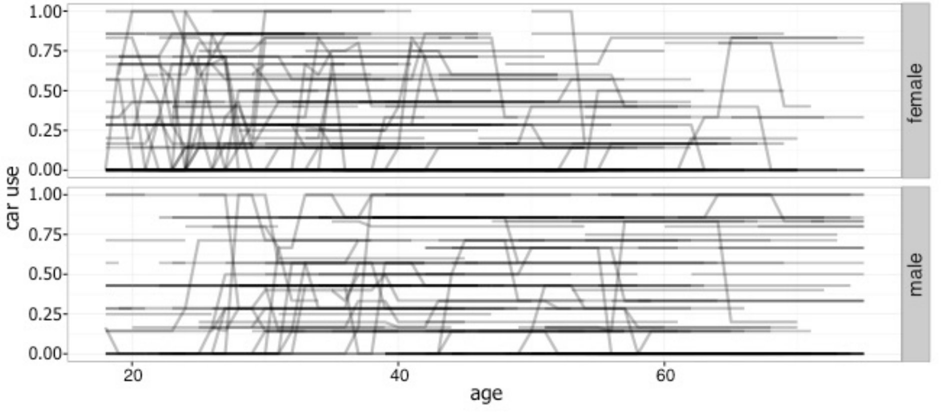


Figure 3.36 | Respondents' car use over time. Each line represents a respondent

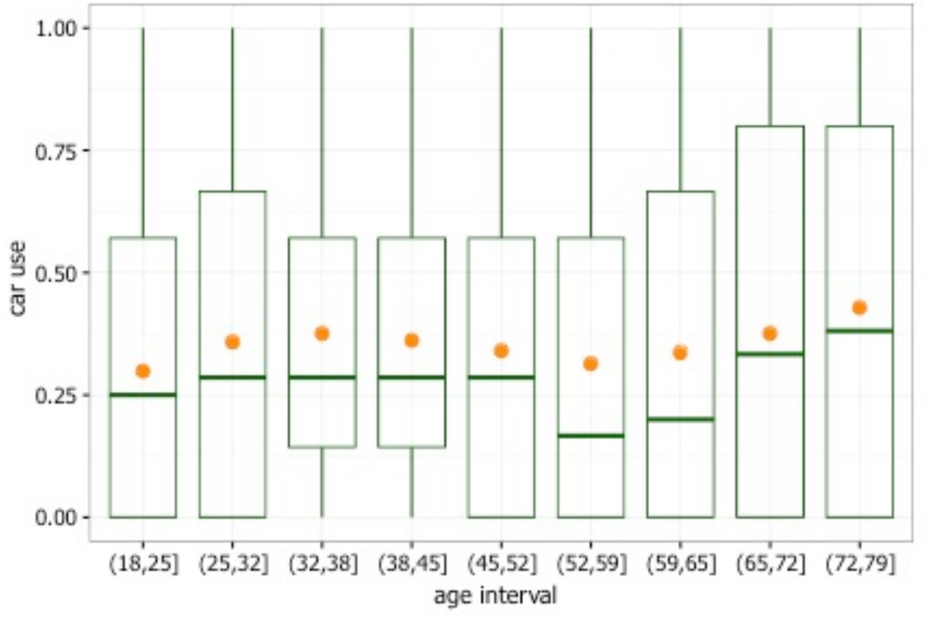


Figure 3.37 | Box plot of the car use distribution per age band. Orange dots represent average

Figure 3.36 shows the car use for each respondent over time. It is apparent that a large number of respondents do not change the proportion of their choices in which the car is chosen over time. A significant number of respondents have variations in their car use, however. This seems to happen mostly at earlier stages of life.

The distribution of car use as a function of different age bands is shown in Figure 3.37. There seem to be two periods of higher car use: one where the mean and 1st quartile is higher, in the 30s, and one where the mean is higher from the 60s onwards. Apart from these two periods, the aggregate view of car use is reasonably steady, with a median around 0.25 and 75% of respondents using the car for less than 60% of their types of trips.

3.8 Conclusions

This chapter described both the method of data collection and sample characteristics of the longitudinal data to be used in the analyses of this thesis. For these analysis, this data will be combined with the urban form data that is described in the next chapter. Due to the framework and the scope of this study, which examines the effects of life trajectory on activity-travel behaviour, it is necessary to collect longitudinal data about the life course of people and changes in their travel behaviour. In order to collect longitudinal data, a retrospective survey covering the 20-year period from 1992 to 2011 was carried out in the Rotterdam area, in the Netherlands. A paper-based questionnaire was designed for the survey, which is made of four parts: personal form (demographic characteristics), life calendar, housing career and future events. Another option would be to use panel surveys but none were available that included the necessary data to test our hypotheses. The design of the paper-based questionnaire was thus carefully driven attempting to reduce the memory bias issues a retrospective data collection raises.

In total, we received 350 questionnaires back from our data collection. The description of the respondents shows that our sample is similar to census data with respect to gender and unemployment. On the other hand, it has an overrepresentation of highly-educated, retired and 40-79 years old people. The information gathered in the questionnaire comprehends information about the respondents, the partner, and four life careers: housing, work, mobility and household careers. The description of the four life careers shows plausible patterns of changes and distributions of the life trajectories.

The next chapter discusses the analysis of the urban form characteristics for the study area.

4

Multi-faceted analysis of urban form

4.1 Introduction

Most studies published on the effects of urban form on travel behaviour limited their analysis to a single aspect of urban form – usually density or mixed land-use –, or at most to a combination of these two aspects (Frank & Pivo 1994; Handy 1996a; Naess & Sandberg 1996; Kitamura et al. 1997; Krizek 2003a; Maat et al. 2005; Schwanen & Mokhtarian 2005; Maat & Timmermans 2009). Fewer studies took into account more characteristics of the city, such as the 3D's concept - density, diversity and design (Cervero and Kockelman, 1997; Cervero, 1996), and whether the street network was a grid or a cul-de-sac (Cervero & Radisch 1996; Crane & Crepeau 1998; Handy et al. 2005; Schwanen & Mokhtarian 2005; Cao et al. 2006; Pan et al. 2009).

We argue that studies that considered only one aspect of urban form are limited in detecting strong relationships between urban form and travel behaviour. They leave out fundamental aspects that potentially can influence people's travel behaviour, such as features that affect accessibility (for example, distance to public transportation) and characteristics of buildings and neighbourhoods that influence how people decide where to live, which in turn influence their travel behaviour. Moreover, the effect of several urban form characteristics combined might be different than considering them isolated. Hence, it is of interest in our context to study new methodologies to analyse urban form from a broader perspective.

The aim of this chapter is to propose a methodology that encompasses several characteristics of the built environment together. Three main features of the built environment are considered and will be used in the analysis of activity-travel behaviour: density, land use and accessibility. To enable the study, GIS data from different sources at the building, neighbourhood, and city levels from 25 different municipalities were combined.

The remainder of this chapter is organized as follows. First, the study area is described, followed by considerations of the structure of the data and level of measurement. Next, the three built environment characteristics are described and analysed. Some considerations about the quality assurance of the data are given before finishing the chapter with the conclusions.

4.2 Study area

The Netherlands offers a challenge to analyse urban forms. Its diversity among neighbourhoods is not as high as it might be seen in other countries. The choice of our study area anticipated this problem. One reason to choose the Rotterdam region is that the area has both modern and traditional neighbourhoods, and has a large territorial extension, which offers more diversity in terms of the built environment than most Dutch areas.

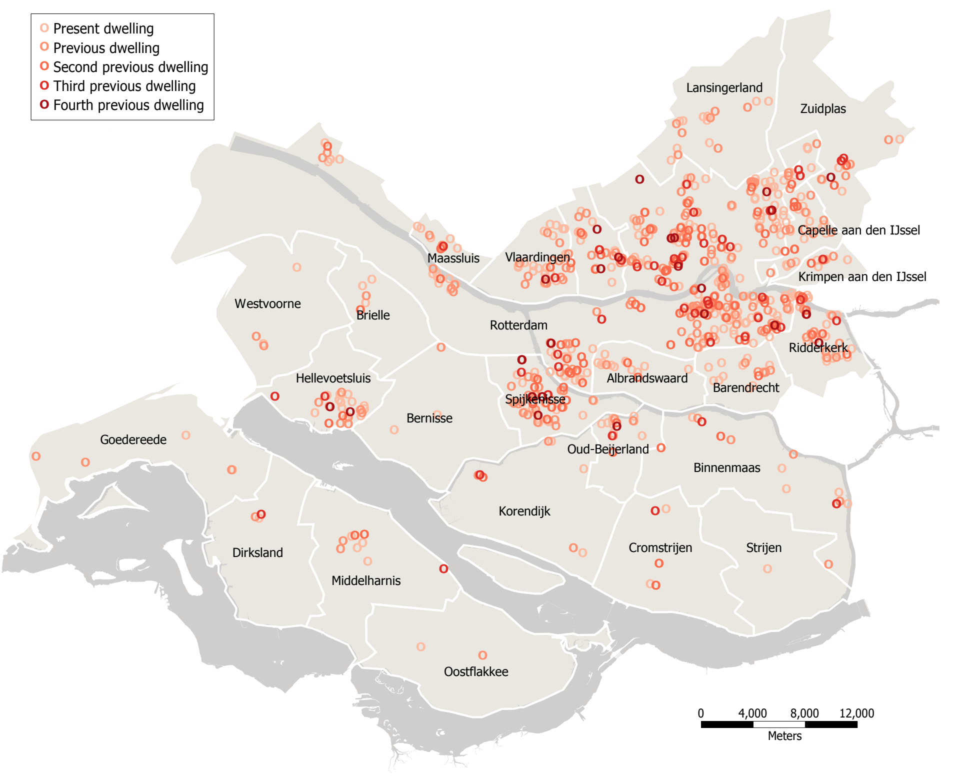


Figure 4.1 | Study area together with the distribution of respondents' dwellings

Table 4.1 | Number of respondents per city in the study area

City	Population (2010)	Present dwelling	Previous dwelling	2nd previous dwelling	3rd previous dwelling	4th previous dwelling	Total per city
Albrandswaard	24.674	8	1	2			**11**
Barendrecht	46.831	11	5	1			**17**
Bernisse	12.404	2	1				**3**
Binnenmaas	28.967	5	5	3	2		**15**
Brielle	15.978	3	1	1			**5**
Capelle aan den Ijssel	66.104	17	9	5			**31**
Cromstrijen	12.789	2		2	1		**5**
Dirksland	8.408	1	1		1		**3**
Goedereede	11.409	2	3				**5**
Hellevoetsluis	39.739	15	7	2	2	2	**28**
Korendijk	10.848	3	3	1	1		**8**
Krimpen aan den Ijssel	28.626	4	3	1	1		**9**
Lansingerland	54.090	10	7				**17**
Maassluis	31.910	5	3	1	1		**10**
Middelharnis	18.050	4	1	2	1		**8**
Oostflakkee	10.406	1	1				**2**
Oud-Beijerland	23.536	9	3	2	1	1	**16**
Ridderkerk	44.889	20	12	6	3	2	**43**
Rotterdam	610.386	152	118	60	28	9	**367**
Schiedam	75.718	12	9	5	2	3	**31**
Spijkenisse	72.244	25	20	11	5	4	**65**
Strijen	8.868	1					**1**
Vlaardingen	71.269	22	14	2	1	1	**40**
Westvoorne	13.992	2	1				**3**
Zuidplas	40.521	5	4	2		1	**12**
Total Rotterdam area	**1.382.656**	**341**	**232**	**109**	**50**	**23**	**755**
% inside study area		99.13%	88.89%	78.99%	73.53%	63.89%	
Other cities		3	29	29	18	13	

Officially, the Rotterdam area consists of 15 municipalities (called stadsregio, see http://stadsregio.nl/). However, for our study area, we added eight municipalities that either has a large sample of respondents, or were municipalities in between two others with a large number of respondents. This allowed for, we have a continuous area of study. Although some cities have a small sample of respondents, this is not considered a problem, because the characteristics of the urban form we analyse are taken at the respondent level, minimizing the effect of neighbourhood size or sample size in our analysis.

The municipalities included in this study are: Albrandswaard, Barendrecht, Bernisse, Binnenmaas, Brielle, Capelle aan den Ijssel, Cromstrijen, Dirksland, Goedereede, Hellevoetsluis, Korendijk, Krimpen aan den Ijssel, Lansingerland, Maassluis, Middelharnis, Oostflakkee, Oud-Beijerland, Ridderkerk, Rotterdam, Schiedam, Spijkenisse, Strijen, Vlaardingen, Westvoorne, and Zuidplas (see Figure 4.1). Together, these municipalities have 1,382,656 inhabitants (CBS, 2010).

Rotterdam is the city with the highest number of respondents for the present and past dwellings of respondents. Because most respondents lived in less than five different houses, there is more data for the present and most recent houses than for the third and fourth previous dwellings. The total number of respondents who reported dwellings in each city of the Rotterdam region is shown in Table 4.1.

As can be seen, larger municipalities have more respondents than smaller ones. These municipalities have different urban form and function characteristics, which will be discussed in the next sub-section.

4.3 Urban forms considered

The decision of the urban forms chosen for the analysis aims to capture the complexity of the urban environment. Additionally, it is contingent on the data that were available. Considering these two aspects, three characteristics of urban forms were chosen: density, land use, and accessibility. In the following, we first describe the data collected, then we discuss the level of analysis, finishing with the description of how the characteristics of urban forms are computed.

4.3.1 Data

To capture the complexity of the urban system, data from different sources were collected. All data collected is available in Geographic Information System (GIS) and for the entire Netherlands. The list of sources and data is:

Centraal Bureau voor de Statistiek (CBS): provided two main data: maps of the division of neighbourhoods and cities, with information about population size, household composition, and income at the neighbourhood and municipality levels; and data about the degree of urbanization per postcode. The maps used in the analysis are from 2010. The main information used for this project from the maps was the population and the boundaries of cities and neighbourhoods. The degree of urbanization was used as a proxy for density.

Data Archiving and Networked Services (DANS): produced maps from 2006 delimiting the land use of areas divided in the following groups: traffic areas, built land, semi-built land, recreational land, agricultural land, forest and open natural terrain, inland water, and outside water. The data from DANS was used to calculate the distance from the respondents to destinations such as retail areas and parks. Besides that, the land use data from DANS was essential to know the locations of wet and agricultural areas, and to draw more precise thematic maps.

Basisregistraties adressen en gebouwen (BAG): in English, basic registration of addresses and buildings, the BAG maps consist of the floor print of the buildings for the entire country, as well as the single or multiple uses for each building. The land use types are divided in 11 types: residential, gathering function, cell function, healthcare function, industrial, office function, accommodation function, educational, sports function, retail function, and other functions. The map is from 2004 and it was used to compute the single and multiple land uses at different levels.

Open street maps (OSM): Open street maps were downloaded from the Geofabriek website (http://www.geofabrik.de/data/download.html). A large amount of data can be downloaded in OSM. For this project we used information about public transportation, which consists of points for the different public transportation modes; and the street network, which allows the computation of distances.

To work with data from the different sources together, one should be careful about the projections of the maps. Different projections can cause an equivocated layering of maps. In our case, open street maps were produced in the world projection while the maps originated in the Netherlands were in the Dutch projection. All our maps were therefore adjusted to the Dutch projection. All data were analysed aggregating the different layers using the TransCad software.

To integrate the data from our questionnaires with the maps, it is first necessary to identify the locations for each house for all respondents. In the questionnaire, the

Table 4.2 | Amount of valid postcodes per house informed, from the most to the least recent house

	House 1	House 2	House 3	House 4	House 5
6-digit postcode	334	242	122	62	29
4-digit postcode	12	27	21	10	11
Total	346	269	143	72	40
Missing	4	52	166	246	290

respondents gave us information about up to five different places where they lived, and for each of them the postcode was asked. With this information, we could create a *shapefile* with the location of every respondent and aggregate it to the urban form analysis. In order to get the *shapefile*, we first used the *batchgeo* website (http://batchgeo.com/nl/) to generate a *kml* file that can be opened in Google Earth. When opening in Google Earth we could check the addresses and change those that were incorrect. For example, some postcodes were found in other countries. After the corrections, we used another online tool to convert from *kml* to *shapefile* (http://www.zonums.com/online/kml2shp.php).

Some respondents (9% of the total) gave information about only the 4-digit postcode either to all or to some of their houses. The *batchgeo* does find a location for the 4-digit postcode but it is not as precise as the complete postcode with the four digits and two letters. We decided to keep the cases with only the 4-digit postcode, accepting that it is close enough to the precise one. Those respondents that didn't give us a valid postcode were excluded from the analysis. Table 4.2 presents the amount of house with 6-digits and 4-digits postcodes per house informed by the respondents.

4.3.2 Level of analysis

In the literature on the relationship between urban form and travel behaviour, the level of analysis for the urban form is often at the neighbourhood level. Characteristics of the neighbourhood are added to the respondent.

Our analysis takes a different approach: it calculates the urban form information at the respondent level. In this way we can precisely see the effect of the built environment at one's residence place, independently of the specific location inside the neighbourhood where the respondent is located.

The knowledge of the precise location of each house where the respondents lived allowed us to analyse all urban form characteristics at the respondent level. The analyses were computed using a buffer around the respondent. For this buffer, we decided to use a distance of one kilometre, which is how the CBS defines a walkable distance. One may argue that, as the study location is in a country with a large use of bicycle as the Netherlands, a cyclable distance should be considered (3km radius). However, due to the disparities of municipalities existent in the study area, 3km radius would be too large and include the whole extent of small municipalities.

Using the respondent as a level of analysis, besides having a singular precision of the built environment, has other advantages in relation to having bigger areas as the level of analysis:

- *To have an abstraction of which neighbourhood a respondent is living in and study more precisely the environment around the respondent's house.* This is especially important when one thinks about the diversity of sizes of the neighbourhoods. In a big neighbourhood the differences between two respondents – one living closer to its centre and other closer to the border – might be important: the two respondents can be in completely different built environments.
- *To minimize the effect for the respondents living in the border of a neighbourhood.* Some respondents that live in the border of a neighbourhood might use more often the facilities and services in the adjacent neighbourhood than from the neighbourhood where he/she is living.
- *To enable the analysis for any respondent in any place where they live.*

Having described the data and level of analysis, the following sections discuss how the analyses for all types of built environment characteristics were done.

4.3.3 Density

Alongside with land use, density is one of the features of urban form most studied in the literature on the relationship between urban form and travel behaviour (Naess 1995; Cervero 1996; Naess & Sandberg 1996; Cervero & Kockelman 1997; Boarnet & Crane 2001; Krizek 2003a; Miranda-Moreno et al. 2011). One reason for that is that high density by definition means shorter distances, and one would expect that if people use nearby facilities, they would travel shorter distances. Moreover, shorter distances imply that dwellers do not necessarily have to use the car but can bike or walk. Another reason is that density is implicitly related to many other characteristics of a city or region. Higher density means not only more people living in a certain area but it usually also means more diversity of urban functions, more transport infrastructure and more complex urban systems.

However, there are different types of density that can be explored for the analysis of an urban area, and often the literature refers only to the most common type of density: the gross density, which is defined by the population in an area divided by the surface of that area. Obviously, this measure is not necessarily directed related to the above reasoning.

Besides the most used type of density, different categories of density can be calculated. A notable one is employment density. Another main distinction that can be made is between gross and net densities, the first being the population divided by the whole area concerned, while the second being the population divided by the area concerned with its use – for example, residential use or employment places (Alexander, 1993; Churchman, 1999; Jenks and Dempsey, 2005).

Despite the extensive literature on the definition and types of density, the literature about the relationship between urban form and travel behaviour has mainly concentrated on the residential gross population (Cervero and Kockelman, 1997; Maat and Timmermans, 2009). Some studies combined residential density with employment density (Frank & Pivo 1994; Cervero & Kockelman 1997; Maat & Timmermans 2009). Others calculated household density, which means the number of households divided by the area concerned (Cervero and Kockelman, 1997; Krizek, 2003b).

Among these different types of density, we should define which one best fits our objective of analysis. Comparing the gross and net residential density definitions, we first considered using net residential density, which for our purpose would suit better, as we aim to understand the immediate surrounding of the respondent's place of living. However, in an initial evaluation, the net density did not reveal the difference among respondents' living environment in a way that resembles our common sense. This might result from the fact that – using the available data – the net density could only be calculated related to neighbourhood areas. Using a neighbourhood-level data may not reflect the characteristics that are perceived as crucial in our analysis, which are at the respondent level.

Finally, instead of calculating the density of neighbourhood areas, we decided to use the degree of urbanization, which is available from the CBS at the postcode level (6-digits). The degree of urbanization can be understood as density, as it is a classification of the density of surrounding addresses. It is categorized into five classes and displays the number of addresses within a circle with a radius of one kilometre around an address, divided by the area of the circle. As a result, it is expressed in addresses per km2. The degree of urbanization represents also a measure of the concentration of human activities in a radius of one-squared kilometres. The human activities considered are housing, work, school, shopping, entertainment and other uses related to the needs of the people living in an area.

The five categories of the degree of urbanization classification are:

1. Extremely urbanised: 2,500 addresses or more per square kilometre;
2. Strongly urbanised: 1,500 to 2,500 addresses per square kilometre;
3. Moderately urbanised: 1,000 to 1,500 addresses per square kilometre;
4. Hardly urbanised: 500 to 1,000 addresses per square kilometre;
5. Not urbanised: fewer than 500 addresses per square kilometre.

The most common degree of urbanization of the respondents is extremely urbanised, accounting for 40% of respondents. The second and third most common degrees of urbanization are strongly urbanized and moderately urbanized, accounting for 28% and 15% of respondents, respectively. When comparing the results of the respondent's degree of urbanization with that from the study area, it is clear that they are similar with a small underrepresentation of the extremely urbanized degree (Figure 4.2).

Further analysing the degree of urbanization in our sample, as changes in the degree of urbanization are related to the house, we analysed first the changes in each house. Secondly, we analysed the degree of urbanization from the 20-year life trajectory perspective. Figure 4.3 displays an example of the different degree of urbanization for ten respondents in up to five houses where they lived in.

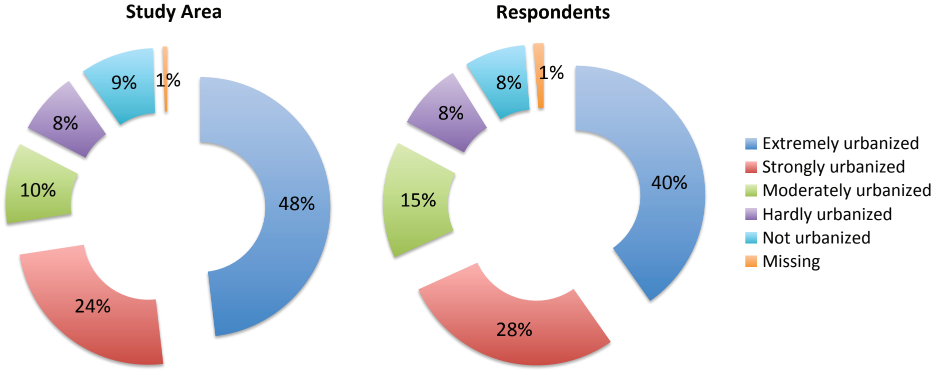


Figure 4.2 | Proportion of degree of urbanization study area versus respondents

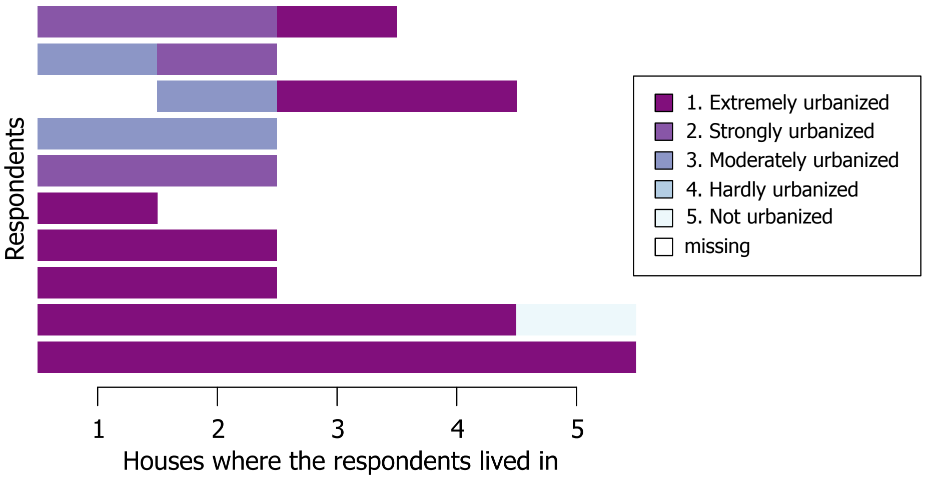


Figure 4.3 | Example of the degree of urbanization per house informed for ten respondents. Houses are ordered from most to least recent

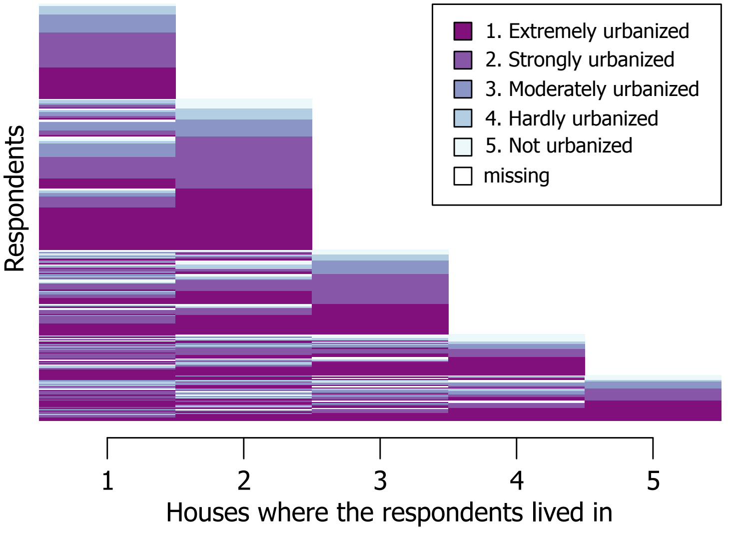


Figure 4.4 | Degree of urbanization per house informed, most recent first

Analysing the changes in the degree of urbanization between the different houses where the respondents lived in, it can be observed that, most frequently, respondents had only one type of degree of urbanization along their life, counting for 50% of

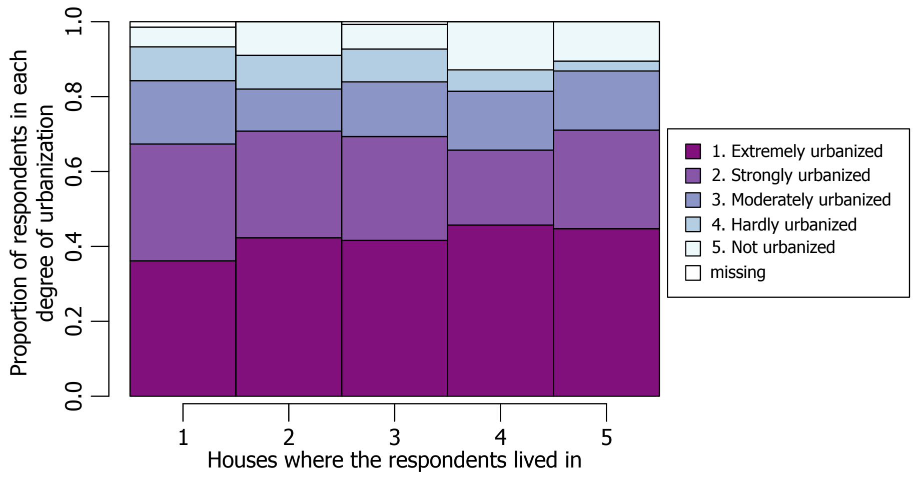


Figure 4.5 | Proportion of respondents in each degree of urbanization per house informed

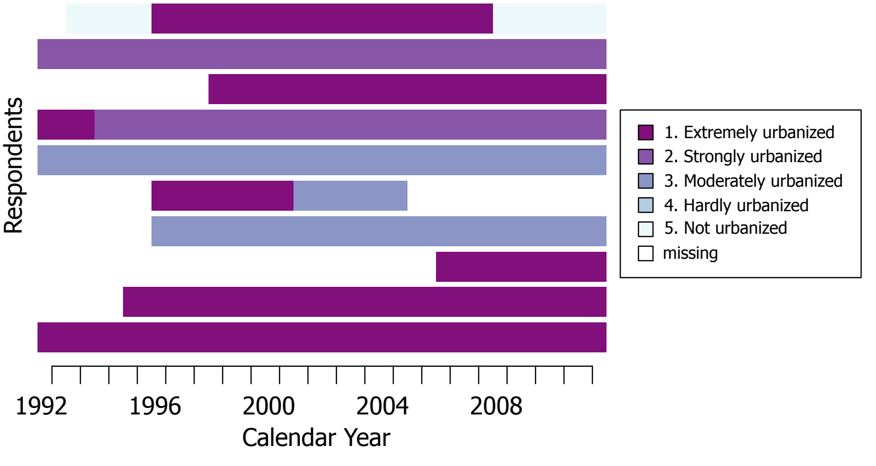


Figure 4.6 | Example of the degree of urbanization distributed by the calendar year for ten respondents

responses (Figure 4.4). Those respondents that changed once their degree of urbanization accounted for 30%, 15% of respondents lived in three different degrees of urbanization, and only a few respondents lived in more than three different degrees of urbanization.

Figure **4.5** shows the proportion of respondents in each degree of urbanization. The majority of respondents lived in a degree of urbanization 1 and 2.

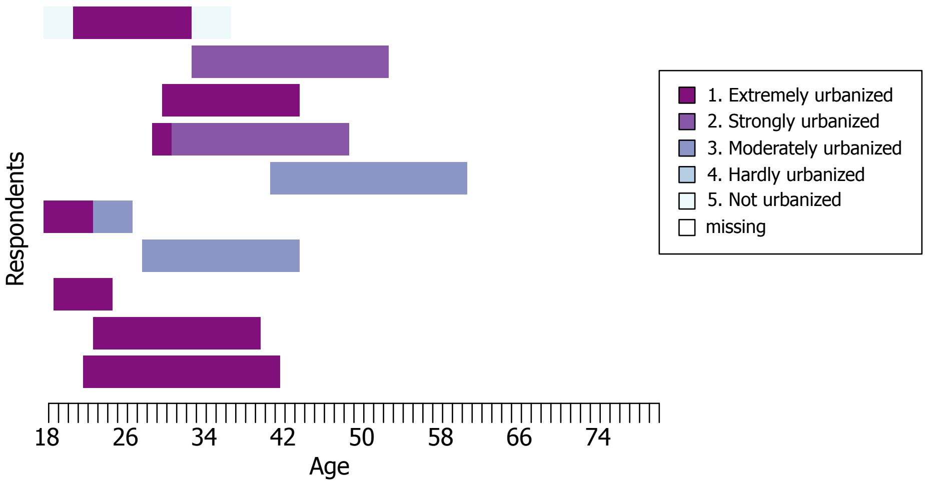


Figure 4.7 | Example of the degree of urbanization distributed by age for ten respondents

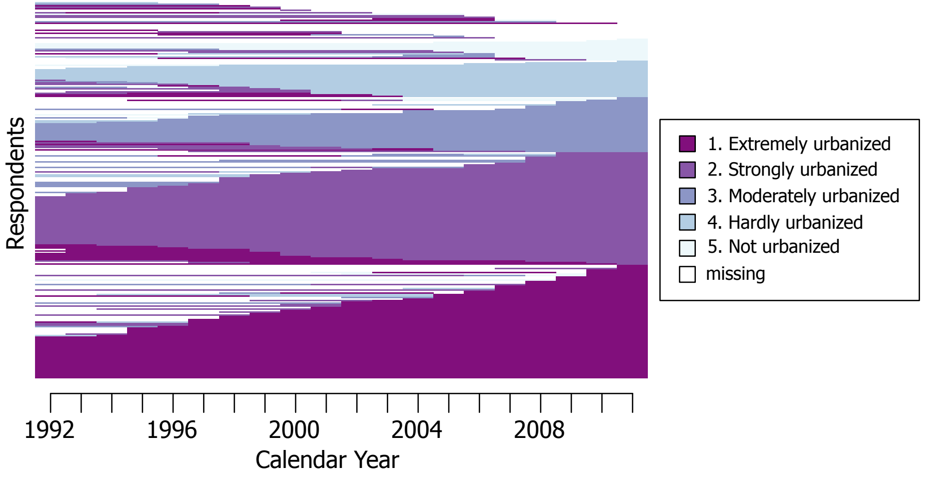


Figure 4.8 | Distribution of the degree of urbanization by calendar year

In order to display the distribution of degree of urbanization in the life trajectory calendar, we use the same methodology of the mobility career. Figure 4.6 shows an example of the trajectory of the degree of urbanization for ten respondents considered the year informed in the questionnaire. The same sample of ten respondents was used in the visualization in Figure 4.7, where the distribution of the degree of urbanization is based on the age the respondents had when the change occurred.

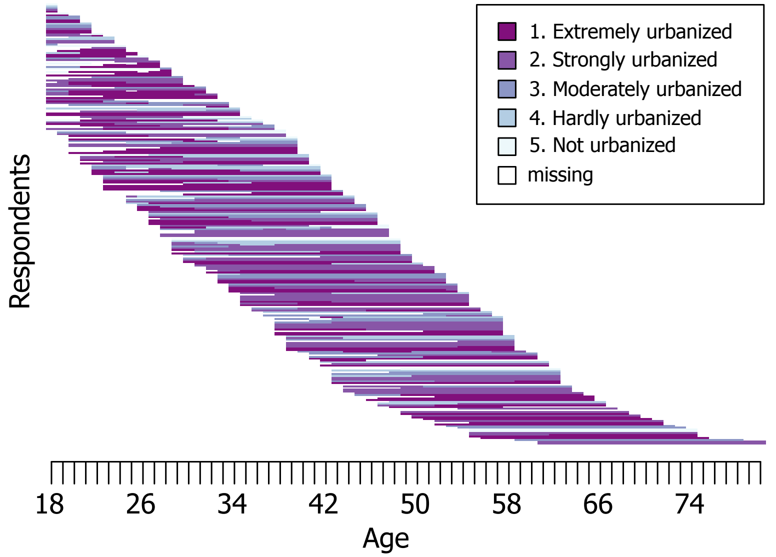


Figure 4.9 | Distribution of the degree of urbanization by age

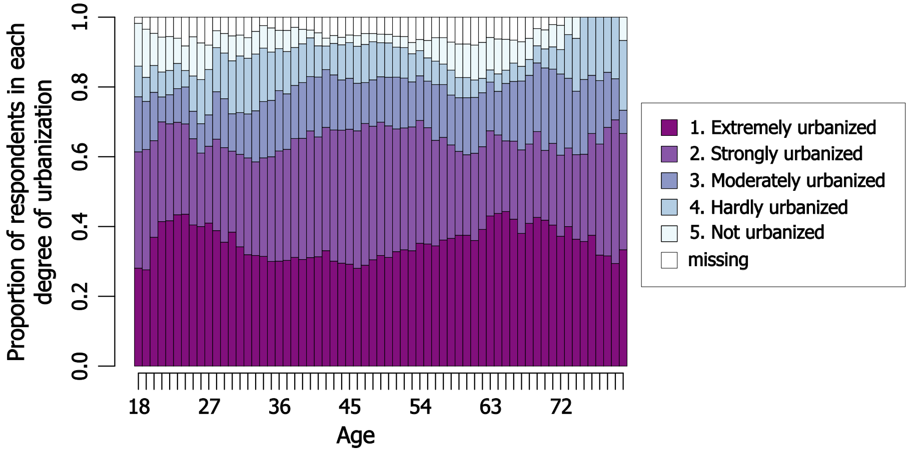


Figure 4.10 | Proportion of respondents in each degree of urbanization according to their age

Figure 4.8 and Figure 4.9 show the trajectory of the degree of urbanization for all respondents distributed by the calendar year and by the age the respondents had when the event happened, respectively.

Looking at the distribution of the degree of urbanization per age over the years, an increase in the extremely urbanized degree of urbanization around the age of 20 is noticeable reaching a higher proportion of respondents living in this degree at the age 23. The decreasing of this peak starts after 27 years old with another peak at the age 64. The respondents seem to have a preference for a strongly urbanized environment at middle ages, at the same period it is apparent a lower variation when comparing when the respondents are between the ages 20 and 30, as shown in Figure 4.10.

4.3.4 Land uses

Another important feature that can indicate differences between urban areas is the mix of uses, in particular when it concerns its relationship with travel behaviour. The availability of different services and shops close to home, for example, can influence directly how a person reaches the places needed.

Because of its impact on travel behaviour, mixed land use is probably the most studied urban form feature in the literature (Frank & Pivo 1994; Cervero & Radisch 1996; Kitamura et al. 1997; Krizek 2003a; Handy et al. 2005; Maat et al. 2005). The types of land use that are considered to calculate mixed land use vary widely in this literature. While some research focuses only on the difference between residential and non-residential, others take into account a variety of land uses. In the case of this project, the types of land use considered were established according to the existent data.

We obtained the land use types at the building level for the whole Netherlands from the *Basisregistraties adressen en gebouwen (BAG)*. For each building in the country, there is the information about the types and the prevalence of land uses in the building. This information is in a dot-formatted file: there exist as many dots per building as the amount of land uses; each dot consists of a unit and thus a land use. For example, a two-floor building with a shop at the ground floor and a house at the first floor will have two dots, one with the 'retail' use label and one with the information 'residential' use label.

The buildings can have one single dot, two or more dots of the same land use type, or two or more dots of different land use types. This information is important in order to calculate the proportion of different uses per building, having thus a realistic idea of the mix of land uses per building.

Eleven different types of land uses exist in the BAG dataset:

- Residential (in Dutch *woonfunctie*);
- Retail (in Dutch *winkelfunctie*);
- Educational (in Dutch *onderwijsfunctie*);
- Gathering (in Dutch *bijenkomstfunctie*);
- Healthcare (in Dutch *gezongheidszorgfuntie*);
- Industrial (in Dutch *industriefunctie*);
- Offices (in Dutch *kantoorfunctie*);
- Sport function (in Dutch *sportfunctie*);
- Lodging (in Dutch *logiesfunctie*);
- Cell function (in Dutch *cellfunctie*);
- Other functions (in Dutch *overigegebruiksfunctie*).

In the area of study, most buildings are solely residential (83.3%). Approximately 6% of the buildings have a mix of uses, which is the second most common land use type (see Table 4.4 for all functions). We should mention that this data was cleaned; almost 40% of the gross data were 'missing data' and were removed

Table 4.3 | Cluster analysis for the 'mixed land uses' buildings. Each column describes one cluster at the building level. Each lines describes the amount of a given function in the clusters.

Function\Cluster	Mixed offices	Mixed shops	Mixed industry	Mixed other functions	Mixed residential	Mixed healthcare
Residential	0.04	0.37	0.36	0.51	0.74	0.47
Other functions	0.11	0.01	0.03	0.47	0.04	0.02
Offices	0.33	0.01	0.07	0.00	0.05	0.01
Gathering	0.24	0.01	0.01	0.00	0.04	0.00
Sport function	0.07	0.00	0.00	0.00	0.00	0.00
Retail	0.06	0.50	0.01	0.00	0.08	0.00
Healthcare	0.02	0.00	0.00	0.00	0.00	0.48
Lodging	0.04	0.01	0.00	0.00	0.01	0.01
Industrial	0.04	0.09	0.51	0.01	0.03	0.00
Educational	0.06	0.00	0.00	0.00	0.00	0.00
Cell function	0.00	0.00	0.00	0.00	0.00	0.00

from the analysis. This was done because checking to which building it was related, we noted that they were in majority related to soft constructions at the back of houses, such as storage places. Consequently, the missing data does not pose any problem to the analyses due to the insignificance of these buildings.

Due to the form in which the data is available, there is first the need to compute whether the building has a single or multiple functions. Second, it is also necessary to calculate which types of mixture of uses exist in the buildings. As presumed by urban planners, a high amount of mixture of uses might have an effect on the transport mode and transport time of individuals. It is worthwhile mentioning that this is a mixture at the building level. This analysis will be used latter on to calculate the mixture of land use at the respondent level.

To define the categories of mixed land use that exist at the building level in our data, we used cluster analysis to group the buildings. A hierarchical clustering algorithm unveiled six clusters of buildings with mixed use according to the proportion of each land use type in the buildings.

Table 4.4 | Land uses at the building level

Uses		Frequency	Percentage
Residential		328,192	83.3%
Other functions		18,834	4.8%
Industrial		8,172	2.1%
Lodging		6,120	1.6%
Retail		2,286	1.6%
Offices		2,246	0.6%
Gathering		2,308	0.6%
Healthcare		498	0.1%
Sport function		355	0.1%
Educational		923	0.2%
Mixed uses	Mixed residential	11,241	2.9%
	Mixed industrial	3,939	1.0%
	Mixed other functions	3,351	0.9%
	Mixed retail	3,414	0.9%
	Mixed offices	1,421	0.4%
	Mixed healthcare	527	0.1%
Total		393,827	100.0%

From the cluster analysis, six types of mixed land use buildings were identified: mixed residential, mixed industrial, mixed offices, mixed retail, mixed other functions, and mixed healthcare. Table 4.3 displays the average proportion of each function in the clusters.

Considering together buildings with a single land use and those with mixed land uses, there are in total 17 types of land use. Table 4.4 displays the occurrence of land use types at the building level in our data.

After examining how the land use types are distributed in the study area, it is necessary to calculate the proportion of land uses around each respondent. For that, we used the same area that was used for density: a buffer with a one-kilometre radius around each respondent. The proportion of each land use in a buffer is calculated as the proportion of the total floor print in all buildings of that buffer devoted to each land use. Figure 4.11 shows an example of a buffer around a respondent.

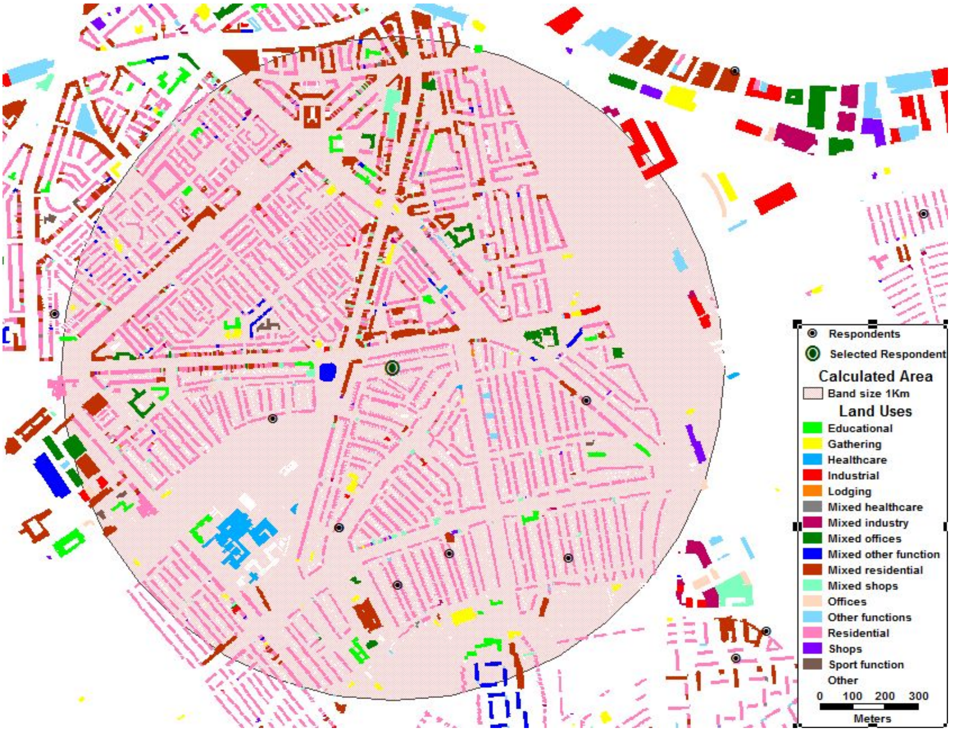


Figure 4.11 | Example of the land use buffer around a respondent

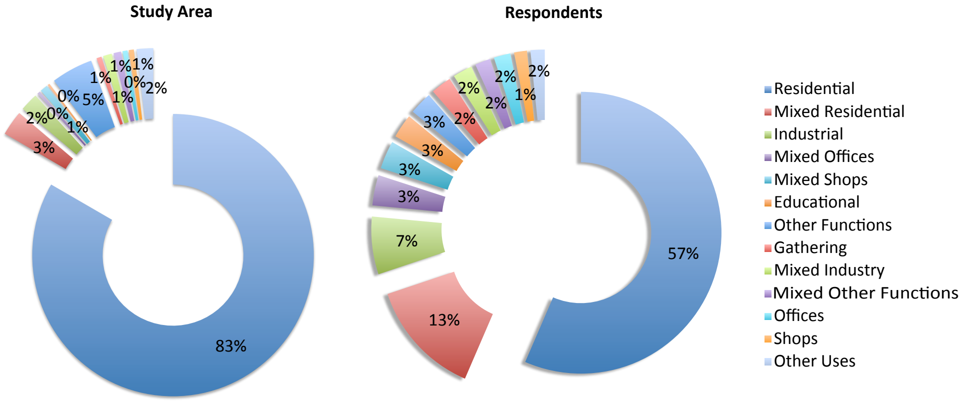


Figure 4.12 | Proportion of land uses: study area versus respondents

Table 4.5 | Descriptive statistics for the land use around the respondents

	Minimum	Maximum	Mean	Std. Deviation	Coefficient of variation
Residential	11.8	95.1	58.5	15.8	0.3
Mixed Residential	0	43.3	11.3	8.4	0.7
Industrial	0	79.8	7.5	11.0	1.5
Mixed Offices	0	20.9	3.0	2.8	0.9
Mixed Shops	0	18.4	3.0	2.9	1.0
Educational	0	9.6	2.7	1.9	0.7
Mixed Industry	0	34.2	2.6	3.5	1.3
Other Functions	0	17.8	2.6	2.6	1.0
Gathering	0	17.9	2.2	2.1	0.9
Offices	0	17.4	1.8	1.9	1.1
Mixed Other Functions	0	11.1	1.7	1.7	1.0
Shops	0	50.7	1.5	2.4	1.6
Sport Function	0	7.4	0.7	0.9	1.4
Healthcare	0	7.5	0.5	0.9	1.7
Lodging	0	34.7	0.2	1.3	7.1
Mixed Healthcare	0	2.7	0.3	0.4	1.4

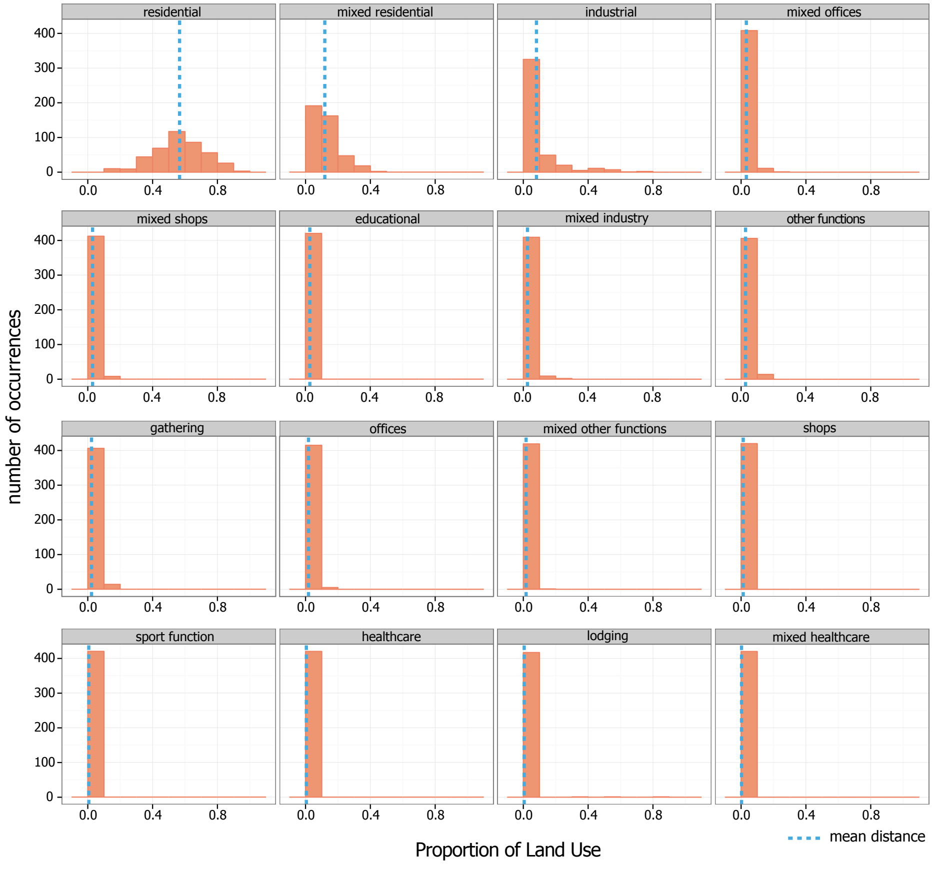


Figure 4.13 | Histogram of the proportion of each land use type around each dwelling

Before performing the buffer calculation, we tested whether it was necessary to include neighbour cities that would affect the calculated proportion of land uses around the respondents. However, all respondents were at least one kilometre away from the border of the city, thus making it unnecessary to include neighbour cities besides the ones from the study area.

The three most common land use types in the buffers around the respondents are Residential, Mixed Residential, and Industrial. The Residential and Mixed Residential uses together account for 70% of land use types in the respondents' surrounding area.

When contrasting the results of the land use around the respondents with the land use in the entire study area, it is clear that the respondents live in a more diverse

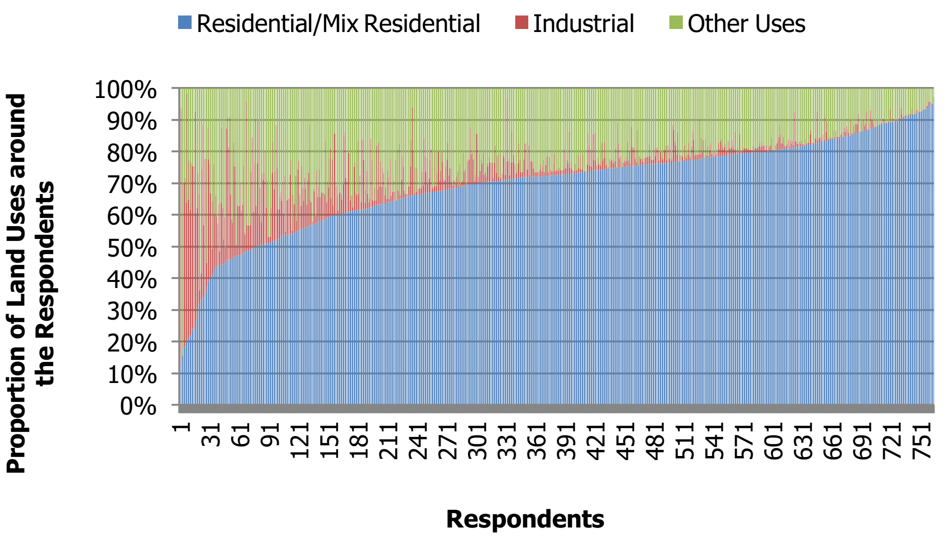


Figure 4.14 | Proportion of residential, industrial and other uses around the respondents

setting when compared to the average on the entire area (Figure 4.12). The land use around the respondents is less predominantly residential: 83% in the entire study area against 57% in the buffers around the respondents is residential. On the other hand, the amount of mixed residential is higher, as well as other land uses.

Table 4.5 and Figure 4.13 presents statistics and the histograms for the land use around respondents. Although Industrial land use is the third most common type of use on average, it is one of the uses that varies the most among respondents. Figure 4.14 shows that when there is a higher proportion of Industrial land use, the proportion of Residential land use tends to decrease. Which is also due to the fact the industrial areas are usually large terrains.

Following the analysis of the proportion of urban form in one-kilometre buffers, each house from each respondent is described in terms of quantifications of 16 different land uses in its surroundings. To discover categories of buffers according to these different land uses, the areas around each of the respondents' houses are clustered using a hierarchical cluster algorithm.

Figure 4.15 presents the distribution of values for the land uses in the surroundings of respondents in each of the found clusters. Four different clusters were

Figure 4.15 | Each point represents the land use for one respondent and each distance has one box-and-whiskers plot summarizing its distribution

defined: mildly residential, mainly residential, mixed environment, and mainly industrial. The amount of houses in each cluster is shown in Table 4.6.

Residential land use type is the land use type predominant in all clusters' types due to the vast majority of land use being residential or mixed residential. Apart from this commonality, the four clusters have the following characteristics:

1. *Mildly residential.* Most of the analysed houses belong to this group. In this cluster, there is high representation of single residential land use. Yet, not as much as in the mainly residential cluster. Mixed residential and mixed shop land uses are as present as in the mixed environment cluster. There are numerous houses with educational land use, which denote that this cluster describes neighbourhoods that are not in the city centre, with local shops and schools available at close distance.
2. *Mainly residential.* In this cluster, the majority of the houses are single residential use, and a few mixed residential land uses. There is a low presence of single industrial land use. The rest of the land use types have low representation. This cluster represents houses typically located in the border of the cities or in smaller cities.
3. *Mixed environment.* This cluster has the highest proportion of mixed land uses. It is the cluster that has the lowest single residential use, except for the mainly industrial cluster. This group of houses is representative of a built environment with all commonly necessary service around.
4. *Mainly industrial.* This cluster is the one that has the highest proportion of single industrial land use. Several houses from this cluster are also in the mixed industrial land use type. There is little presence of all other land use types. Houses that belong to this cluster are usually located close to industrial areas of the city.

Table 4.6 | Division of houses per cluster type

Cluster type	Number of houses	Percentage of houses
1|Mildly residential	368	49.1%
2|Mainly residential	190	25.3%
3|Mixed environment	152	20.3%
4|Mainly industrial	40	5.3%
Total	750	100%

To validate this cluster analysis, we randomly selected five houses from each cluster and verified the built environment in its surrounding area using Google Street View. In all cases, the cluster in which the house was categorized reflected our impression about land use in that area.

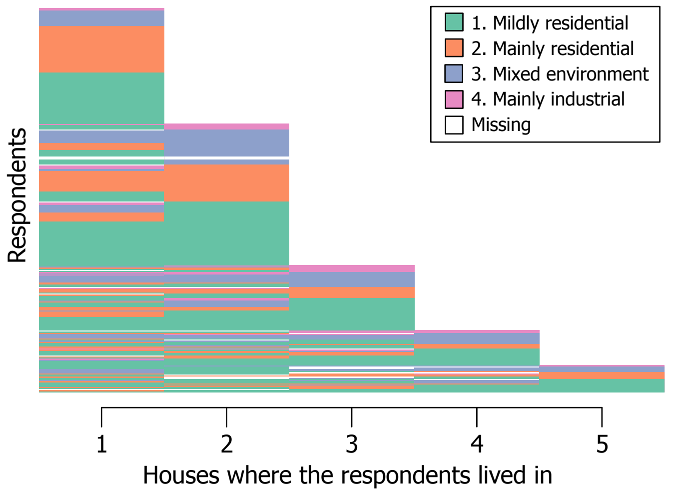


Figure 4.16 | Land use cluster per house informed. Houses are ordered from the most to the least recent

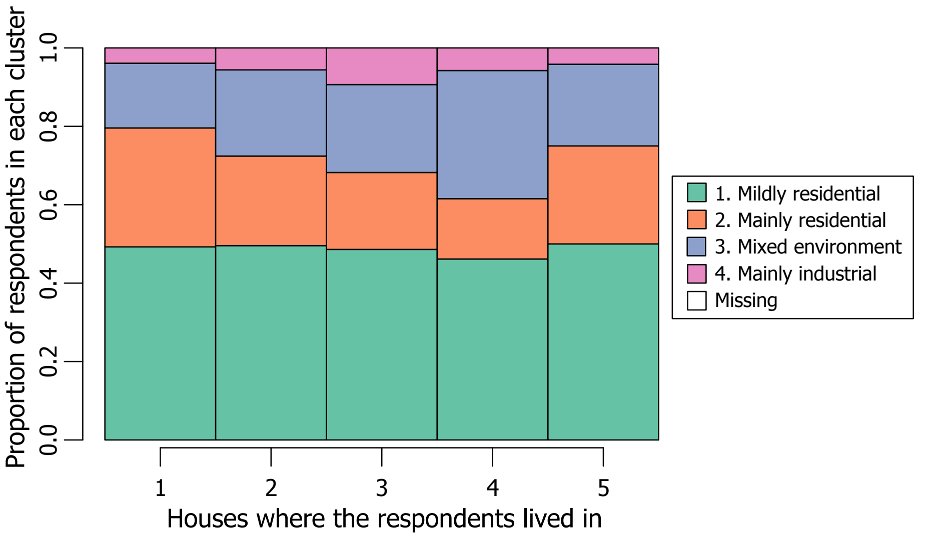


Figure 4.17 | Proportion of land use types per house informed. Most recent first

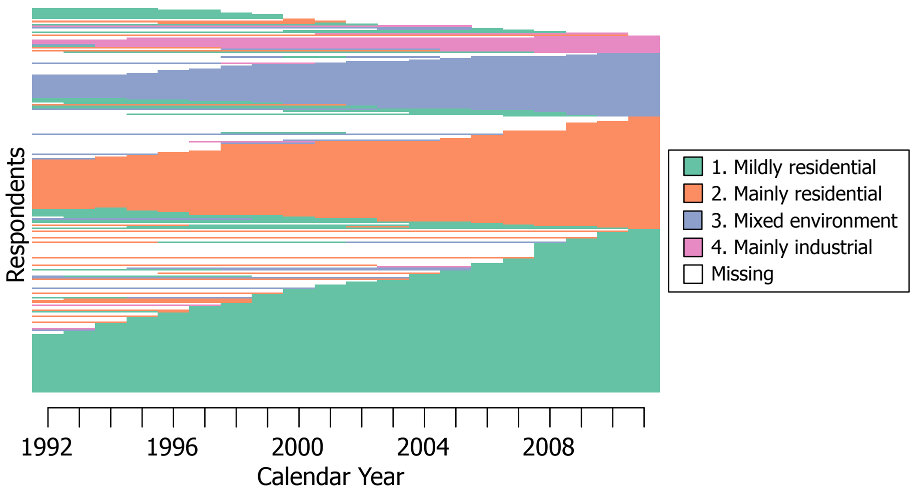


Figure 4.18 | Distribution of the land use types per year informed

Considering the categorization of land use types into the four described clusters, we now examine land use in a longitudinal perspective. Looking at the distribution of the land use clusters in a 20-years period of the life trajectory, the majority of house changes don't mean a change in land use type: 72.7% of respondents had the same land use type over their housing career, 22.9% had two changes, and thus only a few had three or four changes. Figure 4.16 presents the distribution of land use clusters over the years per house informed. In Figure 4.17 it is possible to observe the proportion of each cluster, and that for all houses the majority of respondents belong to the cluster one, followed by the cluster two and three. A few respondents were found in cluster four. As can be seen in the distribution of the land use clusters per calendar year (Figure 4.18), there is no common pattern of change over the years.

Looking at the proportion of land use types over respondents' age (Figure 4.19), it is perceivable that around the age of 25 and above the age of 55, there is an increase in the number of respondents in the clusters three and one, and a decrease of the cluster two. The increase of the cluster mainly residential starts mainly around the age of 25, which is the age when respondents usually get married or have child, thus they might prefer to live in calmer areas or have a bigger house. The cluster four decreases at younger ages but it increases at older ages. This outcome shows that respondents might be living in a more diverse built environment in these age ranges. This may be

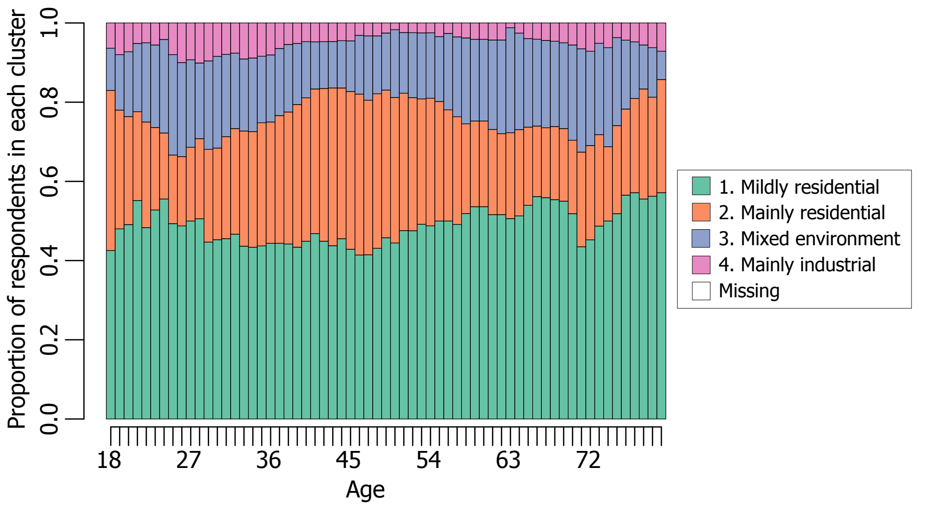


Figure 4.19 | Proportion of respondents in each land use cluster per age

due to the fact that when children leave home, parents might consider moving to a more convenient living environment.

4.3.5 Accessibility

The last characteristic of urban form analysed in our study is accessibility. In this study, accessibility is defined by the set of distances between the respondents' dwellings and public transportation, highways, retail and parks. An area that is dense and consists of a mix of land uses can be indirectly related to the degree of accessibility of this area. Evidently, if one lives in an area full of shops and services, there is no need to travel long distances to reach certain destinations. Additionally, destinations that are closer to home might encourage people to use less the car, and walk and cycle more. However, as the objective of this study is to understand the effects of accessibility on activity-travel behaviour, we judge necessary to include specific measurements of the accessibility to different destinations.

Furthermore, as we are calculating the characteristics of urban form at the respondent level, having the distances to multiple destinations for each respondent may improve the results of the analysis. Thereby, we decided to measure the distances from the respondents' dwellings to all public transportation access, highways, parks and retail centres. More specifically, ten different distances were considered in the analysis:

1. Distance to closest bus stop,
2. Distance to closest tram stop,
3. Distance to closest metro entrance,
4. Distance to closest local train station,
5. Distance to closest intercity train station,
6. Distance to closest retail centre,
7. Distance to closest larger retail centre,
8. Distance to closest park,
9. Distance to closest forest, and
10. Distance to closest highway access.

The retail area was used as a proxy for a city centre, acknowledging that some cities may have multiple of such centres. We consider that the most important feature that defines a city centre in the Netherlands is its commercial area. To identify such areas, we use the retail area existent in the land use classification from DANS[1], which are divided in two types: all retail areas, and all commercial areas that are larger than 100,000 squared meters. In this way we could represent the attraction larger cities have to generate trips from people living in smaller cities, as well as the existence of secondary centres in cities. These areas were selected and exported as centroids to the GIS software.

Concerning the green areas, we used also the information existent in the land use classification from DANS. For that, we consider areas classified as parks and forests (in Dutch *park en plantsoen* and *bos*). These were also selected and exported as centroids.

The information about all public transportation points was obtained via Open Street Maps. In these maps there is the exact location of all tram, bus, and metro stops, as well as train stations in the Netherlands. For the train stations, it was also identified whether at each station, intercity trains or only local trains stop. In this manner it is possible to differentiate between larger and more important stations and minor ones.

[1] The land use classification from DANS differs from that from BAG in the sense that it is divided in larger areas and based on the predominance of land use in those areas. On the one hand, a limitation of this classification is that it doesn't consider areas with mixed land uses. On the other hand, it is efficient in the sense that it defines its boundaries, and therefore it is not attached to formal geographic divisions such as neighborhood or postcodes.

Regarding the definition of the highway access, the road network layer also downloaded from Open Street Maps was used. In order to find the highway access, only roads defined as highways were selected. Then, the nodes that represent the access to the highway were manually selected, and coincided most of the times to the end of the road network line.

To calculate the distance itself, the distance between the origins (respondents) and destinations (bus stop, train station, etc.) was calculated using the shortest path between the two nodes on the existent road network. In most cases, origin and destination are not placed exactly on the road network, as they are usually inside buildings, parks, etc. To be able to calculate the distance between origins and destinations, we considered the nodes in the road network that are closest to origin and destination as the start and end point of the path, respectively. The final shortest path considers, thus, the distance between the closest node of the road network from the origin to the closest node of the road network from the destination. Such distances are considerably more realistic than the often-used Euclidean distances.

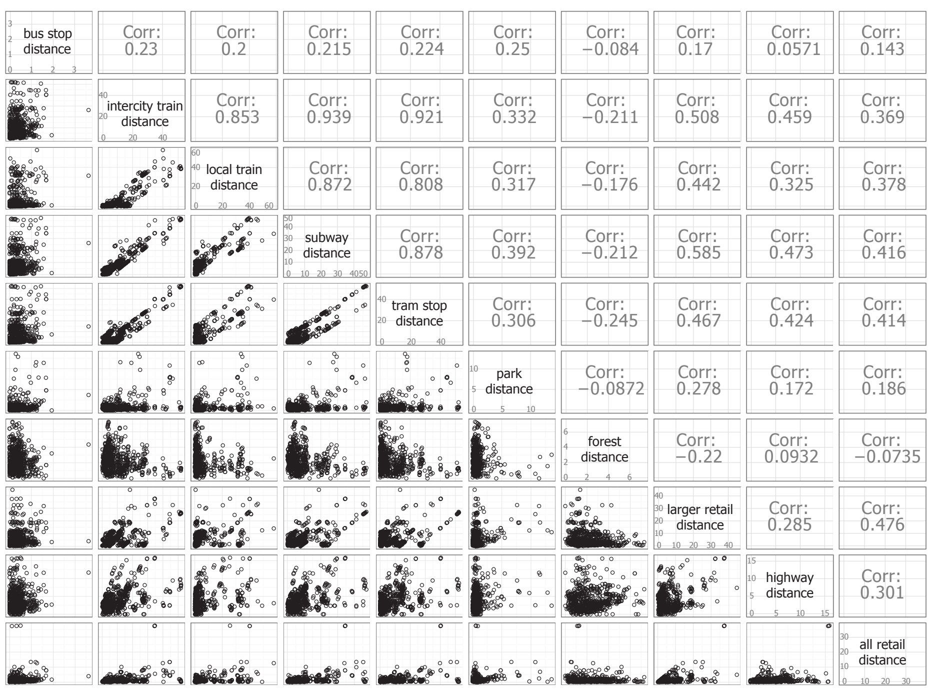


Figure 4.20 | Scatterplot matrix displaying the relations among the ten calculated distances. The upper half of the matrix displays Pearson correlation coefficients for all pairs of distances.

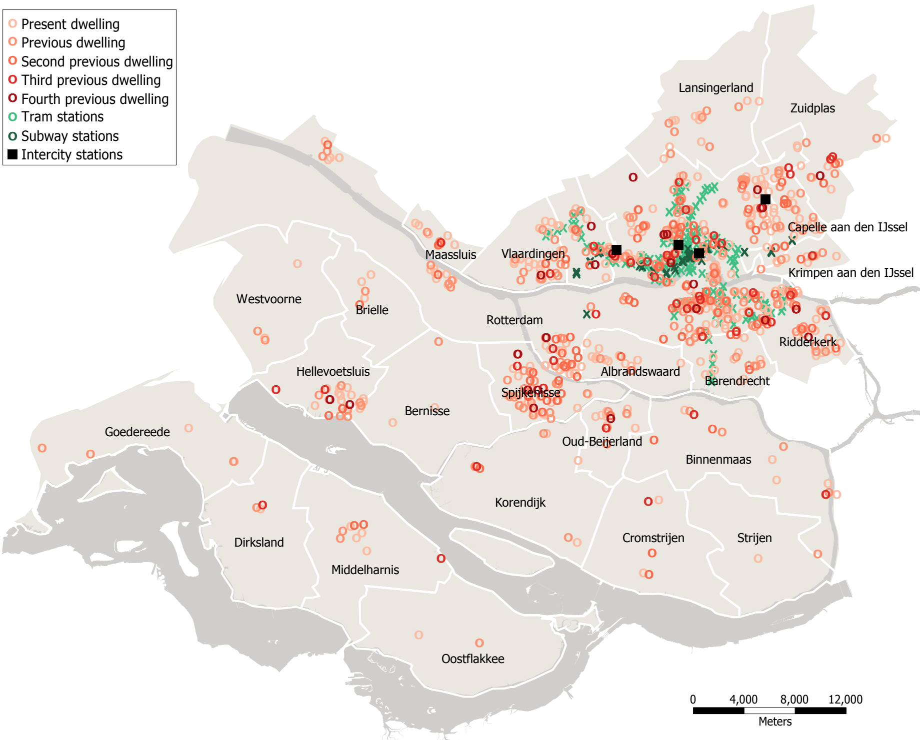


Figure 4.21 | Map with the distribution of intercity train stations, tram stations, and subway stations

To compare how the distance variables correlate with each other, a scatterplot matrix was produced. Figure 4.20 illustrates the degree of correlation between the ten distances considered in the analysis. Distance to intercity train station is highly correlated with distances to subway and tram stations. As it can be seen in Figure 4.21, the explanation to this correlation is due to the concentration of tram stations and subway entrances in the city centre of Rotterdam, where the intercity train stations are also located. In the other cities of the studied area, there are only local train stations and no intercity train stations. Because of this correlation, hereafter the distances to subway and tram stations are not considered in the analyses; the distance to intercity train station represents these two distances.

The histograms of the ten distances calculated per respondent are shown in Figure 4.22. Parks and bus stops are available extremely close to the majority of respondents, with a mean distance of less than one kilometre. Retail, forests and highways are reachable at a mean distance of less than three kilometres, although a considerable number of dwellings are located close to highways or retail. Local train and large retail centre are within a mean distance between five and six kilometres. The largest distance is to the intercity train station. Numerous cities in the Netherlands, including the Rotterdam area, have only one intercity train station. Naturally, only a small fraction of the population lives close to an intercity train station. All the mean distances are shown in Table 4.7.

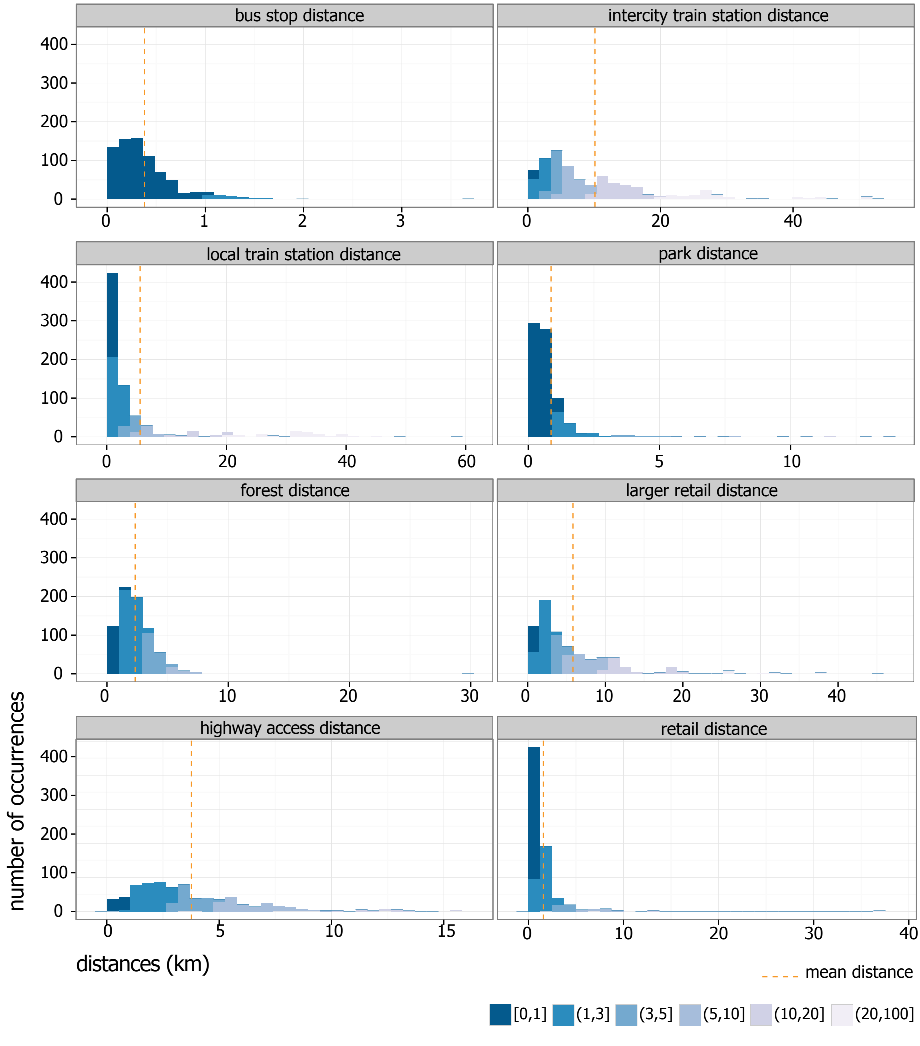


Figure 4.22 | Histogram of the distances from respondent's houses to accessibility proxies.

Table 4.7 | Mean distances to destinations

Destinations	Mean distances
Bus stop	0.38
Parks	0.87
Retail	1.57
Forest	2.32
Highway access	3.76
Local train station	5.57
Larger retail	5.83
Intercity train station	10.12

In order to analyse the distances, we categorized them into ranges: zero to one, one to three, three to five, five to ten, ten to twenty and more than twenty, all in kilometres. The rationale behind this categorization is based on which transport mode would be more suitable to use for each distance. Zero to one kilometre is the walkable distance defined by the CBS; one to three kilometres is a range reachable by foot and a fast cycling distance; three to five kilometres is a comfortable cycling distance; five to ten kilometres is a distance range reachable by local public transportation system or car; ten to twenty kilometres is a long distance range but likely within the same region; twenty or more kilometres is most probably located in a different region.

In terms of accessibility, the calculated distances show that, except for the bus stops, the respondents live mainly closer to leisure and service destinations, shown by parks, retail and forest being the closest distances. Related to the transportation service, the respondents live closer to a highway access than to public transport access, except buses.

Table 4.8 | Changes in distance categories over respondents' life trajectory

Destinations	One category	Two categories	Three categories	Four categories	Five categories	Mean number of states
Bus stop	95.26%	4.74%				1.05
Local train station	69.17%	24.51%	5.14%	1.19%		1.38
Intercity train station	78.26%	18.18%	3.56%			1.25
Retail	71.54%	22.92%	4.74%	0.79%		1.35
Larger retail	72.33%	22.92%	3.95%			1.33
Park	81.42%	15.81%	2.77%			1.21
Forest	73.91%	19.37%	5.14%	0.79%	0.40%	1.33
Highway	73.12%	19.76%	5.93%	0.79%	0.39%	1.35

Next, the final eight distances analysed are described in a longitudinal perspective, considering the changes in distances over the houses, the calendar year, and the respondents' age. For each respondent and distance detailed, we consider the respondent's life course as a string of states, each describing the range category in which the considered distance falls. Before further details, Table 4.8 presents the distribution of the number of different states in each respondent's life course.

4.3.5.1 Distance to closest bus stop

Looking at the distances to bus stop over the 20 years of the life trajectory, respondents had distances to the bus stop in at most two different ranges over their life

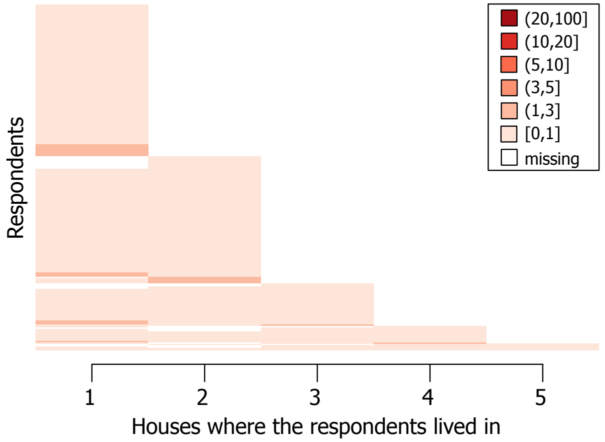


Figure 4.23 | Distance between house and closest bus stop per house informed

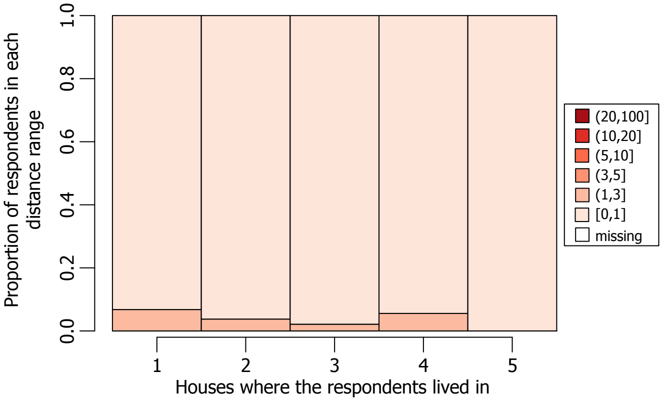


Figure 4.24 | Proportion of respondents in each distance range between house and closest bus stop per house informed

trajectories. The ample majority (95.3%) had only one distance category, illustrated also by the 1.05 mean number of states composing respondents' life course. Figure 4.23 and Figure 4.24 show the predominance of the zero to one kilometre distance range and some one to three kilometre ranges.

There are also no important changes in the bus stop distances range for the respondents when considering both the distribution per calendar year and age, as displayed on Figure 4.25 and Figure 4.26.

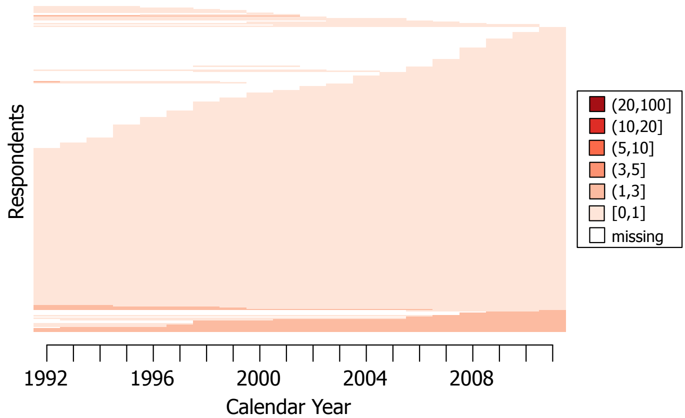


Figure 4.25 | Distribution of the distance range between house and closest bus stop by calendar year

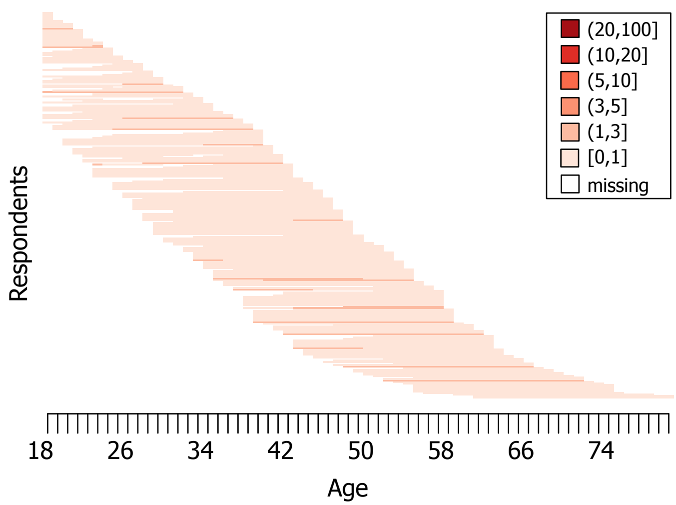


Figure 4.26 | Distribution of the distance range between house and closest bus stop by age

4.3.5.2 Distance to closest local train station

Distance to local train station is the one that has the highest number of changes in our data. Yet, in absolute terms, there is little change: a great majority of respondents (69,2%) reported living in one single distance range throughout their life trajectories.

Figure 4.27 shows the proportion of respondents in each distance range per dwelling in their life trajectories. Looking at the distribution of the distance ranges over the houses, one can observe that most commonly respondents lived one to three kilometres from a local train station. The distance range between zero and one kilometre is the second most common, but it clearly decreases from past houses to the present one.

A considerable proportion (12%) of respondents reported to have lived in a house that is located more than 20 kilometres away from a local train station. This is an indication that the distribution of (local) train stations is not homogenous in the study area.

The distribution of distances over time according to the calendar year shows no relation between distance and calendar year (Figure 4.28). When checking the proportion of respondents in each distance range according to their age (Figure 4.29), the distances to local train station are shorter around the age of 25 and above the age of 60, which may be explained by the fact the young people and elderly may prefer to live in more urbanized areas.

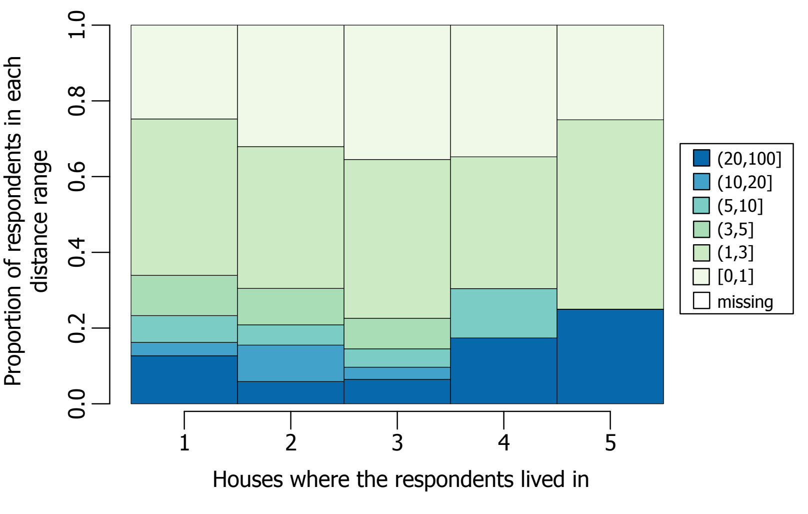


Figure 4.27 | Proportion of respondents in each distance range between house and local train station per house informed

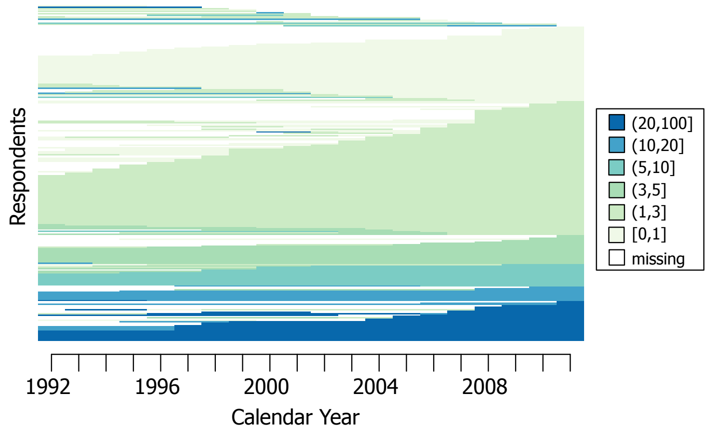


Figure 4.28 | Distribution of the distance range between house and local train station per calendar year

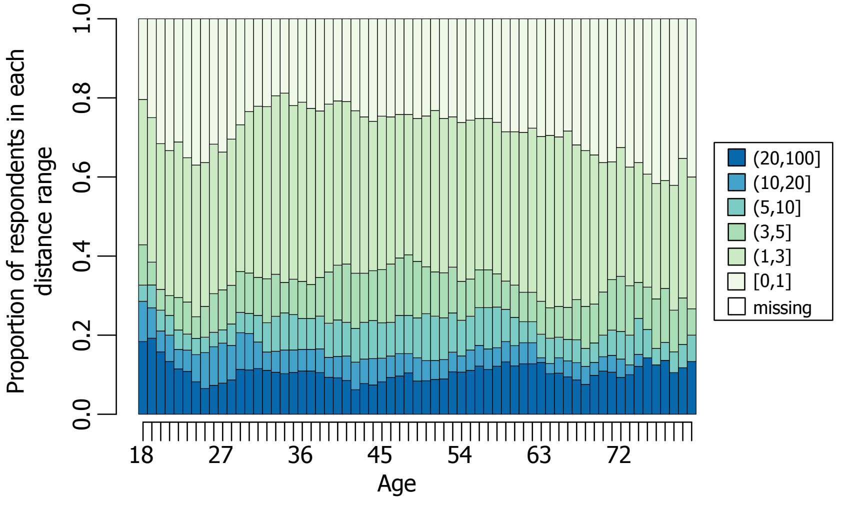


Figure 4.29 | Proportion of respondents in each distance range between house and closest local train station according to their age

In Figure 4.29, it is noticeable that there are two age ranges in which we observe a change over time. Between 18 and 30 years old, there is a reduction followed by an increase in the distance to a local train station. After 60 years old, there is an increase in people living close to a local train station, while at the same time there is a decrease in the 1-3 distance range.

4.3.5.3 Distances to closest intercity train station

When comparing the distances to intercity train stations with all other analysed distances, it is evident that the former has a higher variance among respondents. However, the number of distance categories over the housing career of a same respondent varies to a lesser degree: the respondents reported up to three changes in the distance to the closest intercity train station, as Figure 4.30 and Figure 4.31 show.

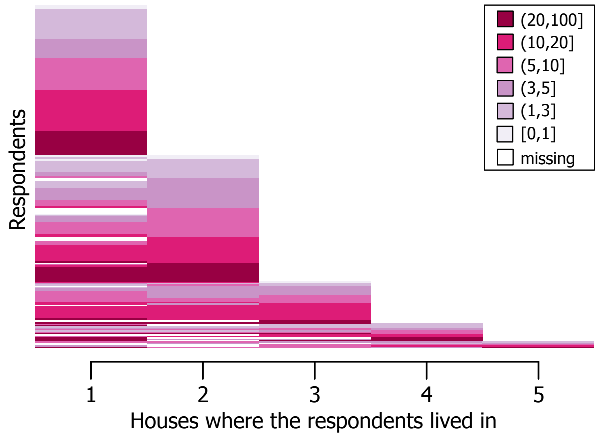


Figure 4.30 | Distance range between house and closest intercity train station per house informed

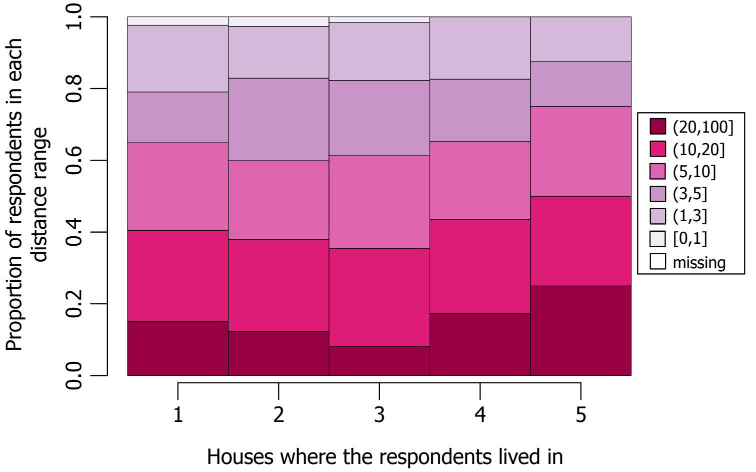


Figure 4.31 | Proportion of respondents in each distance range between house and closest intercity train station per house informed

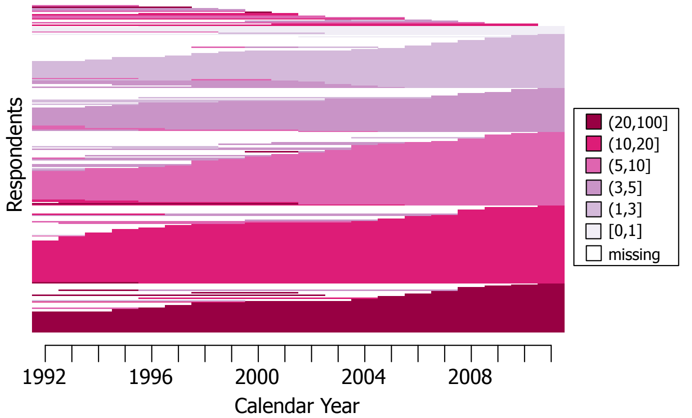


Figure 4.32 | Distribution of the distance range between house and closest intercity train station per calendar year

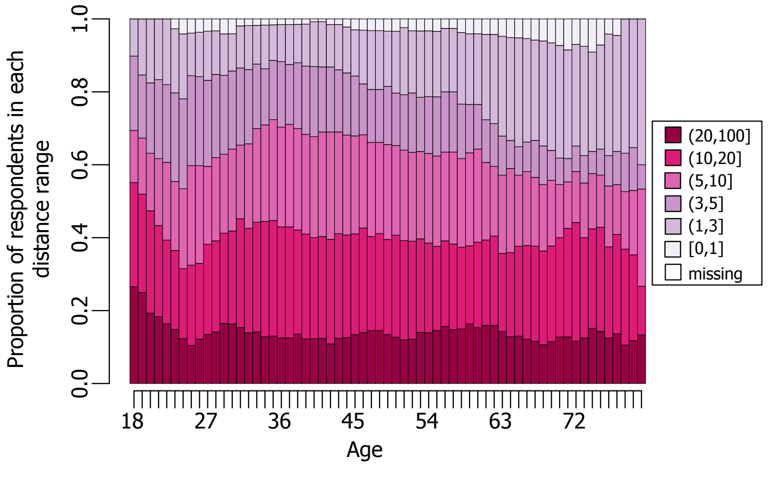


Figure 4.33 | Proportion of respondents in each distance range between house and closest intercity train station per age

Except for the distance range between zero and one kilometre, all other five distances are evenly distributed over time, with slightly more respondents in distance ranges of 10 to 20, and 5 to 10 kilometres. Figure 4.32 displays the distribution of the distance range between the house and the closest intercity train station per calendar year. Again there is no clear tendency between year and distance range to intercity train station.

Looking at the proportion of respondents in each distance range (Figure 4.33), it is noticeable that around the age of 25 and above the age of 60, the distances are shorter.

4.3.5.4 Distances to retail centre

The respondents reported up to four changes related to distances to the closest retail centre over their housing career. The mean number of changes is 1.35, one of the highest among all distances. Most respondents reported to have lived in houses close to retail centres. Figure 4.34 and Figure 4.35 present the distribution of the distance ranges according to the houses where the respondents lived in. The distance to the closest retail centre is shorter in former houses than in present houses, distances from zero to one kilometre are the majority in the fifth house, while in the present house the majority is the distance range from one to three kilometres. A few respondents reported to live at a large distance from a retail centre.

Figure 4.36 and Figure 4.37 show the distribution of the distance range between the house and the closest retail centre per calendar year and age. Both these figures and Figure 4.34 show that the most common changes over time are from zero to one kilometre and the one to three kilometres range.

The proportion of respondents in each distance range per age is shown in Figure 4.38. The distances to the closest retail centre are shorter when the respondents

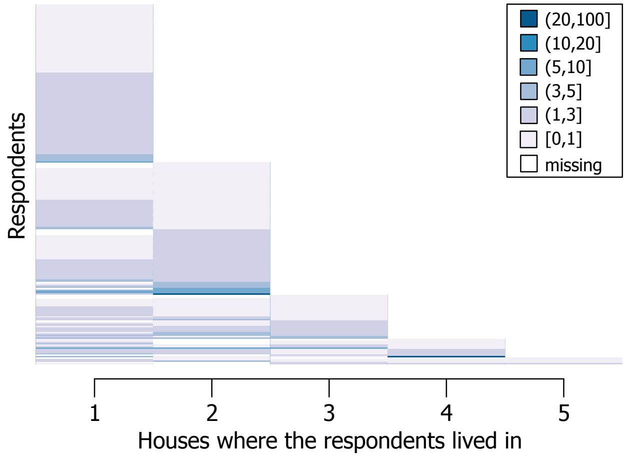


Figure 4.34 | Distance range between house and closest retail centre per house informed

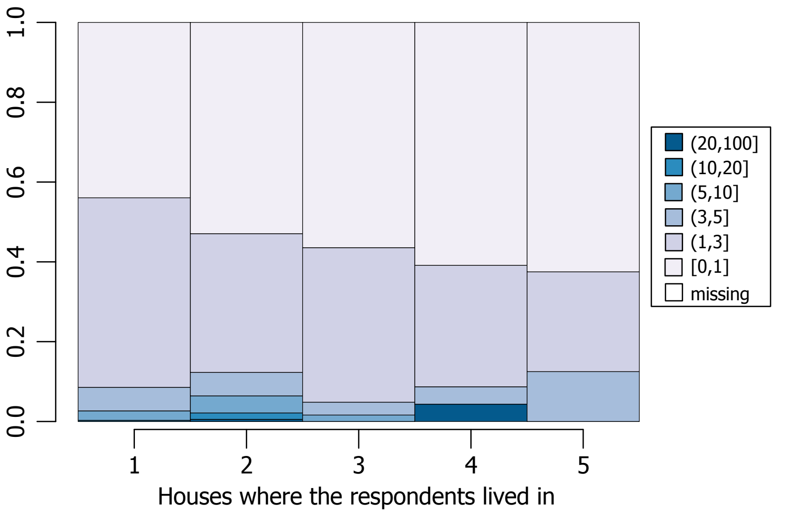


Figure 4.35 | Proportion of respondents in each distance range between house and closest retail centre per house informed

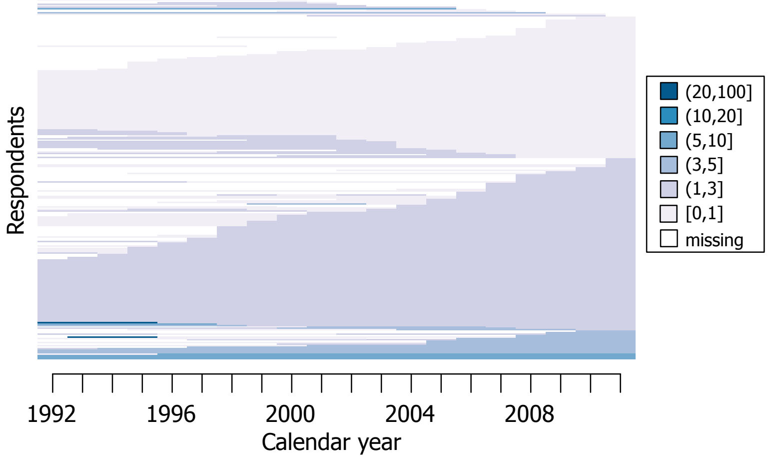


Figure 4.36 | Distribution of the distance range between house and closest retail centre per calendar year

are in their early 20s, with a minimum at the age of 23. At this age, young people typically prefer to live closer to city centres where there is usually a higher concentration of commercial areas.

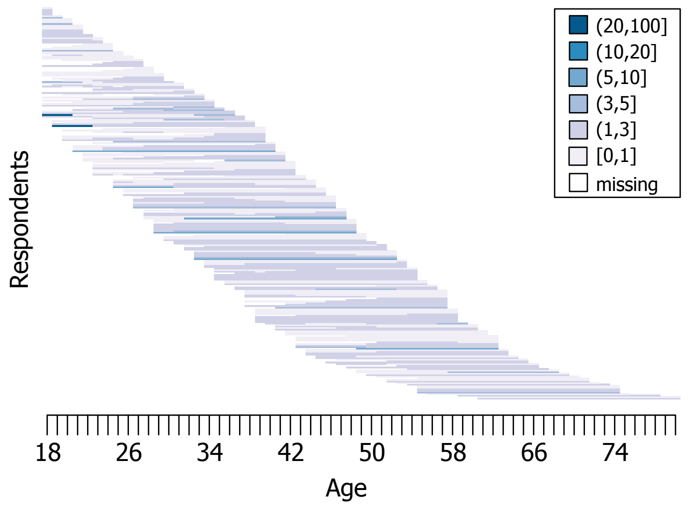


Figure 4.37 | Distribution of the distance range between house and closest retail centre per age

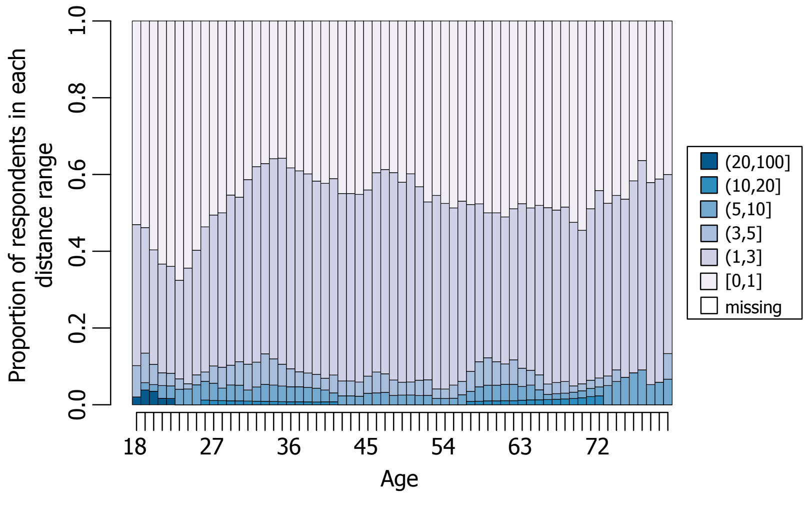


Figure 4.38 | Proportion of respondents in each distance range between house and closest retail centre per age

4.3.5.5 Distances to the closest larger retail centre

The number of changes in the distance to larger retail centres over the housing career is similar to the distances to closest retail centres. Respondents reported up to four changes, with a mean of 1.33 of different states. The majority of respondents (72.3%) again reported only one distance range over their life trajectory.

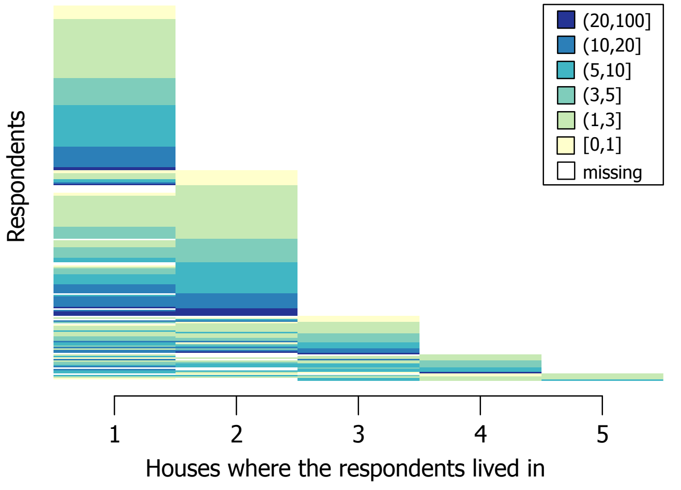


Figure 4.39 | Distance range between house and closest larger retail centre per house informed

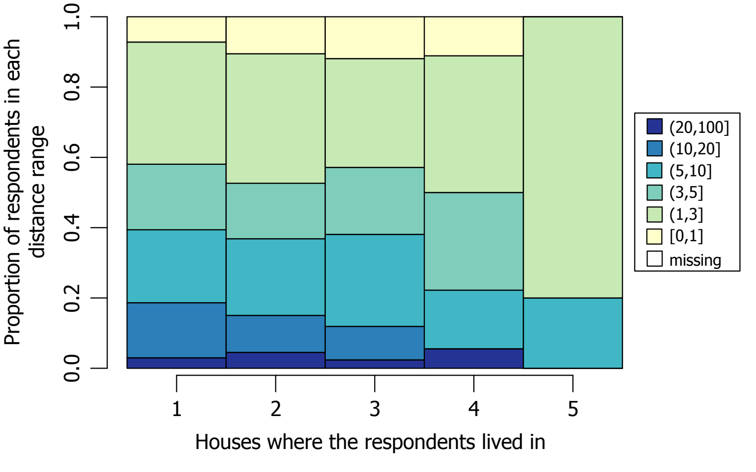


Figure 4.40 | Proportion of respondents in each distance range between house and closest larger retail centre per house informed

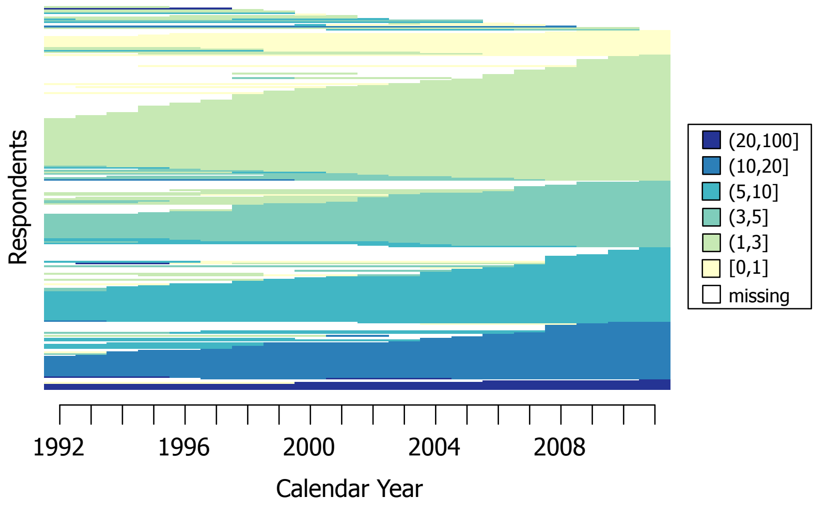


Figure 4.41 | Distribution of distance range between house and closest larger retail centre per calendar year

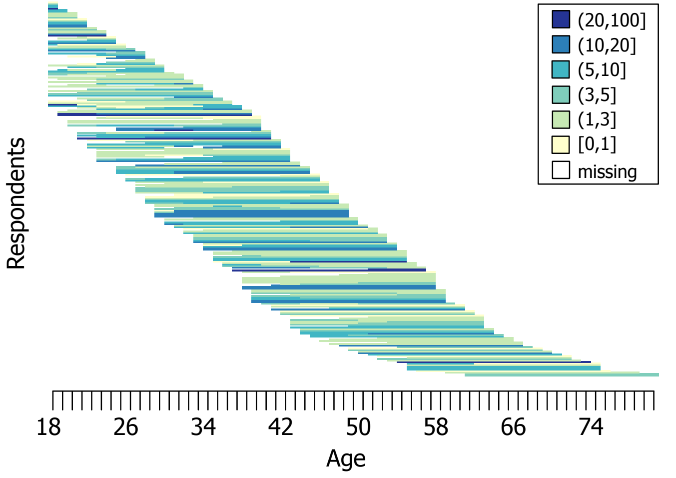


Figure 4.42 | Distribution of distance range between house and closest larger retail centre per age

The distances to larger retail centres are, naturally, larger than the previous retail centre distances. The majority of respondents reported to be in a distance range

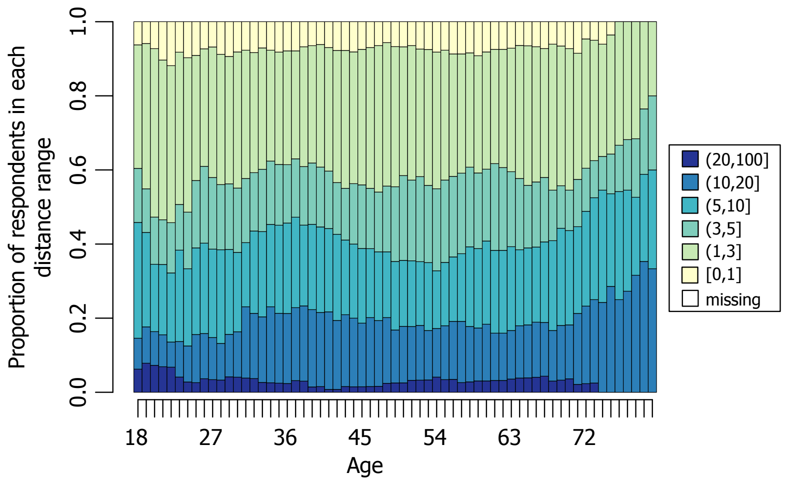


Figure 4.43 | Proportion of respondents in each distance range between house and larger retail centre per age

of one to three kilometres, followed by three to five and five to ten kilometres (Figure 4.39 and Figure 4.40).

Figure 4.41 and Figure 4.42 display the distribution of distance range between the respondent's house and the closest retail centre per calendar year and age, respectively. Figure 4.43 presents the proportion of respondents in each distance range per age and indicate that there exists a small tendency of respondents to live further away from a larger retail centre with age.

4.3.5.6 Distances to closest park

Apart from distance to bus stops, distances to park are the shortest from the distances analysed, with a mean distance of 0.87 km. Respondents reported up to three changes in the distances to the closest park over their housing career. Still, 81% of them lived in the same distance range over the life trajectory.

The predominant distance range to the closest park is zero to one kilometre. A lower proportion of respondents are in a distance range between one and three kilometres and only a few respondents reported to live further away from the closest park. Figure 4.44 and Figure 4.45 show the distribution and proportion of the distance ranges according to the dwelling in the respondent's life trajectory.

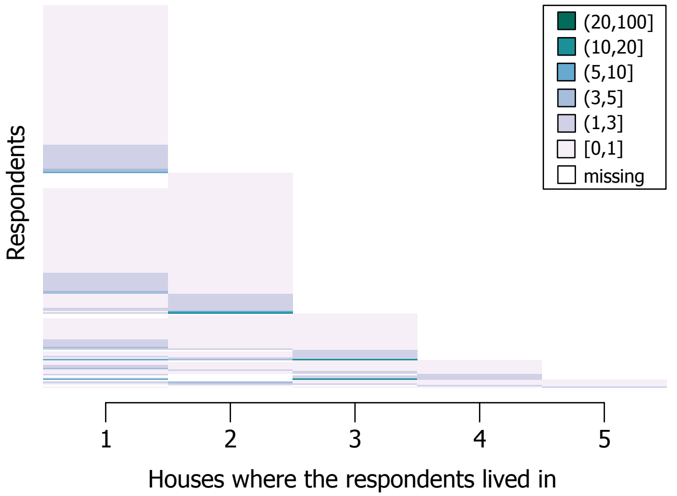


Figure 4.44 | Distribution of distance range between house and closest park per house informed

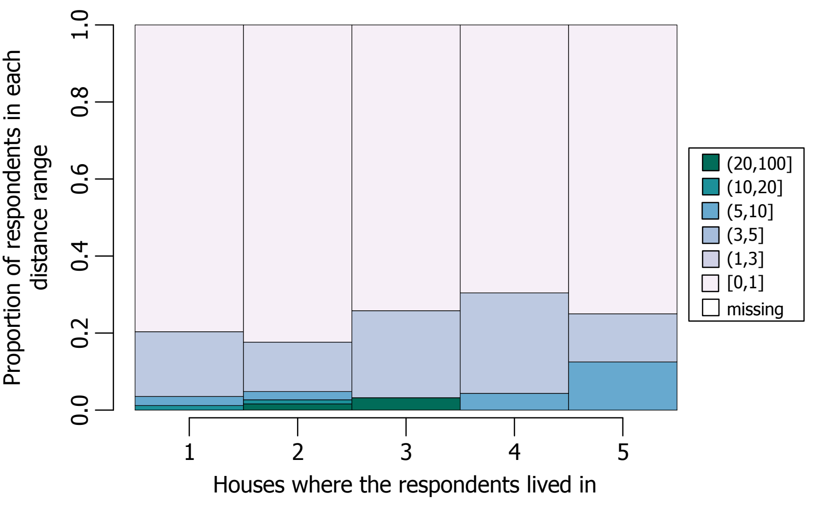


Figure 4.45 | Proportion of respondents in each distance range between house and closest park per dwelling in the respondent's life trajectory

The distribution of distance range over calendar years and age are shown in Figure 4.46, Figure 4.47 and Figure 4.48. There is no clear relation between distance range and calendar year, but there seems to be a small but steady increase in higher distances in the second half of respondents' reported lifetime.

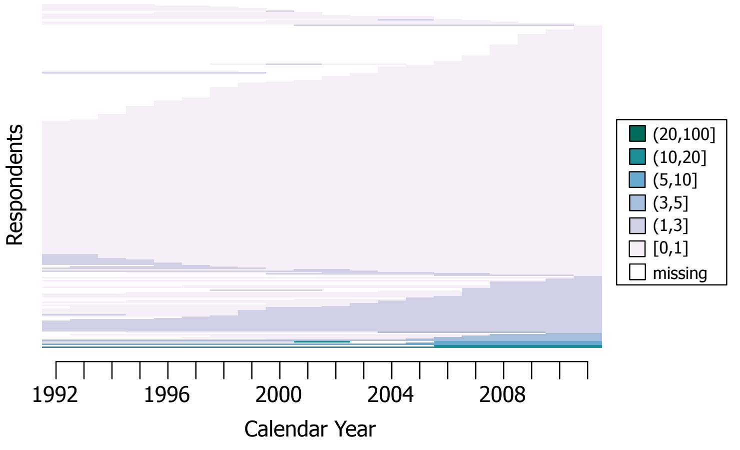


Figure 4.46 | Distribution of distance range between house and closest park per calendar year

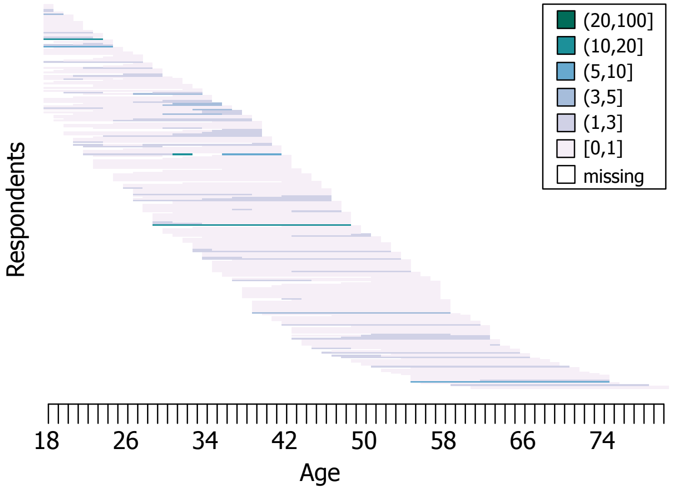


Figure 4.47 | Distribution of distance range between house and closest park per age

4.3.5.7 Distances to the closest forest

The distances to the closest forest is the only one that had five changes over the housing career. Still, the majority (73.9%) of respondents lived in the same distance range over their life trajectory. The mean distance to a forest is reasonably low, 2.3 km,

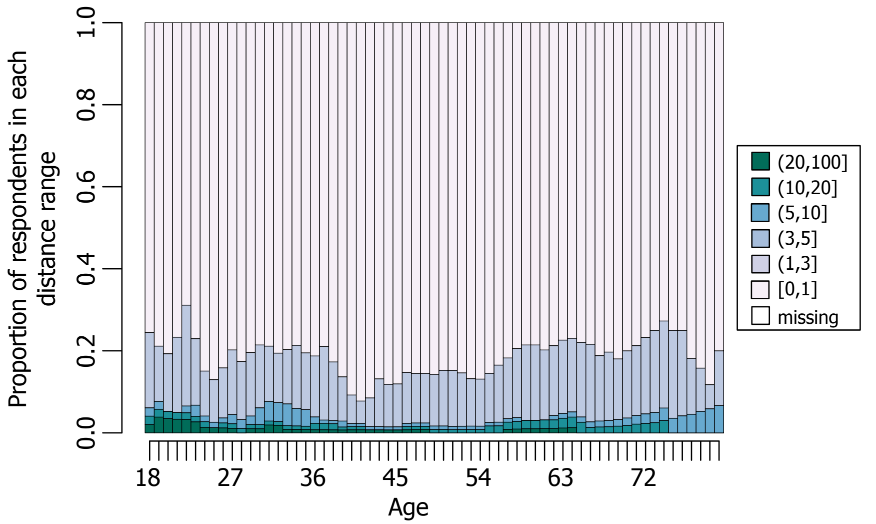


Figure 4.48 | Proportion of respondents in each distance range between house and closest park per age

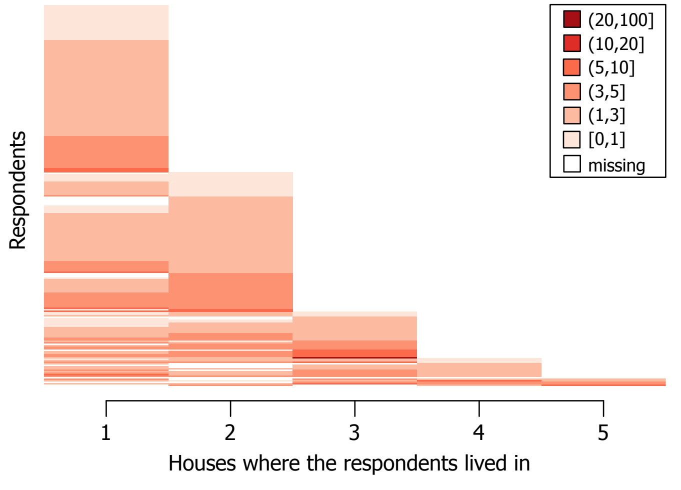


Figure 4.49 | Distance range between house and closest forest per house informed

and a larger part of respondents reported a forest to be between one and three kilometres far from their house. As shown in Figure 4.49 and Figure 4.50, there is no significant difference in the distance ranges to a forest over the houses where the respondents lived in.

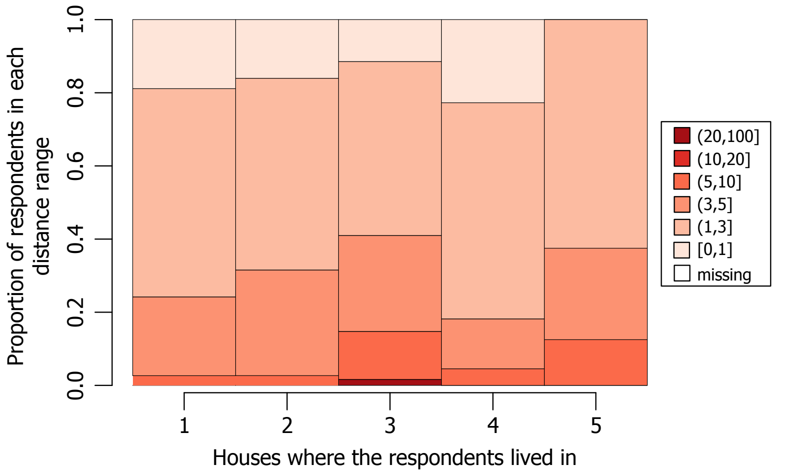


Figure 4.50 | Proportion of respondents in each distance range between house and closest forest per house informed

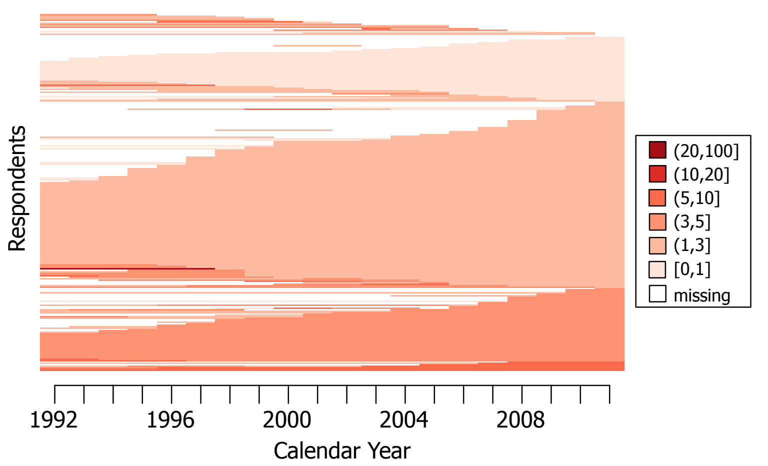


Figure 4.51 | Distribution of distance range between house and closest forest per calendar year

The distribution of distance range between the respondent's house and the closest forest by calendar year and age are displayed in Figure 4.51 and Figure 4.52, respectively. The predominance of the distance range one to three kilometres over time is evident, followed by the distance ranges three to five kilometres and zero to one kilometre. Higher distance ranges are less represented. Figure 4.53 presents the proportion of respondents in each distance range per age. Overall the proportion is equal, with a slightly change in older ages, where the respondents live closer to a forest.

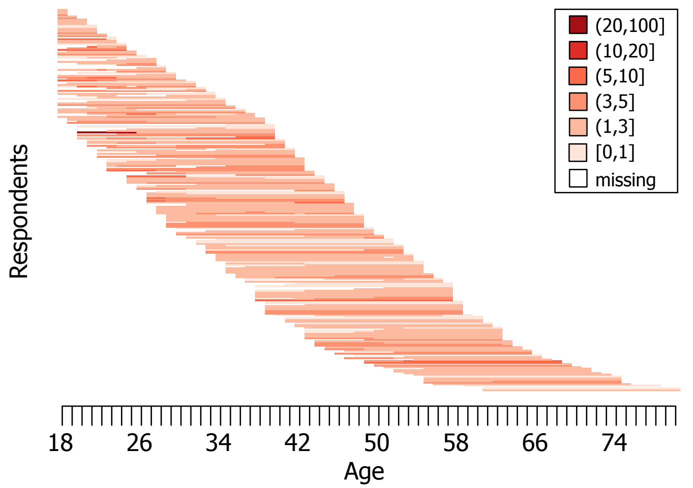


Figure 4.52 | Distribution of distance range between house and closest forest per age

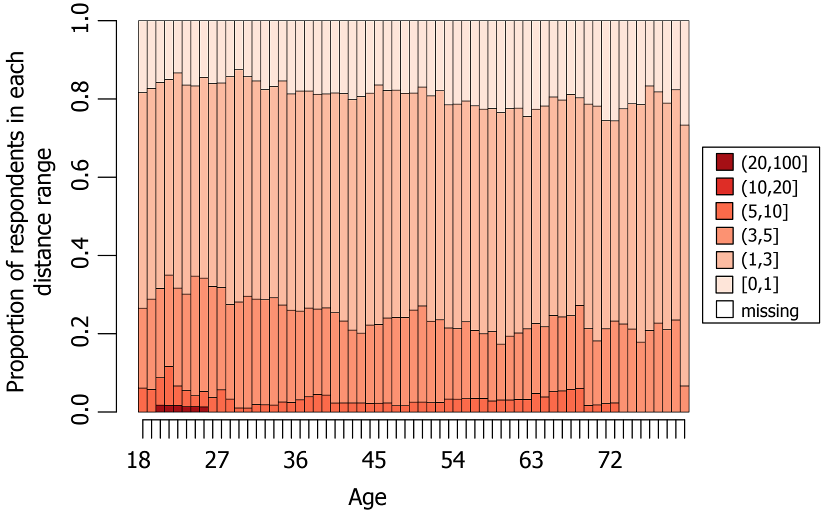


Figure 4.53 | Proportion of respondents in each distance range between house and closest forest per age

4.3.5.8 Distances to the closest highway access

Respondents reported up to five different distance categories to highway access over their life trajectory. The mean number of changes is 1.35, one of the highest. In the observed changes, 67% of the respondents moved to a house further away from

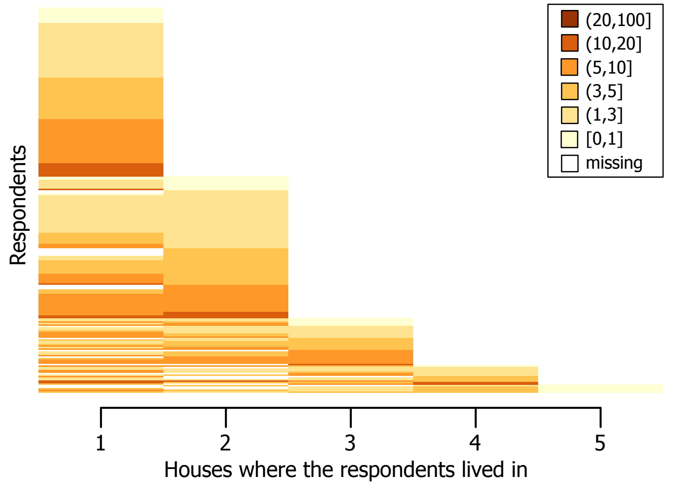


Figure 4.54 | Distance range between house and highway access per house informed

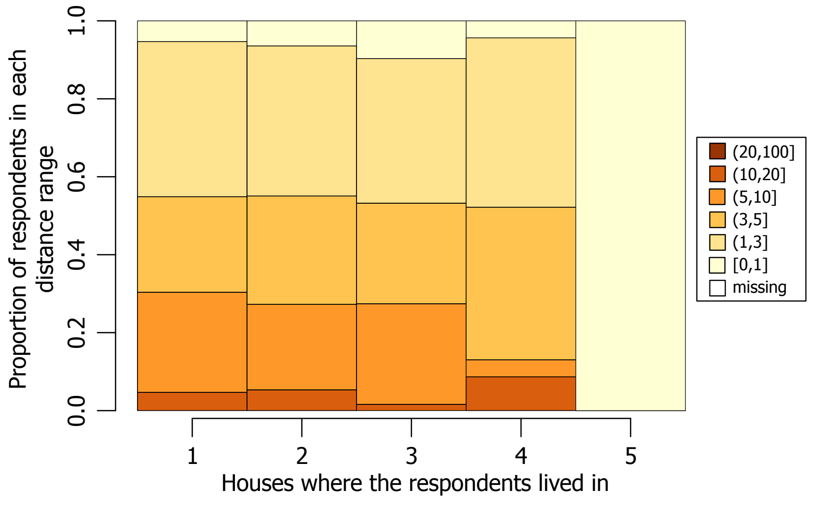


Figure 4.55 | Proportion of respondents in each distance range between house and closest highway access per house informed

highway access. The majority of respondents reported to live in a house one to three kilometres away from the closest highway access. However, over the life trajectory, there is an increase in the number of respondents living more than five kilometres away from the closest highway access. Most respondents in the fifth house reported to be between zero and one kilometre away from the closest highway access, but this might

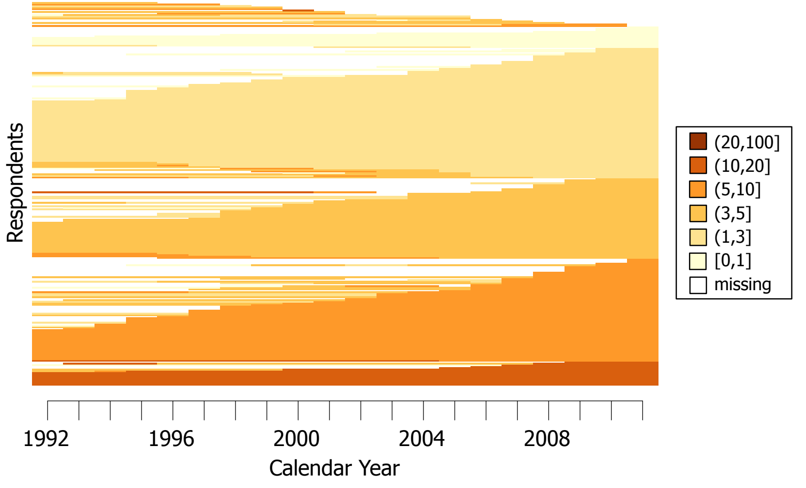


Figure 4.56 | Distribution of distance range between house and closest highway access point per calendar year

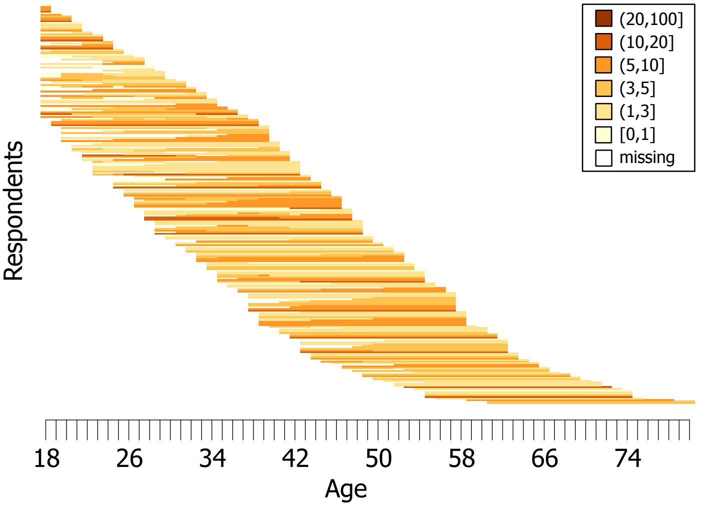


Figure 4.57 | Distribution of distance range between house and closest highway access point per age

be due to the fact that only a few respondents gave information about five houses. Figure 4.54 and Figure 4.55 show the distribution of the distance ranges to the closest highway access according to the houses where the respondents lived in.

Figure 4.56 and Figure 4.57 display the distribution of the distances to the closest highway access according to calendar year and age, respectively. There is no common change pattern whether the respondents move to a house that is closer or not from the highway access point.

Regarding the distribution of the distances to the closest highway access point according to the respondent's age, it is noticeable that around the age of 24 the respondents live in a distance range that is slightly shorter to the highway access point (Figure 4.58).

Looking at the distribution of the calculated distances over the housing career, there is no clear pattern of changes over the houses where the respondents lived in, also for the distribution per calendar year and age. However, it is possible to distinguish a pattern of changes at the distribution of the proportion of distance ranges per age. There is a clear change in their early 20's and a less marked change in their late 30's. At their early 20's, respondents reported to be living at closer distance to all destinations, except for forests. A possible explanation is that at this age, life is less stable. People may be still at the university, start their first job, without a family or a house ownership.

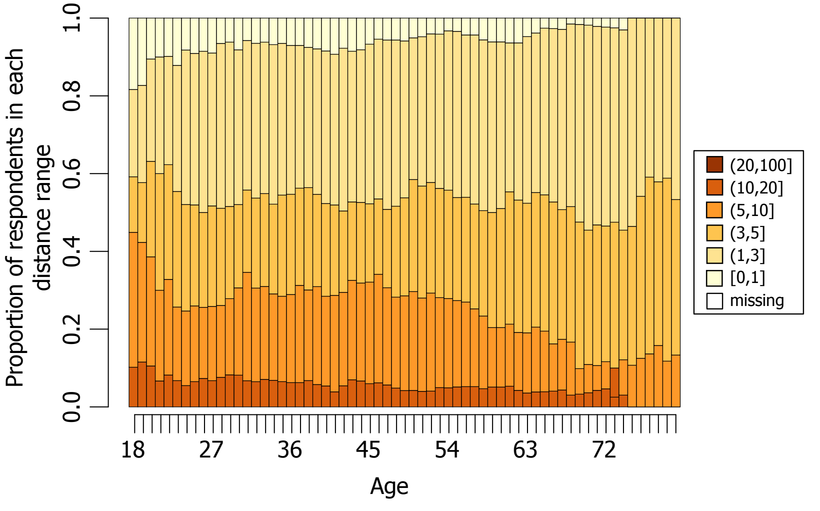


Figure 4.58 | Proportion of respondents in each distance range between house and closest highway access point per age

In their late 30's, the calculated distances to the destinations are slightly higher, except for the forest, which are the closest. Respondents, thus, seem to be living further away from the city centre. A reasoning for this is that at this age life has become more stable. People tend to have their children and they might prefer to live in a greener neighbourhood than in an urban-like neighbourhood, and financial constraints are less of an issue.

4.3.5.9 Clustered distances

In order to better classify the accessibility, distances were categorized according to the eleven determined distances. This way, it is possible to identify typical configurations of accessibility according to the houses where respondents lived in. Figure 4.59 presents the distribution of the eleven distances for each of the respondent's house.

Three different clusters were defined, named as urban, suburban and rural. The urban cluster is the one with the lowest distance to the various destinations. The suburban cluster has distances related to transportation hubs (tram, subway and intercity train for example) not as close from home as the first cluster, however, all distances are still smaller than 10 kilometres. The third cluster was called rural cluster because all transportation hubs (except from buses) are at a mean distance higher than 20 kilometres. This last cluster is also the one with larger distance to larger retails establishments.

Table 4.9 shows the number of houses in each cluster. Most of the respondents' houses (almost 60%) are located in a 'suburban cluster'. This seems plausible, as there is a limitation to houses that can be located close to city centres and main transport hubs. In most cities, the majority of inhabitants are living in suburban areas, usually characterized as mostly residential neighbourhoods.

Considering this categorization of the distances according to the three clusters, the accessibility of respondents' houses can be examined from a longitudinal perspective, looking at the changes in distances for each respondent in our 20-years

Table 4.9 | Division of houses per distance cluster type

Cluster type	Number of houses	Percentage of houses
1| Urban	221	29.0%
2| Suburban	439	57.6%
3| Rural	102	13.4%
Total	762	100%

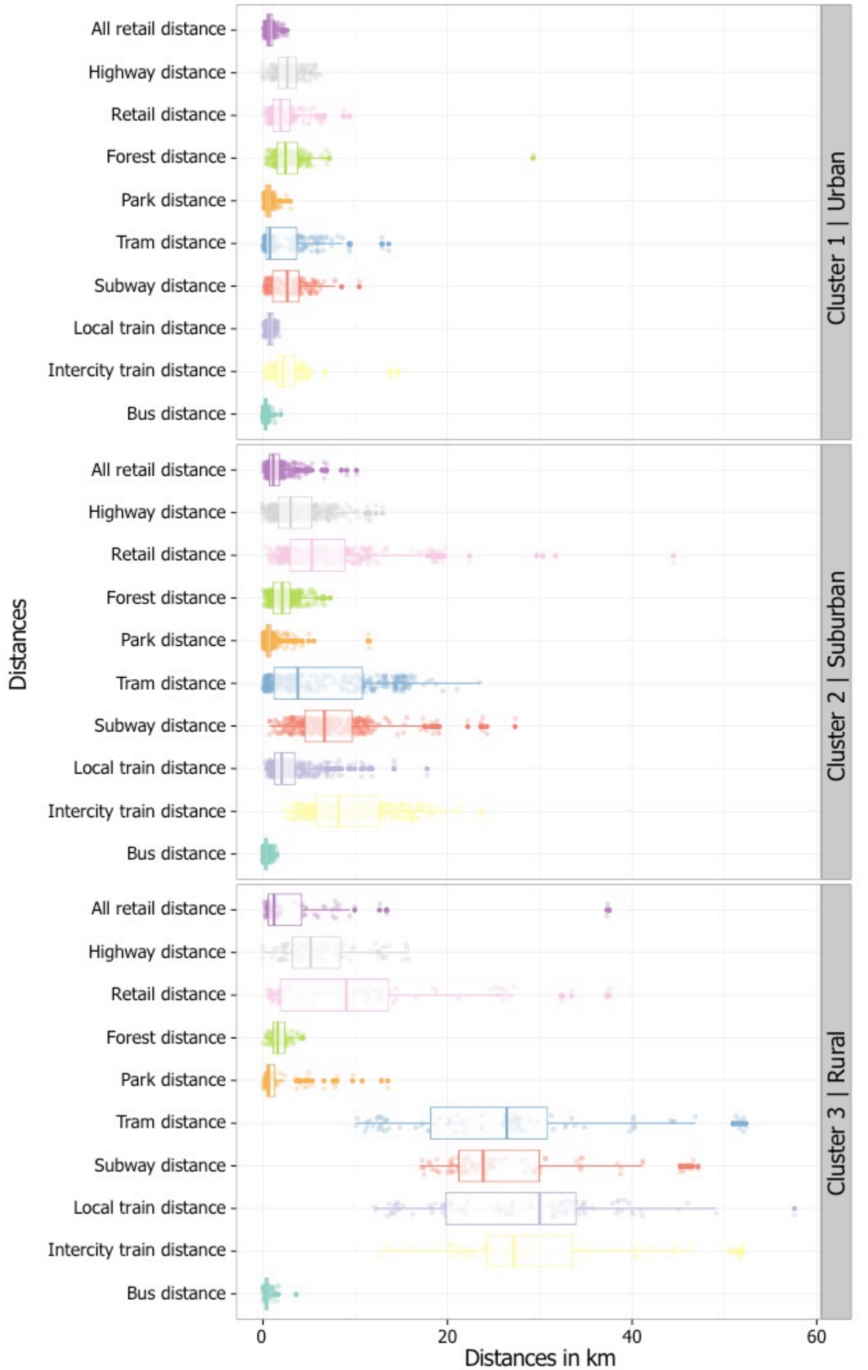


Figure 4.59 | Distance clusters. Each point represents the distance for one respondent and each line has one box-and-whiskers plot summarizing its distribution.

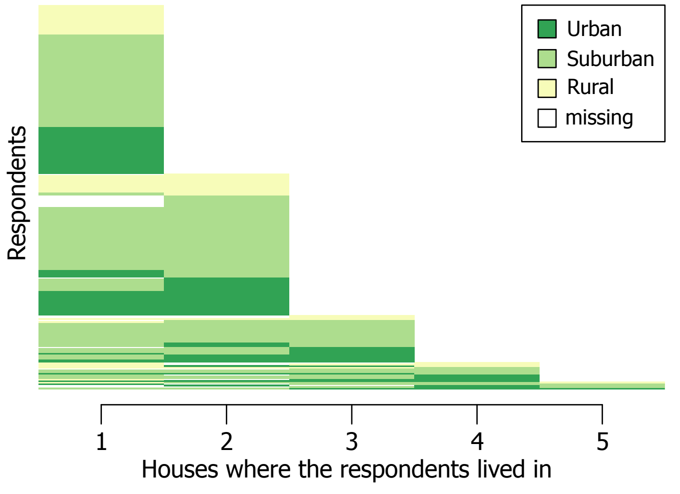


Figure 4.60 | Distance clusters per house informed

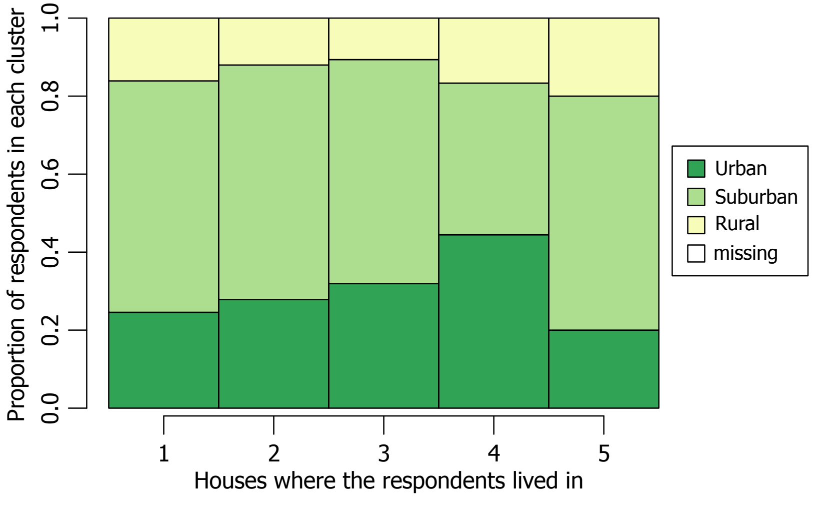


Figure 4.61 | Proportion of distance clusters per house informed

period of study. The large majority of changes in houses do not signify a change in accessibility: 85% of respondents were in the same distance cluster over their housing career, 13% had one change, and only 2% experienced multiple changes.

The distribution of distance clusters over the years per house informed is presented in Figure 4.60. In Figure 4.61 it is possible to observe the proportion of each cluster, for all houses the majority of respondents belong to the cluster two (suburban), followed by the cluster one (urban). A few respondents were found in cluster three (rural). The changes reported where 53% from urban to suburban, and 30% from suburban to urban.

Figure 4.62 shows the distribution of distance clusters per calendar year, where one can notice a small amount of changes from the urban to the suburban distances.

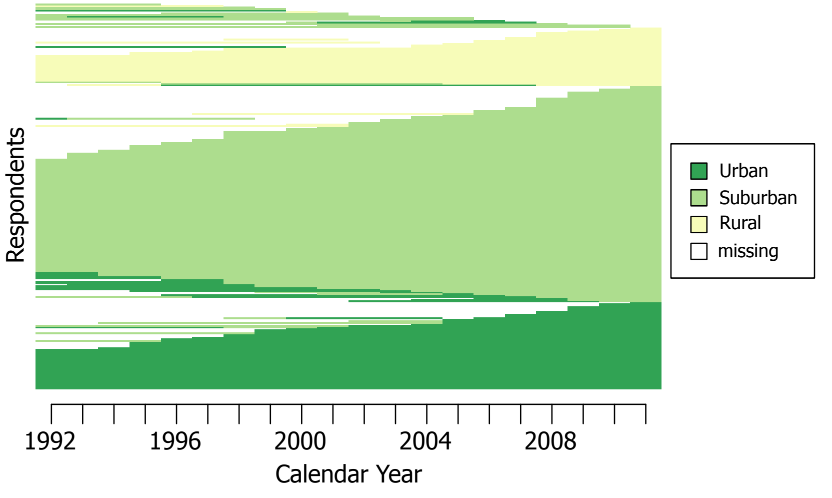


Figure 4.62 | Distribution of distance clusters per year

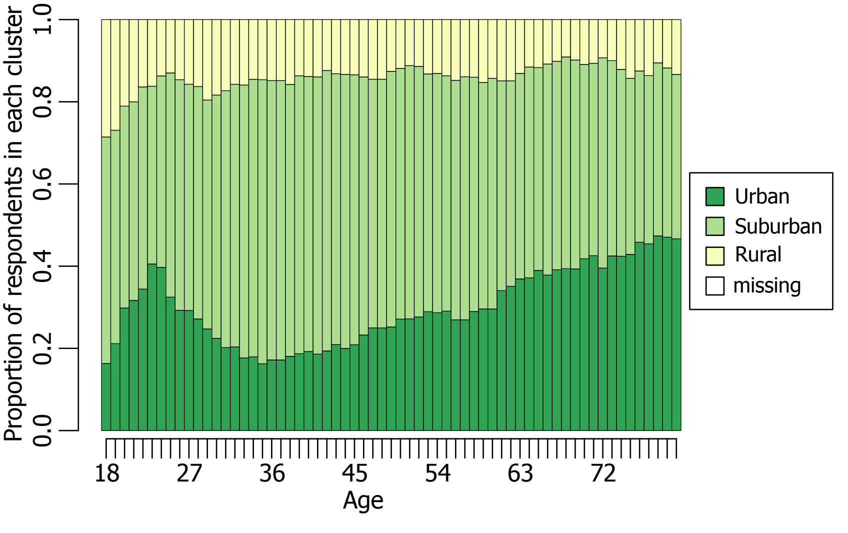


Figure 4.63 | Proportion of respondents in each distance per age

Looking at the proportion of distance clusters over respondents' age (Figure 4.63), it is perceivable that around the age of 25 and above the age of 55, there is an increase in the amount of respondents in the clusters three and one, and a decrease of the cluster two. The increase of the mainly residential cluster starts chiefly around the age of 25, which is the age when respondents usually get married or have child, and thus might prefer to live in calmer areas or have a bigger house. Cluster four decreases at younger ages but increases at older ages. This outcome shows that respondents might be living in a more diverse built environment in these age ranges. This may be due to the fact that when children leave home, parents might consider moving to a more convenient living environment.

4.3.6 Quality assurance

During the process of calculating all urban form characteristics, some procedures were taken to assure the quality of the data.

Density: It was checked whether the degree of urbanization defined by CBS coincided with our (subjective) perception of those areas. For that, random urban and rural areas were chosen, preferentially those areas already known by the author. By and large, the degree of urbanization existent in CBS coincided with our perception.

Mixed Land Use: two points were important to assure the quality of the land use data: the missing data existent in the BAG data, and the validation of the results from the mixed land uses. As said in Section 4.3.4, almost 40% of the data from the BAG had missing information about its use. It was needed to verify if the missing information would affect our analysis.

In the BAG data, there is a code for the floor print of the buildings, one for the land use of the building, and one that links both codes. In the Transcad software, we examined the buildings without information and it was clear that it represented smaller constructions on the back of houses, which was double checked using Google Earth. Similarly to the density, the results of mixed land uses were randomly verified using Google Street View and coincided with the BAG data.

Accessibility: Among all urban form characteristics, the ones related to distance were those that showed more errors. Thus, we checked these more intensively to assure their quality. While calculating distances, the software decides automatically which is the closest destination node, without taking into consideration the road structure to reach that node. In some cases, geographic barriers, such as rivers, imply that the geographically closest node is not the closest node in the road network.

Therefore, the methodology to check the distance was the following: the group of highest and lowest distances were individually checked, and then the distances were verified per neighbourhood (neighbourhoods with higher number of respondents were used). When Transcad selected the wrong node in the road network layer due to ignoring geographic barriers, these wrong nodes were manually connected and the distances were recalculated.

4.4 Conclusions

This chapter defined the characteristics of the built environment we used in our analysis, as well as our method to calculate them. Together these characteristics and methods of calculation compose our methodology to analyse urban form in a multi-faceted way. If one imagines an urban environment that invites people to cycle and walk more, and drive less, he or she will probably picture an urban space that has pleasant streets, diverse land use, close distances to services and shops, easy access to public transportation, good non-motorized infrastructure, etc. Instead, a driving-friendly environment may have different attributes; one can imagine an environment where there is less density, an arid urban space, and difficulties to reach public transportation.

The characteristics of the urban form chosen in this study, considering data availability constraints, seek to capture this differentiation in urban environments. For that, we considered three facets for each respondent, which are:

- Density, represented by the degree of urbanization in the postcode where the respondent lives (using the 6-digit post code);
- Proportion of 16 types of land use in a one-kilometre buffer around respondents, clustered into four clusters; and
- Distance from the respondents to eight different destinations: distance to closest bus stop, distance to closest tram stop, distance to closest metro entrance, distance to closest train station, distance to closest larger retail centre, distance to closest green area, and distance to closest highway access.

Besides the multi-faceted aspects defined, our method contributes in three other respects to the study of the urban form in the context of activity-travel behaviour. First, using the respondent as the level of analysis, applying a buffer of one-kilometre around every respondent, which is what the CBS defines as a walkable distance. We argue this is a very useful way to avoid multi-level problems that come with research on the relationships between urban form and travel behaviour but that very few researchers have dealt with, implying a tendency for their reported significance level tend to be inflated. Secondly, the use of distances calculated using the road network, a more precise approximation to the real distances of respondents' travel is obtained. Finally, a discussion of several problems encountered in the use of real urban form data and how to circumvent them is provided.

Observing the data we analysed using the proposed method, overall there are only limited changes in the urban form characteristics over the housing career. In all urban form careers, the vast majority of respondents changes few times the characteristics of urban form in which they live. This result might also be due to the fact that most respondents lived in one or two houses during the years covered in our data collection. Another possibility is that the built environment in the study area does not vary widely. In that sense, it should be realised that official planning norms and the neighbourhood concept guarantee minimum amenity and service levels in Dutch neighbourhoods, which therefore show a relatively high degree of similarity.

We believe that, besides enabling our analysis, the methodology described in this chapter contributes to the improving analyses of the urban form effects on travel behaviour.

The data described in this chapter, together with those of Chapter 3, will be used on the analysis of the dynamics of activity-travel behaviour, detailed in the next Chapter.

5

Effects of life trajectory and built environment dynamics on activity-travel behaviour

5.1 Introduction

This chapter uses the data described in Chapters 3 and 4 to model the relationships between sociodemographics, life trajectory, built environment, and activity-travel behaviour. In doing so, it tests our hypotheses about the mediating role of the built environment on activity-travel behaviour.

Next, we present an overview of our analysis approach. The chapter continues to describe and summarise the variables considered, report the results of the estimated models, and concludes with a discussion of results.

5.2 Overview of the analysis

As thoroughly discussed before (Section 2.3), the aim of our study is to bring a broader perspective on the relationship between urban form and activity-travel behaviour by considering people's life trajectory. Moreover, our analysis considers that all life careers involved in the matter are dynamic. Therefore, all variables selected in the final conceptual model are from longitudinal data. This means that we must have information over the years about every variable considered for each respondent. For this reason, some variables present in our data collection were not included in the analysis: income and education are not used, as longitudinal data about these variables were not collected.

The conceptual model and the hypothesized links among the variables are shown in Figure 5.1. This model intends to address the relation between socio-demographics characteristics, life trajectories careers (work and household careers), urban form features and activity-travel behaviour. The model captures our initial hypothesis that effects of urban form on activity-travel behaviour are triggered by characteristics of people's life: socio-demographic characteristics and life trajectory events. Built environment characteristics are considered mediating variables between

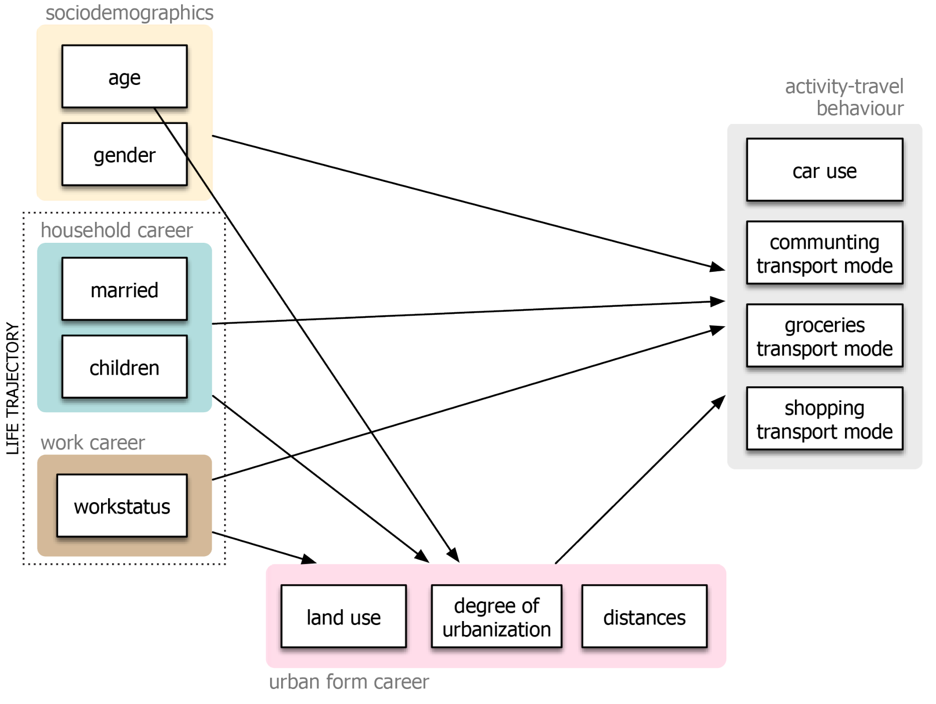


Figure 5.1 | Conceptual model

life trajectory and socio-demographics. The conceptual models test the direct and indirect relationships of life cycle events on activity-travel behaviour.

The activity-travel behaviour features considered in the analysis are car use and transport mode choice for three destinations: commuting, grocery shopping, and shopping. Within the socio-demographics, age and gender are selected. However, gender has no link to the urban form characteristics, as we consider that the choice of a new house is a household decision. All variables used in the models are described in detail in Chapter 3, except for the built environment variables that are described in Chapter 4. Some variables were restructured for the analyses, and they are explained in the next section.

Throughout this chapter, when commenting on the significance of associations found in through our models, we take a more permissive attitude and consider as significant associations with a p-value of 0.10 or less. This implies that the threshold for our results to be considered as indications of an association are less stringent than the default Statistics textbook threshold of 0.05. However, considering that our sample size is relatively small for the number of variables considered in our study, and that there is a high cost to produce much larger samples, it seems reasonable to consider our results more permissively and to take them as pointing for further analyses when relevant associations are found. In contrast, it is relevant to note that when an association is not found, it means our data did not bring evidence for it even in this more liberal approach.

5.3 Model variables

This section discusses the selection of variables that are included in the models used in this chapter. As mentioned before, the selection of variables used in the models was triggered by the availability of longitudinal data, and the variables are divided in four groups: socio-demographics, life trajectory careers, urban form career and activity-travel behaviour. Table 5.1 presents the categorical or ordered (but not continuous) variables. Only two variables are continuous: age and car use, and they are shown in Table 5.2. For each of these variables, a reference level is indicated as used when the variable is added in a regression model later on.

In both tables, the *overall* column summarizes results in terms of observations – that is, person-years. The *between* column counts how many respondents had a particular value at least once. For categorical variables, the *within* percentage measures the fraction of observations with a given value, conditional on a respondent ever having that value, and is therefore a measure of the stability of a state of respondents over time. For the continuous variables, *between* summaries are calculated using the average value of the variable across respondents, and the *within* column is averaged per respondent – for example, there is more variability across respondents' car use than in the car use of a respondent over time.

For the household variables, both respondents that are married and living together are considered as married. The categories of workstatus *<12h/week* and *12-30h/week* are joined in a same category *≤ 30h/week*. For the distances, clusters are ordered with the *urban* cluster having the highest accessibility, and the *rural* cluster having the lowest accessibility (following the analysis in Section 4.3.5). For the land use, the variable considered represents the degree of mixed land use surrounding the respondent house location in the following manner: less mixed, including the *Mainly residential* and *Mainly industrial* clusters; mildly mixed, considering the *Mildly residential* cluster; and, more mixed, comprising the *Mixed environment* cluster (see Section 4.3.4 for more details). For the degree of urbanization, the degree labels were ordered according to the level of urbanization they represent, with the degree of urbanization 1 being the most urbanized, and the degree of urbanization 5 the least.

5.4 Methodology

5.4.1 Overall approach

Our conceptual model includes four aspects of the activity-travel behaviour, each measured by a variable. The analysis conducted henceforth considers each of these aspects in turn, separately, but using the same methodology on each variable that measures activity-travel behaviour. For each of these four variables the conceptual

Table 5.1 | Descriptive statistics of model variables (except continuous variables)

		Overall		Between		Within
		frequency	**percent**	**Frequency**	**percent**	**percent**
Socio-demographics						
Gender	*male (ref.)*	3320	47.56	166	47.56	100.00
	female	3660	52.44	183	52.44	100.00
	total	6980	100.00	349	100.00	100.00
				(n=349)		
Household career						
Married	*yes*	1929	65.77	136	83.95	75.68
	no (ref.)	1004	34.23	112	69.14	52.75
	total	2933	100.00	248	153.09	65.32
				(n=162)		
Children	*yes*	998	34.03	84	51.85	64.84
	no (ref.)	1935	65.97	153	94.44	70.29
	total	2933	100.00	237	146.30	68.35
				(n=162)		
Working career						
Student		270	4.42	67	19.14	41.13
Unemployed		756	12.38	66	18.86	59.91
<=30h/week		1099	17.99	120	34.29	56.48
>30h/week *(ref.)*		2835	46.41	211	60.29	73.10
Retired		1149	18.81	93	26.57	65.48
Total		6109	100.00	557	159.14	62.84
				(n=350)		
Urban form career						
Degree of	*degree 1*	2078	36.11	161	47.63	77.17

Urbanization	*degree 2*	1848	32.11	143	42.31	72.57
	degree 3	878	15.26	86	25.44	61.77
	degree 4	588	10.22	51	15.09	65.87
	degree 5	363	6.31	41	12.13	56.74
	total	5755	100.00	482 (n=338)	142.60	70.12
Mixed Land Use	*low (ref.)*	1919	34.19	147	43.36	79.87
	medium	2689	47.92	203	59.88	80.74
	high	1004	17.89	82	24.19	70.36
	total	5612	100.00	432 (n=339)	127.43	78.47
Distances	*rural*	818	14.30	56	16.23	91.86
	suburban	3358	58.70	224	64.93	89.83
	urban	1545	27.01	116	33.62	79.59
	total	5721	100.00	396 (n=345)	114.78	87.12
Activity-travel behaviour						
Commuting Transport Mode	*car (ref.)*	1934	46.75	133	51.75	84.40
	bicycle	1022	24.70	76	29.57	79.25
	public transportation	853	20.62	91	35.41	70.54
	walking	124	3.00	19	7.39	47.30
	other	204	4.93	13	5.06	87.31
	total	4137	100.00	332 (n=257)	129.18	77.41
Groceries Transport Mode	*car (ref.)*	2058	35.95	139	41.99	83.46
	bicycle	1649	28.80	121	36.56	80.38
	public transportation	38	0.66	4	1.21	47.50
	walking	1819	31.77	141	42.60	76.45
	other	161	2.81	10	3.02	80.50
	total	5725	100.00	415 (n=331)	125.38	79.76

Shopping Transport Mode	*car (ref.)*	2248	39.65	149	45.29	84.65
	bicycle	1483	26.16	117	35.56	78.32
	public transportation	666	11.75	52	15.81	75.07
	walking	1120	19.76	84	25.53	76.13
	other	152	2.68	9	2.74	91.67
	total	5669	100.00	411 (n=329)	124.92	80.05

Table 5.2 | Descriptive statistics of model continuous variables

		Mean	Std. Dev.	Min	Max	Observations
Age	Overall	45.30	15.41	18	92	N = 6221
	Between		15.52	18	82.5	n = 347
	Within		5.59			T-bar = 17.93
Car Use	Overall	.35	.32	0	1	N = 5840
	Between		.30	0	1	n = 338
	Within		.11			T-bar = 17.23

model is instantiated with the variable in question as the response variable, and the analysis is performed in two steps.

For the first step we perform a simpler single-predictor regression analysis[2] examining the relationship between each life trajectory and each urban form variable, and between each of all variables and the response variable. In other words, single-predictor models are created for all direct effects in our conceptual model. This single-predictor regression analysis works as a descriptive analysis of the effects to be found if individually analysing the factors affecting the urban-form and activity-travel behaviour variables considered.

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[2] Throughout this document, the term *single-predictor regression model* refers to a model with one predictor and one outcome variable. In contrast, *multivariate models* are those with multiple predictors and those with exogenous and endogenous variables.

After the single-predictor regression analysis, in the second step a multivariate path analysis is conducted to assess which life trajectory and urban form variables significantly contribute to explaining the response variable when their effects are examined simultaneously. The multivariate models created in this analysis are the main support for our discussion and conclusions.

Overall, four characteristics of the data make it challenging to choose appropriate statistical methods to be used:

(i) the data is longitudinal, with a same individual observed over a 20-year period – this at the same time allows the analysis to use data from the individual as a control, and creates a dependence on the data that conflicts with the independence (i.i.d) assumption of most conventional statistical techniques;
(ii) there is a sizable number of missing values for several of the variables;
(iii) there are several panel variables which present very little variance, making it more difficult for model fitting methods to converge;
(iv) there are endogenous and response variables which are unordered categorical and mediator variables which are ordered but not continuous, calling for the need to use nonlinear models.

In the following we discuss methodological decisions taken in light of these challenges to choose the models and methods for the single-predictor regression and multivariate analyses. All analysis in this chapter was performed using Stata version 14.

5.4.2 Single-predictor models

Each single-predictor regression model aims to assess the significance and strength of the relationship between a pair of variables. The response variables in this case are either the activity-travel behaviour variables or the urban form ones. Among these, there are continuous variables (car use), ordered variables not measured on a continuous scale (degree of urbanization and distances), and categorical variables with more than two levels (land use, and the three transport mode variables). The variable whose association is to be measured is sometimes binary (gender, married, children), categorical (work status and land use), ordered (degree of urbanization, distances), or continuous (age). Moreover, all single-predictor models used must account for the fact that our data is longitudinal/panel data.

All single-predictor models used in our analysis are regressions. These were chosen in favour of association methods such as correlation or Chi-square tests to allow the use of multilevel techniques and robust error estimation methods that account for the panel structure in our data (Hox, 1998). When fitting the regression models, two measures were taken to account for the correlation in model error terms. First, all models were estimated with clustered-robust standard errors and inference at the respondent level (Cameron & Miller, 2015). Cluster robust estimation methods account for the fact that model errors at different moments in time for a given respondent may be correlated, while errors between respondents are uncorrelated. Nonlinear cluster-robust standard error estimation methods (Liang & Zeger, 1986) also relax the assumption of homoscedasticity in the model errors.

Second, whenever feasible, this study uses multilevel mixed models that account for the multiplicity of observations at the respondent level through random effects. More specifically, all single-predictor models of car use are Linear Mixed Models (LMM), which extend basic linear models to incorporate random effects that model multilevel variable patterns in the data.

To apply the same approach to the urban form or mode choice variables as (multinomial or ordered) dependent variables, Generalized Linear Mixed Models (GLMM), which extend LMM to cater for non-normal data through link functions and errors from the exponential family of probability distributions (eg. Poisson or binomial) (Bolker et al., 2009) were used. However, GLMMs of urban form or mode choice variables as (multinomial or ordered) dependent variables did not converge. Estimation methods were not able to converge when fitting multilevel multinomial or multilevel ordered logit models with our data with any of the different integration and maximization methods available in Stata 14. Different combinations of methods for providing better initial values, or varying the number of integration points used in the integration methods were also tried. The models presented for these variables are thus not multilevel. They do however account for some correlation in error terms through the robust clustered standard error calculation.

As a result, the following choice of models is employed for the single-predictor analyses as a function of the dependent variable at hand:

- Car use: LMM with random intercepts for respondents and clustered robust variance-covariance matrix and error estimation at the respondent level.
- Land use, commuting mode choice, groceries mode choice and shopping mode choice: Multinomial regression model with Logit link function and clustered robust variance-covariance matrix and error estimation at the respondent level.

- Distance and Degree of urbanization: Ordered Logit Models with clustered robust variance-covariance matrix and error estimation at the respondent level.

All models were estimated using Maximum Likelihood. It is worthwhile to mention that traditional and absolute measures of goodness of fit that exist for linear models are not available or widespread accepted for multilevel models, for logistic and for multinomial models. It follows that for all models henceforth presented, we focus on the discussion of the significance and sign of the effects found.

5.4.3 Multivariate analysis

Our multivariate analysis aims at testing a set of direct and indirect relationships among observed variables. Moreover, this set of relationships includes nonlinear relations and non-normal data due to the presence of categorical and non-continuous ordered response variables. In light of this setting, we use Generalized Structural Equation Modelling (GSEM) (Rabe-Hesketh et al., 2004) to perform a path analysis of the effects of Sociodemographics, Life Trajectory careers and Urban Form careers on each activity-travel behaviour variable.

Structural Equation Modelling (SEM) is a framework that enables the confirmatory analysis of simultaneous set of direct and indirect effects among a set of exogenous, endogenous and latent variables. Path analysis is a special case of SEM where the analyst is solely concerned with observed variables; no latent variables are used. In this approach, a structural component specifying the observed variables and their hypothesized relationships – including causal direction – is defined by the analyst as a simultaneous set of equations. In such equations, variables are termed exogenous if they are not caused by any other variable in the model. Endogenous variables are affected by the exogenous variables either directly or through other endogenous variables in the system. This set of equations can also be represented by a path diagram such as the one used to represent our conceptual model in this chapter. In such graphical representation, exogenous variables have arrows starting at them, whereas endogenous variables have also arrows reaching them.

SEM has been used in several aspects of activity-travel behaviour studies (e.g. (Golob 2003; Van Acker et al. 2007; Cao et al. 2007; Gao et al. 2008; Weis & Axhausen 2009; Lin & Yang 2009; Cervero & Murakami 2010; Schmöcker et al. 2012; Jahanshahi & Jin 2016). GSEM is a generalization of Structural Equation Modelling (SEM) to encompass two characteristics that are not available in SEM: the ability to fit models containing generalized linear response variables, and the ability to fit multilevel data structures. Both features can be used separately or together (Rabe-Hesketh et al. 2004).

Because SEM models linear relationships among variables, it assumes that the variables in the model are jointly distributed normally. GSEM extends SEM and offers a framework of structural equations that allows the investigator to circumvent the assumption of joint-normality distribution among the endogenous and exogenous variables in the model. Instead, it is possible to leverage Generalized Linear Models and Generalized Linear Mixed Models to model the relationships among variables considering different probability distributions and link functions.

Two model designs are used in our four multivariate models: one for car use and one for the three mode choice variables. These two designs are identical in the relationships hypothesized; the sole change among them is in the specification of the regression equation for the response variable. For the model with the car use variable, we use a Multilevel GLMM that accounts for the multilevel structure in the longitudinal data through a random effect at the respondent level. For the other three models, we use a Multinomial regression with a Logit link function, as integration and maximization methods available were not able to derive a Mixed-effects Multinomial GLMM modelling the random effect at the respondent level. The regression equations for distance and degree of urbanization are Ordered Logit regressions, and land use is modelled by a Multinomial Logit regression. In all cases, models were estimated through maximum likelihood and had robust errors clustered by respondent.

As in the single-predictor models used in this chapter, there are no widespread accepted measures for the goodness of fit of GSEM models. Thus, when presenting the results of our estimates, we focus on the discussion of the significance and sign of the effects found.

5.5 Results

5.5.1 Single-predictor models for urban form aspects

In this section, we analyse single-predictor regression models relating each exogenous variable and each urban form variable (ignoring transport mode variables). Therefore, in all models presented in this section, urban form variables are dependent variables. In analyses after this section, urban form variables are considered as mediating variables.

Table 5.3 presents a series of single-predictor regression models examining how

Table 5.3 | Multinomial models regressing land use against each exogenous variable individually

Land use	Indep. Variable	Coef		Odds ratio	z	N (obs)	n (groups)
Medium	Age	.006		1.007	0.82	5,780	336
	Constant	.064			0.20		
High	Age	.005		1.005	0.53		
	Constant	-.873	**		-2.00		
Medium	Married: *yes*	-.143		.866	-0.44	2,497	158
	Constant	.321			0.55		
High	Married: *yes*	-.379		.684	-0.92		
	Constant	-.113			-0.16		
Medium	Children: *yes*	-.798	**	.450	-2.58	2497	158
	Constant	1.18	***		2.65		
High	Children: *yes*	-.596		.550	-1.49		
	Constant	-.094			0.16		
Medium	Workstatus:					5,481	338
	< 30h/w	-.134		.874	-0.40		
	Student	.432		1.541	1.14		
	Unemployed	-.367		.692	-1.32		
	Retired	.385		1.470	1.29		
	Constant	.266			1.65		
High	Workstatus:						
	< 30h/w	-.051		.950	-0.11		
	Student	.399		1.490	0.82		
	Unemployed	-.118		.888	-0.34		
	Retired	.326		1.385	0.83		
	Constant	-.740			-3.42		

Reference level for land use is low mixed land use; for workstatus is >30h/week

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5.4 | Ordered Logit models examining the relationship between degree of urbanization - as independent variable - and age, married and workstatus individually

Independent variable	Coef		z	N (obs)	n (groups)
Age	-.002		0.27	5,695	335
Married: *yes*	-.364		-1.57	2,674	159
Children: *yes*	-.139		-0.58	2,674	159
Workstatus:				5,674	338
< 30h/w	-.146		-0.71		
Student	.002		0.01		
Unemployed	.489	*	1.78		
Retired	-.035		-0.13		

Reference level for workstatus is >30h/week

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5.5 | Ordered Logit models examining the relationship between distances - as independent variable - and age, married and work status individually

Independent variable	Coef		z	N (obs)	n (groups)
Age	-.013	*	-1.84	5,694	342
Married: *yes*	.114		0.40	2,559	160
Children: *yes*	.991	***	3.41	2,710	159
Workstatus:				5,674	338
< 30h/w	0.92		0.37		
Student	-.425		-1.35		
Unemployed	-.122		-0.39		
Retired	-.519	*	-1.84		

Reference level for work status is >30h/week
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

each of the exogenous variables hypothesized to be related with mixed land use affects this variable. The only variable that appears to be significant is the existence of a child in the household. Respondents in such households are less likely to live in medium mixed land use areas compared to low mixed land use areas.

The analysis of single-predictor regressions between the same set of independent variables and degree of urbanization is presented in Table 5.4. Unemployed respondents are more likely to live in a more urbanized area (higher degree of urbanization) than fulltime workers. The remaining of the models did not reveal any significant relationship.

The distances associated with respondents' houses are significantly affected by age, children, and work status in single-predictor models (Table 5.5). Older and retired respondents tend to live in areas with higher accessibility than younger and fulltime-working respondents. In contrast, having a child in the household is associated with living in lower accessibility areas. This is consistent with the age-based pattern observed in Chapter 4 (see Figure 4.63).

The results shown in the models are in general in accordance to what is commonly accepted as the main influences of socio-demographic variables on built environment characteristics (e.g. results from Doling 1976; Deurloo et al. 1994; Feijten & Mulder 2005). In initial stages of the life trajectory, people want to marry and have children. To pursuit this life career, there is a need of a bigger place for a larger household size foreseen. At the same time, there are also budget constraints that restrict the option for a bigger house, and places further away from the city centre are usually more affordable. The results of the single-predictor model show that for our respondents, there is a tendency of living in low mixed land use areas with lower accessibility if the household has a child. With age and retirement, when the household size reduces, people may prefer and tend to live in places with easier access to services. These results differ from those of Doling (1976), who found no significant effect between household reduction and the likelihood of living closer to the city centre. In the same study, however, Doling (1976) reports that marriage and childbirth lead people to live in houses with more space. It is possible that our respondents move to neighbourhoods with lower accessibility in search of bigger houses.

At the single-predictor regression level, results on work status show little significance. Indeed, previous studies found that choosing a new house is mainly related to characteristics of the house itself than to work-related reasons (Borgers & Timmermans 1993; Pontes de Aquino & Timmermans 2012).

5.5.2 Car use

5.5.2.1 Single-predictor regression analysis

The linear mixed models regressing car use against each other variable individually are presented in this session. Results in Table 5.6 show that there is a significant relationship between age and car use. With age, respondents tend to have a higher proportion of car use to reach different destinations. Gender effects show that women use cars in a lower proportion than men. Both marriage and having children in the household increase significantly the proportion of car use. Few work status categories are related to car use; the only work status category with a significant coefficient in the regression is student.

Regarding the single-predictor models with urban form variables, there are significant relationships in the three models. Living in an area that is more urbanized and has higher accessibility leads to a lower proportion car use. A mildly mixed land use environment also decreases the car use proportion compared to a low mixed land use area. When interpreting these single-predictor models' results, one should be suspicious about possible spurious effect as by definition single-predictor models do not control for the possible effects of any other variables.

These results show that when the observed variables are considered individually in their relationship with car use, both household and built environment characteristics are related to individuals' choice of activity-travel behaviour. The observed relationships are in line with previous research that shows that marriage and children typically increase car use (Prillwitz & Lanzendorf 2006; Lanzendorf 2010) and that living close to the city centre and/or in a more urbanized and mixed land use environment decrease car usage (Frank & Pivo 1994; Cervero & Radisch 1996).

Table 5.6 | Linear mixed models regressing car use against each other variable individually. The variance of the random intercept at the respondent level is presented separately from residual variance.

Indep. Variable	Level	Estimate		Robust std. error	z	N (obs)	n (groups)
Age		.002	**	.272	2.34	5,780	335
Constant		.272	**	7.85	7.85		
Var (constant)		.091		.005			
Var (residuals)		.012		.002			
Gender	*female*	-.117	***	.033	-3.59	5,820	337
Constant		.408	***	.025	16.35		
Var (constant)		.087		.005			
Var (residuals)		.012		.002			
Married	*yes*	.072	*	.038	1.90	2,710	159
Constant		.344	***	.352	9.76		
Var (constant)		.086		.007			
Var (residuals)		.019		.004			
Children	*yes*	.072	**	.029	2.49	2,710	159
Constant		.367	***	.256	14.32		
Var (constant)		.088		.007			
Var (residuals)		.019		.003			
Workstatus	*30h+/w (ref)*					5,674	338
	< 30h/w	.017		.021	0.79		
	Student	-.077	**	.031	-2.50		
	Unemployed	-.015		.026	-0.56		
	Retired	.024		.018	1.35		
Constant		.348	***	.018	19.35		
Var (constant)		.090		.005			
Var (residuals)		.012		.002			
Degree of urbanization		-.077	***	.014	-5.52	5,562	330
Constant		.645	***	.569	11.33		
Var (constant)		.079		.005			
Var (residuals)		.010		.001			
Distances		.128	***	.038	3.31	5,529	336
Constant		.109		.074	1.46		
Var (constant)		.084		.005			
Var (residuals)		.009		.001			
Land use	*low (ref)*					5,420	330
	medium	-.101	**	.040	-2.54		
	high	-.077		.054	12.83		
Constant		.406	***	.032	12.83		
Var (constant)		.088		.005			
Var (residuals)		.009		.001			

Reference level for workstatus is >30h/week; for land use is low mixed land use;
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.5.2.2 Multivariate analysis

We now turn to analyzing simultaneously the effects hypothesized among our exogenous and endogenous variables. Table 5.7 presents the results of the multilevel GSEM model for this analysis, where the endogenous variables are built environment and car use. The significant relationships and the signs are depicted in Figure 5.2.

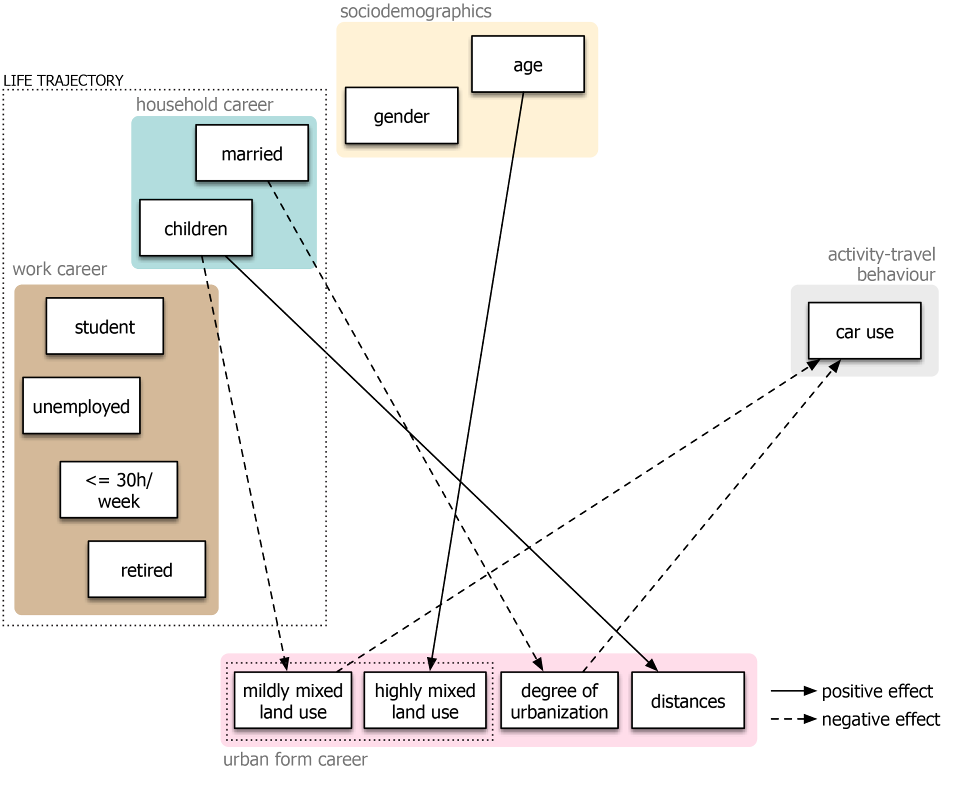

Figure 5.2 | Significant relationships found in the GSEM model for car use

Overall the most striking observation is that all effects of the respondents' life trajectory on the car use variable are mediated by the built environment variables. Marriage and having children are both indirectly associated with an increase in the proportion of car use through changes in the urban environment of the respondents' houses. Therefore, changes on life trajectory lead to respondents living in housing locations with certain built environment characteristics which, in turn, trigger car use.

Table 5.7 | Generalized SEM Structural Model Coefficients/Direct Effects for car use

	Car use	Mildly mixed Land use	High mixed land use	Degree of urbanization	Distances
Sociodemographics					
age	0.002 *	0.005	0.031	0.006	-0.023
gender: female	-0.019				
Working career					
student	-0.067 *	-0.187	0.067	0.049	-0.402
unemployed	-0.040 *	0.746	1.079	0.225	0.076
<=30h/week	-0.043	-0.306	-0.660	-0.209	-0.088
Retired	-0.004	-0.116	-0.400	0.053	-0.975
Household career					
married: yes	0.042	-0.261	-0.500	-0.482 **	0.356
children: yes	0.002	-0.798 **	-0.514	-0.132	0.785 ***
Urban form career					
mildly mixed Land use	-0.066				
high mixed land use	-0.052				
degree of urbanization	-0.058 ***				
distances	0.021				
Intercepts					
constant	0.532 ***	0.408	-1.449 **	-	-
Var (constant)	0.075				
Var (residuals)	0.011				

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In our data, age is significantly associated with an increase in the likelihood of respondents living in a highly mixed land use area compared to low mixed land use areas. As in the single-predictor regression analyses, children in the household is associated with respondents living in lower accessibility areas and in low mixed land use areas. This effect of having children on the land use preferred by respondents, associated with the effect of land use in the proportion of car use, implies that having children indirectly affects car use. Furthermore, this effect is fully mediated, as there is no significant direct effect of the variable children on the variable car use.

Simultaneously, married respondents tend to live in less urbanized places, which, in turn, leads to more car use. There is, thus, an indirect effect of marriage on car use, fully mediated by the degree of urbanization.

5.5.3 Commuting

5.5.3.1 Single-predictor regression analysis

We now analyse single-predictor models considering the relationship between each socio-demographic variable, life trajectory, and built environment variable and the choice of respondents for transport mode to commute. Table 5.8 presents the results of these models. In all models, except the one focusing on marriage, the independent variable had a significant effect on the transport mode choice to commute.

Age significantly decreases the odds of a respondent walking to work comparing to using the car. Being a female impacts the choice for public transport and walking by increasing the chance of using these modes over the car. Conversely, there is a decrease in the choice for public transport when the respondent has a child in the household. Having a child also increases the use of the 'other' transport mode compared to the car. Related to the work career, being a student decreases the odds of using a car instead of bicycle and public transport. Working 30 hours or less significantly decreases the chance of using bicycle and 'other' transport modes compared to the car. Unemployed and retired respondents tend to use the car more than walking.

With respect to the built environment variables, respondents that live in a higher degree of urbanization area have significantly higher odds of using public transport and using less 'other' transport mode to commute. Living in higher accessibility areas increases the odds of a respondent using more bicycle and public transport. More mixed land use is associated with a higher probability of respondents choosing bicycle and public transport to go to work comparing to those respondents living in lower mixed land use. Unexpectedly, respondents living in mildly mixed land use areas have lower odds to choose walking for commute instead of the car, when compared to those respondents living in low mixed land use.

Overall the isolated effects of sociodemographics, life trajectory and built environment variables on commuting mode choice are as expected, and are similar with those observed in the single-predictor analysis for the car use variable. The results follow the same trends: older respondents and male respondents are inclined to use the car; children in the household has an influence on choosing individual motorized transport modes; and living in more lively built environment has a positive effect on deciding for non-motorized and public transportation transport modes.

Table 5.8 | Multinomial logistic models regressing commuting transport mode against each other variable individually

Mode choice level	Indep. Variable	Coef.		Odds ratio	N (obs)	n (groups)
Bicycle	Age	.008		1.008	4,077	254
	Constant	-.958	**			
Public Transport	Age	-0.16		.984		
	Constant	-.166				
Walking	Age	-.032	*	.969		
	Constant	-1.50	**			
Other	Age	.024		1.025		
	Constant	-3.31	***			
Bicycle	Gender:*female*	.538	*	1.714	4,117	256
	Constant	-.890	***			
Public Transport	Gender:*female*	.584	*	1.794		
	Constant	-1.09	***			
Walking	Gender:*female*	.991		2.695		
	Constant	-3.27	***			
Other	Gender:*female*	-.483		0.617		
	Constant	-2.06	***			
Bicycle	Married:*yes*	-.649		.523	2,138	132
	Constant	-117				
Public Transport	Married:*yes*	-.365		.694		
	Constant	-.529				
Walking	Married:*yes*	-.536		.585		
	Constant	-2.09	***			
Other	Married:*yes*	-.540		.582		
	Constant	-1.94	***			
Bicycle	Children:*yes*	.229		1.258	2,138	132
	Constant	-.645	**			
Public Transport	Children:*yes*	-.939	**	0.391		
	Constant	-.519	**			
Walking	Children:*yes*	.279		1.322		
	Constant	-2.58	***			
Other	Children:*yes*	1.92	**	6.879		
	Constant	-3.49	***			
Bicycle	Workstatus:				4,015	256
	< 30h/w	-.134	**	2.190		
	Student	.805	*	2.238		
	Unemployed	.187		1.206		
	Retired	.385		1.259		
	Constant	-.861	***			
Public Transport	Workstatus:					
	< 30h/w	.150		1.163		
	Student	1.41	***	4.126		
	Unemployed	-.851		0.427		
	Retired	-.056		0.945		
	Constant	-.902	***			
Walking	Workstatus:					

	< 30h/w	.359		1.433		
	Student	.020		1.021		
	Unemployed	-2.00	*	0.135		
	Retired	-2.59	**	0.074		
	Constant	-2.64	***			
Other	Workstatus:					
	< 30h/w	-1.40	**	0.245		
	Student	-.617		0.539		
	Unemployed	.303		1.355		
	Retired	-.835		0.434		
	Constant	-2.00	***			
Bicycle	Degree of urb.	.223		1.250	3928	251
	Constant	-1.50	**			
Public Transport	Degree of urb.	.245	*	1.278		
	Constant	-1.83	***			
Walking	Degree of urb.	-.112		0.894		
	Constant	-2.50	**			
Other	Degree of urb.	-.474	**	0.622		
	Constant	-.719				
Bicycle	Distances	-.552	**	0.575	3868	256
	Constant	.395				
Public Transport	Distances	-.853	***	0.426		
	Constant	.698				
Walking	Distances	-.254		0.775		
	Constant	-2.40				
Other	Distances	.220		1.246		
	Constant	-2.73	***			
Bicycle	Land use:				3868	256
	Mildly mixed	.980	*	2.666		
	Highly mixed	1.29	**	3.650		
	Constant	-1.58	***			
Public Transport	Land use:					
	Mildly mixed	.861		2.368		
	Highly mixed	1.65	***	5.236		
	Constant	-1.85	***			
Walking	Land use:					
	Mildly mixed	-1.68	*	0.186		
	Highly mixed	.220		1.247		
	Constant	-2.30	***			
Other	Land use:					
	Mildly mixed	.920		2.512		
	Highly mixed	-1.23		0.291		
	Constant	-2.86	***			

Reference level for land use is low mixed land use; for workstatus is >30h/week; for commuting mode choice is car
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.5.3.2 Multivariate analysis

Table 5.9, Table 5.10 and Figure 5.3 display the results of the GSEM for all relationships in our conceptual model with commuting mode choice as the response variable. In general, we see little support for our hypothesis of the built environment as a mediator of the effects of life trajectory events on commuting mode choice. Life trajectory variables directly affect both built environment and commuting mode choice. But, there is no effect of any of the built environment aspects influenced by life trajectory on commuting mode choice. The single built environment variable that significantly affects commuting mode choice is *highly mixed land use*, which increases the odds of walking compared to car.

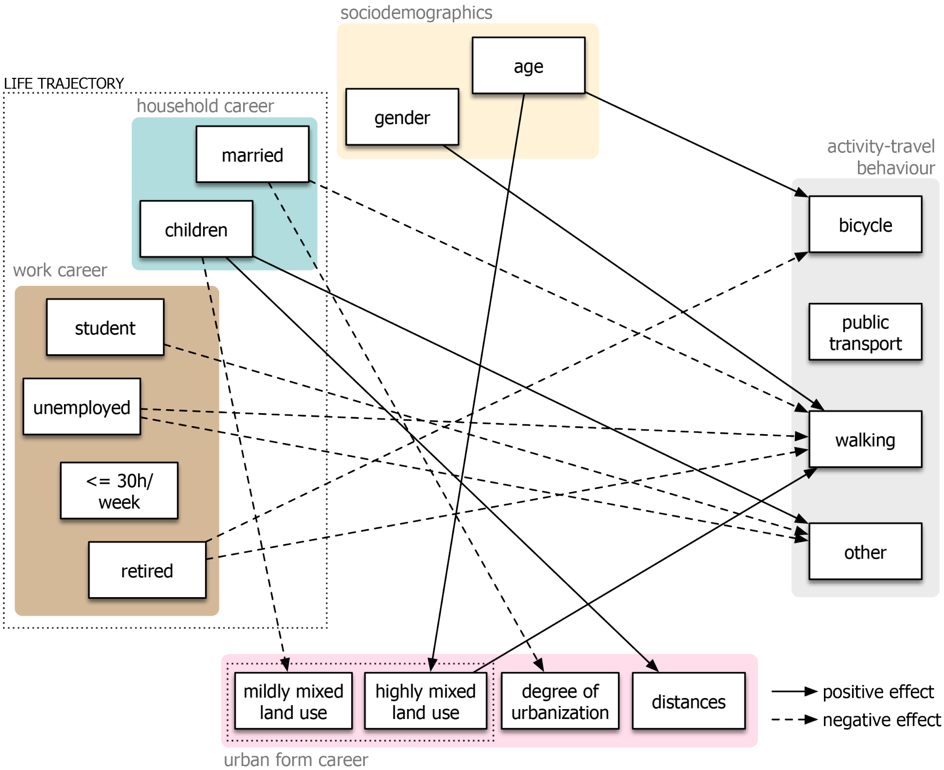

Figure 5.3 | Significant relationships in the GSEM model for commuting transport mode

Table 5.9 | Generalized SEM Structural Model Coefficients

	Mildly mixed Land use		High mixed land use		Degree of urbanization	Distances
	Coef.	**OR**	**Coef.**	**OR**		
Sociodemographics						
age	0.005	1.005	0.031 *	1.032 *	0.006	-0.023
gender: female						
Working career						
student	-0.187	0.829	0.067	1.069	0.049	-0.402
unemployed	0.746	2.109	1.079	2.942	0.225	0.076
<=30h/week	-0.306	0.736	-0.660	0.517	-0.209	-0.088
Retired	-0.116	0.891	-0.400	0.670	0.053	-0.975
Household career						
married: yes	-0.261	0.770	-0.500	0.607	-0.482 **	0.356
children: yes	-0.798 **	0.450 **	-0.514	0.598	-0.132	0.785 ***
_cons	0.408	1.504	-1.449 **	0.235 **		

Reference level for workstatus is >30h/week

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5.10 | Generalized SEM Structural Model Coefficients/Direct Effects for commuting transport mode

	Bicycle		Transport mode		Walking		Other	
	Coef.	**OR**	**Coef.**	**OR**	**Coef.**	**OR**	**Coef.**	**OR**
Sociodemographics								
age	0.036 *	1.036 *	-0.009	0.991	0.000	1.000	0.042	1.043
gender: female	0.319	1.376	0.569	1.767	3.818 ***	45.524 ***	-1.571	0.208
Working career								
student	-0.277	0.758	0.217	1.242	-1.541	0.214	-15.702 ***	0.000 ***
unemployed	-0.123	0.885	-0.903	0.405	-18.326 ***	0.000 ***	-15.554 ***	0.000 ***
<=30h/week	0.305	1.356	-0.404	0.668	-0.982	0.374	-1.177	0.308
Retired	-2.276 **	0.103 **	0.291	1.337	-15.132 ***	0.000 ***	0.728	2.070
Household career								
married: yes	-0.608	0.545	-0.373	0.689	-1.245 *	0.288 *	-0.861	0.423
children: yes	0.203	1.225	-0.637	0.529	0.951	2.588	2.573 ***	13.104 ***
Urban form career								
medium mixed land use	0.189	1.208	0.003	1.003	0.276	1.318	-0.774	0.461
high mixed land use	0.851	2.341	0.489	1.630	2.521 *	12.444 *	1.270	3.560
degree of urbanization	-0.130	0.878	-0.075	0.928	0.563	1.757	-0.872	0.418
distances	-0.523	0.593	-0.654	0.520	1.102	3.009	0.319	1.376
_cons	-0.445	0.641	1.232	3.428	-10.011 *	0.000 *	-2.235	0.107

Reference level for workstatus is >30h/week; for land use is low mixed land use;

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Although work career variables do not affect the built environment, they do have a direct effect on commuting mode choice. As mentioned before, it is expected that the work career does affect the commuting mode choice but not the choice for a housing location: work-related reasons are far less important when choosing the house when compared to characteristics of the house itself. Household variables such as marriage and children seem to have a higher impact on the choice of the built environment. Having children seems to have an effect on the preference to live in lower accessibility areas and in lower mixed land use. These results are in accordance with the assumption that when having a child there is a need for a bigger house, garden etc. The availability and affordability of a bigger house is higher in areas at some distance from the city centre and, thus, in less urbanized areas. Marriage has a negative impact on degree of urbanization, meaning that respondents chose to live in more urbanized areas when having a partner.

Looking at the direct effects on commuting transport mode, public transport has no relationship with any of the variables in the model. The transport mode that is most affected is walking. Being female is positively associated with walking. However, being married, unemployed and retired has a negative impact on walking as a transport mode to commute. Only one built environment variable, highly mixed land use, is associated with a higher likelihood of walking as the commuting mode choice. Together with the results about life trajectory events, these observations about relatively small relationship between built environment and commuting transport mode point that life trajectory aspects have stronger role on the choice for a commuting transport mode than built environment characteristics.

5.5.4 Grocery shopping transport mode choice

5.5.4.1 Single-predictor regression analysis

Table 5.11 contains the results for the single-predictor regression analyses with grocery shopping transport mode as the dependent variable and each other variable from our conceptual model as the independent variable. Broadly speaking, results are similar to the single-predictor regression analysis for commuting mode choice: all variables, except marriage, are significant in the single-predictor models.

Older respondents have higher odds of going to the grocery store by public transport instead of using the car (base category). Being a woman has a positive effect on the odds of using bicycle or the ‘other’ transport mode compared to the car; at the

Table 5.11 | Multinomial logistic models regressing grocery shopping transport mode against each other variable individually

Mode choice level	Indep. Variables	Coef.		Odds ratio	N (obs)	n (groups)
Bicycle	Age	-.011		0.989	5,665	328
	Constant	.279				
Public Transport	Age	.092	***	1.097		
	Constant	-9.14	***			
Walking	Age	.001		1.001		
	Constant	-.136				
Other	Age	.012		1.012		
	Constant	-3.11	***			
Bicycle	Gender: *female*	.981	***	2.669	5,705	330
	Constant	-.700	***			
Public Transport	Gender: *female*	-1.17		0.309		
	Constant	-3.68	***			
Walking	Gender: *female*	-6.25	**	1.869		
	Constant	-.397	**			
Other	Gender: *female*	2.24	**	9.420		
	Constant	-3.97	***			
Bicycle	Married: *yes*	-.082		0.921	2,644	156
	Constant	-.331				
Public Transport	Married: *yes*	-.249		0.779		
	Constant	-3.36	***			
Walking	Married: *yes*	-.383		0.681		
	Constant	-.117				
Other	Married: *yes*	-1.33		0.265		
	Constant	-2.76	***			
Bicycle	Children: *yes*	-.339		0.712	2,644	156
	Constant	-.255				
Public Transport	Children: *yes*	-15.6	***	0.000		
	Constant	-2.96	***			
Walking	Children: *yes*	-.601	*	0.548		
	Constant	-.156				
Other	Children: *yes*	2.24	*	9.452		
	Constant	-5.03	***			
Bicycle	Workstatus:				5,559	331
	Student	.876	**	2.401		
	Unemployed	1.31	***	3.714		
	< 30h/w	.728	**	2.072		
	Retired	-.033		0.968		
	Constant	-.552	***			
Public Transport	Workstatus:					
	Student	-14.2	***	0.000		
	Unemployed	-15.0	***	0.000		
	< 30h/w	.208		1.231		
	Retired	1.75		5.739		
	Constant	-4.56	***			

Walking	Workstatus:					
	Student	.668	*	1.950		
	Unemployed	.264		1.302		
	< 30h/w	.442		1.556		
	Retired	.536	*	1.709		
	Constant	-.371	**			
Other	Workstatus:					
	Student	-.026		0.974		
	Unemployed	2.50	***	12.23		
	< 30h/w	-.845		0.429		
	Retired	-.317		0.728		
	Constant	-3.29	***			
Bicycle	Degree of urb.	.186	*	1.204	5,447	323
	Constant	-.898	**			
Public Transport	Degree of urb.	.234		1.263		
	Constant	-4.79	***			
Walking	Degree of urb.	.522	***	1.686		
	Constant	-2.12	***			
Other	Degree of urb.	.187		1.206		
	Constant	-3.17	***			
Bicycle	Distances	-.406	*	0.666	5,414	329
	Constant	.568				
Public Transport	Distances	-2.03	**	0.131		
	Constant	-.487				
Walking	Distances	-1.03	***	0.358		
	Constant	1.80	***			
Other	Distances	-.567	*	0.567		
	Constant	-1.39	*			
Bicycle	Land use:				5,305	323
	Mildly mixed	.287		1.333		
	Highly mixed	.501		1.650		
	Constant	-.427	*			
Public Transport	Land use:					
	Mildly mixed	1.97		7.187		
	Highly mixed	1.94		6.976		
	Constant	-5.37	***			
Walking	Land use:					
	Mildly mixed	1.15	***	3.145		
	Highly mixed	1.28	***	3.596		
	Constant	-.885	***			
Other	Land use:					
	Mildly mixed	1.09		2.988		
	Highly mixed	.816		2.262		
	Constant	-3.14	***			

Reference level for land use is low mixed land use; for workstatus is >30h/week; for commuting mode choice is car
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

same time, women have lower odds of walking instead of using the car for groceries. A child in the household significantly decreases the odds of using public transport or walking compared to the car, while the child also increases the odds of the respondent using the 'other' transport mode.

Together, these effects suggest that having a child seems to lead respondents to use individual transport modes for grocery shopping. Work status has various relationships with the odds of choosing different transport modes for grocery shopping. Students, unemployed and respondents working less than 30h/week have significantly higher odds of using the bicycle compared to using the car. Students and unemployed respondents also have considerably lower odds of using public transport for the groceries. Students and retired respondents have higher odds of walking to the groceries stores, and unemployed respondents have higher odds of resorting to the 'other' transport mode.

Living in more urbanized areas is significantly related with respondents having higher odds of using bicycle or walking instead of using the car to go to the grocery store. Longer distances and thus lower accessibility increases the odds of using the car against all other transport modes. Living in an area with more mixed land use significantly increases the odds of respondents to walk instead of using the car for grocery shopping.

Likewise, for the dependent variables commuting and car use, in general the isolated effects of socio-demographics, life trajectory and built environment variables on grocery shopping mode choice are as expected. Younger respondents and women tend to use the car less for grocery shopping, except when the choice is for walking: Women walk less to do the groceries than men, which might be related to the need to carry weight. The results of work status are slightly different than expected due to the direct relation between work status and commuting. Overall, there are more significant choices to non-motorized and 'other' transport mode. Last, living in a more lively built environment has a negative effect on deciding for the car.

5.5.4.2 Multivariate analysis

The GSEM model that simultaneously models the effects in our conceptual model with the grocery shopping as the response variable is presented in Table 5.12. Because all effects from the exogenous variables on the urban form variables are identical for the three transport mode choice response variables, these are omitted in this section – the

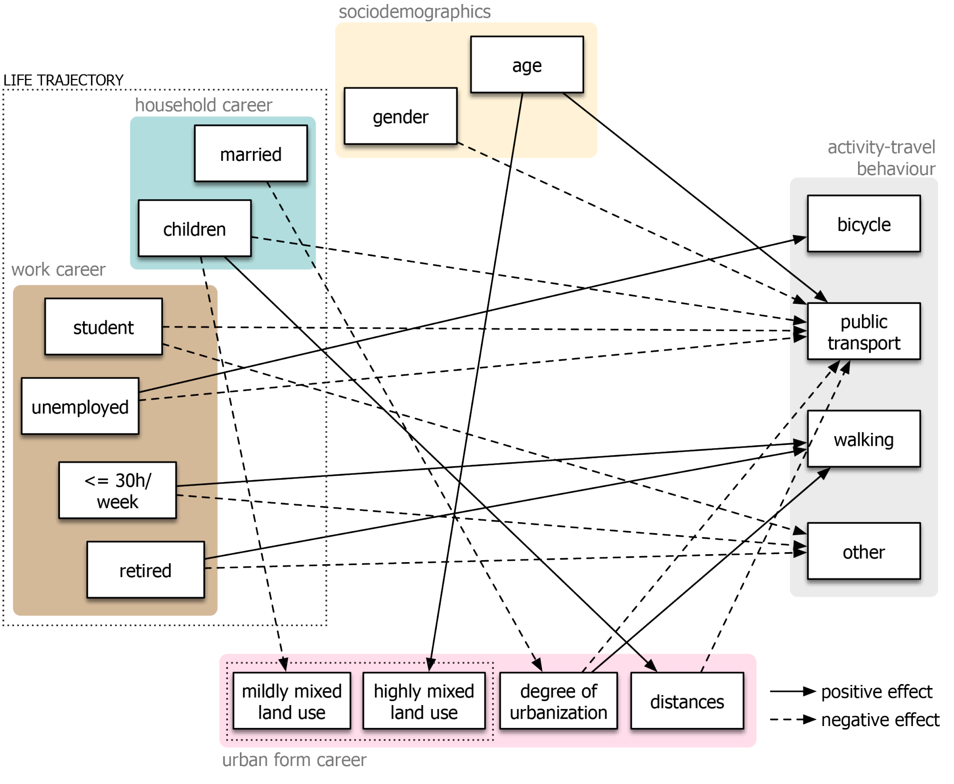

Figure 5.4 | Significant relationships found in the GSEM model for groceries transport mode

omitted coefficients are the same as presented in Table 5.9. Significant effects in the GSEM are graphically represented in Figure 5.4.

The model fit points to multiple direct effects between life trajectory careers and both the built environment where respondents live and the grocery shopping mode choice. Most important for our analysis, it also shows indirect effects of the household career on the transport mode chosen for grocery shopping that are fully mediated by the urban form. Being married is associated with respondents living in less urbanized areas, which in turn increases the odds of walking and decreases the odds of using public transport compared to the car for the grocery shopping activity. Similarly, having children in the household tends to increase the distance the respondent lives from the city centre, and higher distances are significantly associated with lower odds of using public transport instead of the car.

Different from the commuting mode choice model, in the grocery shopping model, independent variables are significantly associated with all transport modes, and specially with the public transport mode. Household career variables appear to affect indirectly grocery shopping mode choice through the built environment variables degree of urbanization and distances.

5.5.5 Shops

5.5.5.1 Single-predictor regression analysis

Like for the commuting and grocery shopping mode choices, we first model the effect of each other variable in our conceptual model on the transport mode chosen for shopping. The multinomial logistic single-predictor regression models are shown in Table 5.13. All variables have a significant effect on transport mode choice for shopping when considered individually.

Increasing age is associated with lower odds of using the bicycle and higher odds of using the public transport than using the car for shopping. Women tend to have higher odds than men of using the bicycle and 'other' instead of the car. Marriage

Table 5.12 | Generalized SEM Structural Model Coefficients/Direct Effects for groceries transport mode

	Bicycle		Transport mode		Walking		Other	
	Coef.	**OR**	**Coef.**	**OR**	**Coef.**	**OR**	**Coef.**	**OR**
Sociodemographics								
age	-0.008	0.983	0.203 ***	1.017	-0.019	0.986	0.088	1.014
gender: female	0.462	1.042	-17.586 ***	2.978	0.144	1.024	3.802 **	0.000 ***
Working career								
student	-0.388	0.741	-12.664 ***	0.120 ***	0.173	1.087	-15.546 ***	0.000 ***
unemployed	1.317 *	0.972	-15.284 ***	0.000 ***	-1.093	0.309	0.628	0.289
<=30h/week	0.435	0.893	-0.766	0.376	0.968 *	0.702	-17.488 ***	0.000 ***
Retired	0.328	0.985	-2144	2.440	1.802 **	4.165	-19.432 ***	0.089
Household career								
married: yes	0.127	0.563	-1.384	0.282 **	-0.351	0.653 *	-0.388 **	0.106 **
children: yes	-0.157	0.892	-17.084 ***	0.764	-0.413	1.179	3.045 ***	0.000 ***
Urban form career								
medium mixed land use	0.255	1.948	1.897	2.156	0.698	3.072 **	0.904	4.166
high mixed land use	-0.690	1.130	4.137	2.423	0.385	1.398	-0.673 ***	0.000 ***
degree of urbanization	0.167	1.345 *	-3.874 **	2.743 ***	0.406 **	1.890 **	0.302	1.052
distances	-0.577	0.843	-8.729 **	0.527	-0.281	0.668	-0.947	0.178
_cons	-0.048	0.780	12.142	0.008	-0.974	0.109 *	-10.560	0.000

Reference level for workstatus is >30h/week; for land use is low mixed land use

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5.13 | Multinomial logistic models regressing shopping transport mode against each other variable individually

Mode choice level	Independent Variable	Coef		Odds Ratio	N (obs)	n (groups)
Bicycle	Age	-.023	***	0.977	5,609	326
	Constant	.601				
Public Transport	Age	.017	*	1.017		
	Constant	-2.03	***			
Walking	Age	-.004		0.996		
	Constant	-.486				
Other	Age	-.000		1.000		
	Constant	-2.66	***			
Bicycle	Gender: *female*	.492	*	1.637	5,649	328
	Constant	-.655	***			
Public Transport	Gender: *female*	.351		1.421		
	Constant	-1.37	***			
Walking	Gender: *female*	.152		1.164		
	Constant	-.758	***			
Other	Gender: *female*	17.7	***	4942692		
	Constant	-19.58	***			
Bicycle	Married: *yes*	-.708	**	0.493	2,655	157
	Constant	.098				
Public Transport	Married: *yes*	-1.01	**	0.362		
	Constant	-.756	*			
Walking	Married: *yes*	-.436		0.646		
	Constant	-.558				
Other	Married: *yes*	-1.99		0.136		
	Constant	-2.57	**			
Bicycle	Children: *yes*	-.351		0.704	2,655	157
	Constant	-.264				
Public Transport	Children: *yes*	-.746		0.474		
	Constant	-1.18	***			
Walking	Children: *yes*	-.386		0.680		
	Constant	-.732	***			
Other	Children: *yes*	15.8	***	7347522		
	Constant	-18.5	***			
Bicycle	Workstatus:				5,503	329
	Student	.788	**	2.200		
	Unemployed	.798	*	2.222		
	< 30h/w	.206		1.228		
	Retired	-.542		0.582		
	Constant	-.496	***			
Public Transport	Workstatus:					
	Student	.152		1.164		
	Unemployed	.748		2.114		
	< 30h/w	.198		1.219		
	Retired	.794	*	2.213		
	Constant	-1.52	***			

Walking	Workstatus:					
	Student	.156		1.675		
	Unemployed	.400		1.491		
	< 30h/w	-.363		0.696		
	Retired	.212		1.236		
	Constant	-.722	***			
Other	Workstatus:					
	Student	.643		1.902		
	Unemployed	2.79	***	16.30		
	< 30h/w	-.249		0.779		
	Retired	-.111		0.895		
	Constant	-3.62	***			
Bicycle	Degree of urb.	.465	***	1.593	5,391	321
	Constant	-2.14	***			
Public Transport	Degree of urb.	1.18	***	3.239		
	Constant	-5.97	***			
Walking	Degree of urb.	.774	***	2.169		
	Constant	-3.66	***			
Other	Degree of urb.	.208		1.232		
	Constant	-3.38	***			
Bicycle	Distances	-.711	***	0.491	5,362	327
	Constant	.962	*			
Public Transport	Distances	-1.87	***	0.154		
	Constant	2.17	***			
Walking	Distances	-1.12	***	0.326		
	Constant	1.44	***			
Other	Distances	-.687	*	0.503		
	Constant	-1.27				
Bicycle	Land use:				5,253	321
	Mildly mixed	.702	**	2.019		
	Highly mixed	1.15	***	3.153		
	Constant	-.870	***			
Public Transport	Land use:					
	Mildly mixed	1.47	***	4.338		
	Highly mixed	2.04	***	7.672		
	Constant	-2.19	***			
Walking	Land use:					
	Mildly mixed	1.53	***	4.634		
	Highly mixed	1.69	***	5.404		
	Constant	-1.69	***			
Other	Land use:					
	Mildly mixed	.779		2.179		
	Highly mixed	.676		1.966		
	Constant	-3.02	***			

Reference level for land use is low mixed land use; for workstatus is >30h/week; for mode choice is car

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

increases the odds of using the car instead of bicycles and public transportation. Different from the single-predictor models for the previous response variables, children in the household affect only the odds of using 'other' instead of the car for shopping, and by increasing such odds. Students and unemployed respondents have higher odds of using the bicycle instead of the car compared to respondents working 30h/week or more. Against this same base category, retired people have higher odds of using public transportation and unemployed respondents have higher odds of using 'other' transport mode instead of the car for shopping.

By and large, higher urbanization, higher accessibility (shorter distances) and more mixed land use all lead to similar effects, decreasing the odds of respondents using the car compared to other alternatives for shopping.

The shopping single-predictor model is the only one where married is significant and children is significant only with 'other' transport mode. The significance

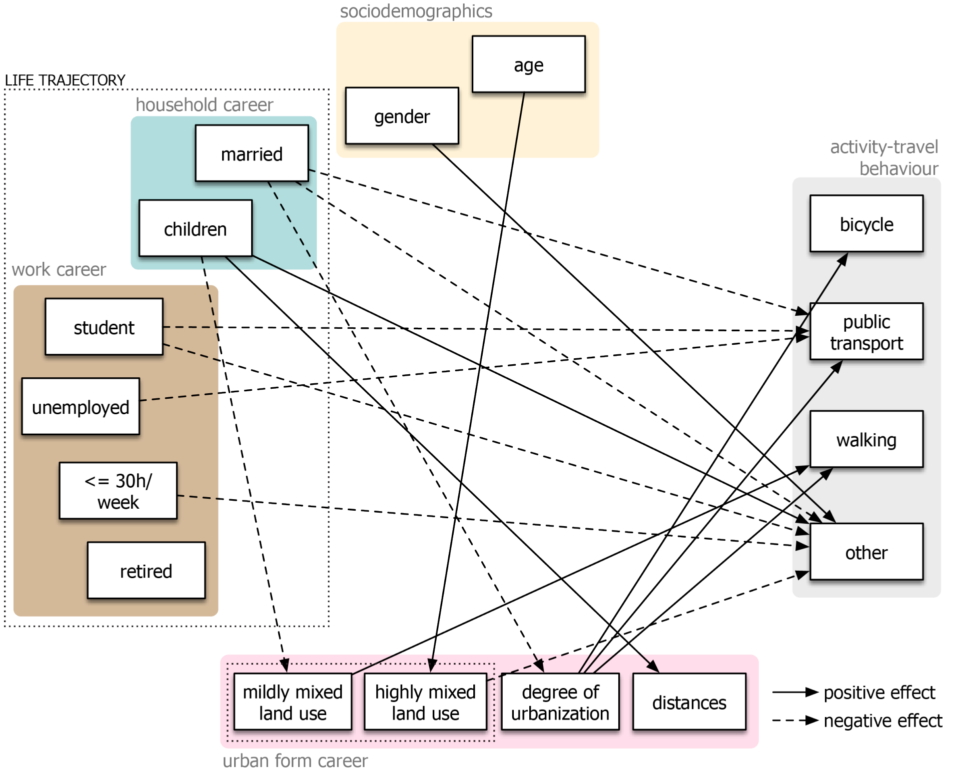

Figure 5.5 | Significant relationships found in the GSEM model for shopping transport mode

and signs of the work status variables are equivalent to those in the grocery shopping model, and, thus, contrast with the results of the commuting mode choice model. It is noticeable that all built environment variables are significantly associated with the transport modes bicycle, public transport and walking. Furthermore, the results reinforce the assumption that more lively built environments lead people to use less the car.

5.5.5.2 Multivariate analysis

Figure 5.5 displays the effects found significant in the GSEM fit for the shopping transport mode as the response variable in our conceptual model. The coefficients are shown in Table 5.14. As for the grocery shopping GSEM, the direct effects of socio-demographics and life trajectory careers are omitted and identical as those presented in Table 5.9.

As in the other two models for transport mode choice for other activities, our data shows no significant association between workstatus and the urban form when controlled for other life trajectory and sociodemographic variables.

The choice for shopping transport mode is the only model where all transport

Table 5.14 | Generalized SEM Structural Model Coefficients/Direct Effects for shopping transport mode

	Bicycle		Transport mode		Walking		Other	
	Coef.	**OR**	**Coef.**	**OR**	**Coef.**	**OR**	**Coef.**	**OR**
Sociodemographics								
age	-0.017	0.983	0.017	1.017	-0.014	0.986	0.014	1.014
gender: female	0.041	1.042	1.091	2.978	0.024	1.024	19.577 ***	0.000 ***
Working career								
student	-0.299	0.741	-2.118 ***	0.120 ***	0.084	1.087	-16.831 ***	0.000 ***
unemployed	-0.028	0.972	-24.625 ***	0.000 ***	-1.176	0.309	-1.242	0.289
<=30h/week	-0.113	0.893	-0.979	0.376	-0.354	0.702	-19.970 ***	0.000 ***
Retired	-0.015	0.985	0.892	2.440	1.427	4.165	-2417	0.089
Household career								
married: yes	-0.574	0.563	-1.266 **	0.282 **	-1.245 *	0.653 *	-2.243 **	0.106 **
children: yes	-0.115	0.892	-0.269	0.764	0.951	1.179	19.148 ***	0.000 ***
Urban form career								
medium mixed land use	0.667	1.948	0.768	2.156	1.122 **	3.072 **	1.427	4.166
high mixed land use	0.122	1.130	0.885	2.423	0.335	1.398	-17.190 ***	0.000 ***
degree of urbanization	0.296 *	1.345 *	1.009 ***	2.743 ***	0.637 **	1.890 **	0.051	1.052
distances	-0.171	0.843	-0.640	0.527	-0.403	0.668	-1.725	0.178
_cons	-0.248	0.780	-4.823	0.008	-2.220	0.109 *	-2.235	0.000

Reference level for workstatus is >30h/week; for land use is low mixed land use

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

modes are associated with built environment variables. Household career variables show direct and indirect effects on mode choice through built environment characteristics, also differing from the previous models.

5.6 Discussion

A number of regularities and differences surface when we compare the four multivariate models devised in this chapter. In the following we discuss such findings. The discussion is focused on the multivariate models, as these are more accurate for the joint description of the variables we examine – these are the models that control for the effect of other variables when examining the relationship between a given pair of characteristics in the analysis.

5.7 Built environment as a mediator

The first GSEM model presented in this chapter considers as response variable the proportion of car use to reach seven different destinations. In this model, it is important to note that all effects on car use are fully mediated by aspects of the built environment. Age, having a partner, and having children affect aspects of the built environment, which in turn affect car use.

Observing the three GSEM models about transport mode choice, there is a clear difference between the commuting mode choice model and the other two models: the built environment has a smaller role in commuting mode choice than in the grocery shopping and leisure shopping models. Cervero & Radisch (1996) also found differences in the results from models of work and non-work trip purpose. In their models, the neighbourhood characteristics had a stronger effect on local non-work trips than on commuting trips. Both our results and Cervero & Radisch (1996) are different from Frank & Pivo (1994) in this respect.

This less pronounced role of the built environment on the commuting mode choice model is somewhat expected, as previous studies already demonstrated that work-related reasons are less important when choosing a new house than aspects of the dwelling itself (Borgers & Timmermans 1993; Pontes de Aquino & Timmermans 2012). Additionally, people frequently change work places without changing housing location. Thereby, personal aspects, household aspects, and work status aspects directly affect activity-travel behaviour, but effects of the built environment on commuting mode choice are not significant. The effect of the built environment on activity-travel behaviour is however clearly seen in the models concerned with grocery and leisure shopping, as well as in the model that captures the aggregate behaviour regarding the use of the car for seven destinations (car use).

The lack of effects of the built environment on commuting mode choice also means that no aspect of the life trajectory has an effect mediated by the built environment in the commuting model. Besides the commuting mode choice model, in all models there is an indirect effect of the household career variables on activity-travel behaviour that is mediated by the built environment variables. These results support our hypothesis that life trajectory career has an impact on the choice of a housing place: although this effect is not seen for the commuting mode choice, it is observed when one considers transport mode choice for other destinations. Furthermore, the mediating effects observed imply that modelling only direct affects would provide an incomplete picture of the dynamics in the relationship between life trajectory, built environment, and activity-travel behaviour.

5.7.1 Commuting versus grocery shopping and leisure shopping mode choices

When comparing the three transport mode choice models, it is noticeable that the grocery shopping and the leisure shopping models have a similar pattern among them but different to the commuting mode choice model. The commuting mode choice model has less significant relationships and not all transport modes have significant relationships.

Considering also what was mentioned in the previous section, the choice for transport mode to go to work is less related with the house or the built environment where one lives. When people move to a new house, they might reconsider their activity-travel pattern to go shopping, both for groceries and leisure, but the change in transport mode to go to work is less often considered.

5.7.2 Decisions for the transport modes

Built environment variables show results that are expected by the new urbanism movement. Living in a mixed land use or more urbanized area decreases car use of respondents in the four models. Moreover, in all three models of mode choice, effects of characteristics of the built environment – mixed land use, degree of urbanization or both – increase the odds of bicycle use and walking. These results corroborate a series of previous studies in our literature review, e.g. Banister et al. (1997); Newman and

Kenworthy (1999); Stead (2001); Lee et al. (2012); Akar et al. (2016); Kamruzzaman et al. (2016), among others.

No variable in our commuting mode choice model has a significant effect on the odds of using public transport. For the other models, results are in line with previous studies, with household characteristics exerting a significant effect on choosing public transport instead of the car: both children and marriage decrease the odds of using public transport to different destinations, similar to Prillwitz and Lanzendorf (2006); and Lanzendorf (2010). Being student or unemployed also reduces the chance of using public transport both for grocery and leisure shopping.

Similarly to the analysis for non-motorized transport mode choice, the results related to the effect of the built environment on the choice for public transport are in agreement with expectations from the new urbanism movement. A higher degree of urbanization increases the odds of using public transport for leisure shopping. Better accessibility has a similar effect for grocery shopping. Less expectedly, a higher degree of urbanization has a negative effect in the odds of using public transportation to the grocery store. At the same time, these relationships between urban forma and activity-travel behaviour should be seen in a broader context.

5.7.3 The work status role in activity-travel behaviour

Work status has no significant relationship with the built environment characteristics in any of the GSEM models. As mentioned before, the choice of a new house, both in the literature and in our previous studies, is more related to the characteristics of the house itself than to work-related reasons, this is true not only to the commuting mode choice but also to the proportion of car use, and to the shopping – both grocery and leisure – mode choice.

When moving to a new house, size and quality of the house, affordability, quality of the living environment, and family-related reasons such as living together and marriage have a stronger weight in the choice of the place to live. Indeed, our respondents mentioned these reasons in our questionnaire (Figure 3.13 in Chapter 3).

5.8 Conclusions

The aim of this study is to examine the relationship between built environment characteristics and activity-travel behaviour through a broader perspective, adding life trajectory to the framework. Using a 20-year retrospective questionnaire, we analysed the direct and indirect associations between life trajectory, built environment and activity-travel behaviour. We consider as activity-travel behaviour four different variables: proportion of car use to reach seven different destinations, and transport mode choice for commuting, grocery shopping and leisure shopping. Each outcome variable was analysed in a different GSEM model, which enables us to model direct and indirect effects among the types of variables we use.

The analysis put forward in this chapter overall supports our hypothesis that the dynamics of the relationship between life trajectory, built environment and activity-travel behaviour are organized with the life trajectory affecting activity-travel behaviour both directly and mediated by the built environment. The role of the built environment is not prominent for the commuting mode choice in our study, but is clearly observed when one considers other destinations in the activity-travel behaviour. Such results call for the need of considering such indirect dynamics when studying activity-travel behaviour and inform urban planners about the effect of different designs.

Further discussion on the results shown in this chapter are explored in the conclusions that follows.

6

Conclusions

6.1 Introduction

Cities all over the world have drastically changed in the last century, a short time-period when compared to the existence of cities. The arrival of cars in cities changed the way they were built: the urban form was adapted to the use of motorized vehicles, which in turn affected substantially the urban function of cities. In addition to this change, since 2009 there are more people living in urban environments than in rural areas. Combining these circumstances with socio-economic factors, the existing scenario in cities all over the world includes poverty, social exclusion, chaotic urban mobility, environmental problems, to name a few urban problems.

Naturally this scenario differs according to places - different countries have different realities - and is affected by economic, social and cultural aspects. However, independent of the country, the choices people make are influenced by the needs and desires they have and the constraints people face over their life course. As an example, independently of were one lives, people might have the need to get married, buy a house, work etc., but at the same time they might be constrained by financial aspects, availability of houses, job opportunities, etc.

In reducing the negative aspects of rapidly increasing mobility needs, urban planners and designers often see their main contribution as developing plans for cities that stimulate people to avoid using the car. Expectations that the urban form (which in applied research is operationalized as a combination of urban form in the sense of morphology and accessibility to urban functions) has a strong positive effect on activity-travel behaviour are high, particularly in urban planning practice and among policy makers. Results of academic research, however, are mixed. A substantial share of early work can be discarded as this research is questionable on methodological grounds. Nevertheless, even well conducted studies are often difficult to judge as it is not always clear whether the effects of the built environment on activity-travel behaviour are statistically significant or can be interpreted in a causal manner. Two methodological principles can improve this situation: (i) enlarging the set of variables considered to include for example life trajectory variables, and (ii) replacing a cross-sectional approach for a longitudinal one.

Given these considerations, the main goal of this thesis is to examine the relationship between the built environment and activity-travel behaviour considering people's life trajectory and a longitudinal perspective. It is hypothesized that the relationship between the built environment and activity-travel behaviour should be evaluated from this larger perspective, due to the fact that life events happening in people's life might influence their choices for both residential location and their activity-travel behaviour.

The remaining of this chapter discusses the contribution of this thesis, both from a methodological point of view and from its results; reflects on its limitations; and discusses its implications and future work.

6.2 Methodological contributions

The analysis of effects of aspects of the built environment on activity-travel behaviour has been mainly concentrated on cross-sectional data. The use of longitudinal data instead of cross-sectional data allows one to capture the effects of changes in people's life that might trigger changes in activity-travel behaviour. Hence, this study uses a 20-year retrospective questionnaire to collect longitudinal information over the life trajectory of respondents, related to their household career, work career, and housing career. The questionnaire captures details about up to five different houses in which respondents lived, and the mobility patterns that were associated with each house.

The data collected through a retrospective survey may be biased due to memory errors: people may provide mistaken information. To address this problem, the design of the questionnaire was made such as to minimize inaccuracy. The use of panel data could be a way to resolve the problems of retrospective data. However, at the time the data were collected, no panel data were available covering all aspects raised in our conceptual framework.

A central contribution of this thesis is an improvement in the methodology for the analysis of the effects of the built environment on activity-travel choices. The characteristics of the built environment are commonly analysed using a pre-set delimitation of neighbourhoods. However, there are two main problems with the use of that delimitation: the first is that formal delimitations of neighbourhoods are not necessarily related to its characteristics or its identity. Therefore, inside the same neighbourhood one can find different characteristics related both to urban form and urban function. The second limitation is that one person may live close to the borders of a neighbourhood and prefer to use facilities of another neighbourhood instead of the one he/she lives in. Analysing built environment characteristics at the respondent level allows capturing a more precise approximation of the real characteristics of the respondents' built environment. Our analysis applies a buffer of one-kilometre around every respondent, which is what the CBS defines as a walkable distance. To the best of our knowledge, this approach is unique in this area of research. In addition to better capturing the immediate action space of people, it also solves or at least reduces the effects of a key limitation of research on the effects of urban form on travel behaviour. Attributes of the built environment have been commonly defined at some spatial unit, implying that all respondents living in that unit share the same values of the built environment variables. Subsequent analysis assumes that these values are independent but in reality they are not. Because the significance of coefficients in the applied models is a direct function of the number of independent samples, significance levels in these studies are inflated. In other words, many researchers have falsely concluded that the effects of the built environment are statistically significantly whereas in reality they were not for that sample size. By measuring individual spaces, this problem is avoided or at least reduced.

In addition to the analysis at the respondent level, another contribution is the multi-faceted analysis conducted in the investigation of the built environment characteristics. Three main aspects of the built environment were captured in the analysis: accessibility to different destinations, including shops, green areas, public transport and retail hubs; level of mixture in the land uses; and density. All distances were calculated using the road network, a more precise approximation to the real distances respondents travel when compared to Euclidian distances.

From the perspective of understanding transport mode choices, this thesis contributes to the literature by providing an analysis of the transport mode used in a specific year as the response variable in a series of models. This contrasts with the more common practice of modelling distance travelled or commuting time as response variables. Although this is not necessarily better than modelling distance travelled, it offers a complementary understanding of activity-travel choices which we contend as insightful.

6.3 Contribution from our results

Our results come mainly from four GSEM models. All four consider the relationship between socio-demographics, household career, work status career, built environment characteristics, and activity-travel behaviour. The models differ in their response variable. One of the models considers as the response variable the proportion of car use for seven different types of trips: commuting, grocery shopping, leisure shopping, restaurants and cafés, green spaces, cultural centres, and sport centres. The response variables of the other three models are the mode choice to travel when commuting, shopping for groceries, and leisure shopping.

The analysis of the four models points that in general the built environment mediates the effects of socio-demographics and household career on activity-travel behaviour. This effect is not significant for the commuting mode choice, but it is significant for the proportion of car use, and for the leisure and groceries shopping mode choice. Such results both describe the relationship of life trajectory, built environment and activity-travel behaviour, and highlight the need for considering the mediation effects of our models when studying these three constructs together.

The less relevant role that the built environment has in the results regarding the commuting mode choice when compared with the other two mode choices studied in detail (grocery and leisure shopping) corroborates several previous studies. Our results reinforce the impression that the built environment is a prominent factor for the mode choice of local and non-commuting trips, while the mode choice for work is determined by other factors. Moreover, the work status of respondents had no significant relationship with the built environment in our models. This result is more interesting when complemented with the descriptive results from our questionnaire, which also point that work-related reasons are not often mentioned when eliciting one's motivations to choose a house.

One main contribution of this thesis is the study of the role of the built environment when considering people's life trajectory into the relationship. In all four GSEM models, life trajectory has a bigger role in affecting activity-travel behaviour than the built environment characteristics. In all models the built environment mediates the effect of being married or having children. Some direct effects were also observed. These results corroborate with the hypothesis put forward in this thesis.

When considering the effects of the built environment on the activity-travel behaviour, our data might seem to confirm expectations from the new urbanism movement. Increased mix of land uses and more urbanization are associated with less car use, and the characteristics of the built environment are often significantly related to the odds of respondents preferring to cycle or walking. However, in all cases that the built environment is correlated with activity-travel behaviour, it is a mediator of aspects of the life trajectory.

6.4 Limitations and future work

This thesis has a number of limitations that must be taken into consideration and possibly addressed in future research. The first set of limitations is related to issues in the data collection. Although the use of a retrospective questionnaire provided a wealth of information that was not available through panel data, even a careful design did not prevent a high number of missing data.

Questionnaire design

Although our questionnaire was effective in collecting event information in a period of 20 years, it was not without problems that were observed only after data collection. First, it did not ask necessary information about marital status and children in the household prior to these 20 years. For example, in cases where respondents have no marriage or children events during the time-period of the questionnaire, it is impossible to determine whether such respondents were ever married or had children. The same might occur to work related events. Thus, the tendency to curb the time in retrospective data should be avoided. A second issue of the questionnaire is related to collecting data about education and income. Education was not collected as a longitudinal variable; it was collected instead as the state at the time of data collection. This prevented education data from being used in the longitudinal analysis. Income data proved complicated to be provided precisely by respondents, maybe because they did not know or because they were not willing to provide such information. Our approach was to ask about increases and decreases over time, but the resulting data was impossible to use in the analysis. Future work should incorporate further questions in the data collection instruments to address such lack of information.

Sample size and event likelihood

The number of questionnaires collected is considerable. However, data shows that changes in housing career and activity-travel behaviour are rare. This complicates statistical analyses in such samples. Future work can tackle such issue either focusing on a population that has more changes in the life trajectory (all careers) or collecting a larger sample size. In the present study, sample size was dictated by the available budget. An example of a population where changes are more likely is a population between 20 and 40 years old. An option is to oversample this segment of the population and then weight to obtain final population-level results.

Further analysis

In our analysis, we assumed that respondents used only one main transport mode for each trip destination, ignoring any variability. There is room for improving the resolution of this data, both in situations where an individual uses the car and the bike on different days for a same trip destination, and in situations where the individual changes transport mode while living in a same house. Other data can also complement the understanding of triggers to change mode choices: household agreements, the availability of transport modes, and weather characteristics for example. From this perspective, it is important to note that there are relevant decisions that are made at the household level. Future work should explore the possibility of analysing the household as a whole, as well as the relationship between the individual and the other member of the household. In this direction, it seems relevant to examine gender issues related to activity-travel behaviour. This plea for household level analysis reflects a general lack of this level of analysis. However, whereas there has been some attention to household decision making and gender role in the activity-based modelling literature, to the best of our knowledge it has not been applied in the research on the relationship between the built environment and activity-travel behaviour.

This thesis relies on quantitative data and analyses. A qualitative investigation is necessary to deepen the understanding of the motivations and causal relationships observed in the quantitative data. It seems especially promising to interview people that passed through life events and examine how these events affected their careers and activity-travel behaviour.

Reproduce our experiment in different countries

The data used in this study was collected in 25 municipalities in the Rotterdam area, in the Netherlands, a denominated developed country. In general, variations in the urban environment in this country are relatively small. The results exposed here are thus considerations about urban environments that overall are able to produce equal rights and opportunities to people.

The study on the relationship of the built environment and activity-travel behaviour has for long being concentrated in North American and European countries. Lately, some studies in other type of environments were also published such as Australia (Kamruzzaman et al. 2016), China (Pan et al. 2009), and Brazil (Larrañaga et al. 2014). Nevertheless, there is still an urge to better understand in different environments, cultures, and policies how the built environment is affecting not only activity-travel behaviour, but also how it is fulfilling their social function, sustainable mobility included. Moreover, needs and constraints that the urban population in different countries face may differ significantly the understanding of these aspects. Reproducing our study in different countries might contribute to an improvement in public policies also in different urban form and urban functions environments.

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Curriculum Vitae

Aida Pontes was born on September 12th, 1980, in João Pessoa, Brazil. She studied architecture and urbanism at the Federal University of Paraíba, in João Pessoa, Brazil. During her studies, she became aware of the necessity to improve the bicycle as a transport mode in Brazil after she started cycling to the University. This awareness increased after a stay at the University of Technology of Compiègne, in France, with an internship at the Urbanism and Architecture Atelier of the Amiens Metropolitan Region.

After her graduation, she enrolled in a Master in Urban Engineering at the Federal University of Paraíba. In her master's research, she studied the integration between train and bicycle as an element of sustainable urban development. With this work she won the first place on the third edition of the Dissertation Contest of CBTU (The Brazilian Company of Urban Trains). During the masters' studies, she also worked as architect and urbanist at the Urban Planning Department of the City Council of João Pessoa.

In March 2009, Aida joined the Urban Planning Group at the Eindhoven University of Technology as a PhD candidate. During her PhD, she combined research with activities of the *Bouwkunde* PhD Network.

During 2013, back in Brazil, she contributed to the Superintendence of Urban Mobility of the City Council of João Pessoa as an Urban Planner, developing several urban projects. Since 2014 she joined the University UniFacisa in Campina Grande as a Professor of Urban Planning and Urban Design. She created in Campina Grande the Laboratório de Rua (LabRua) in 2015, a group of research and intervention in public spaces, enrolling professionals and students on the analysis and interventions on public spaces.

Her background is a local reference on how to think and design cities for people. She is often invited to give talks on this subject, for example at TEDx João Pessoa in 2016. In the same year, she got the second place at the Contest *Concurso Areas 40*, organised by the World Resources Institute Brazil, with an Urban Intervention for the Brás neighbourhood in São Paulo.

Aida is also actively engaged in the Brazilian Architects' Institute (IAB), having assumed the vice presidency of the Paraíba chapter of the Institute from 2014 to 2016, and currently acting in the administrative council both at state and national levels.

Publication list

Journal papers

Aquino, A.P.P., Mendes, B.B., Macedo, F.G.de, Fernandes, H.T.R., Tavares, M.S.C., Costa, P.H.S. (2018). Os Espaços Públicos do Núcleo Central da Cidade de Campina Grande na Percepção do seus Usuários (The Public Spaces of the Central Nucleus of the City of Campina Grande in the Perception of its Users). Revista Tema, v.17, n.26/27.

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Appendix

A. Questionnaire used for data collection

Introductie

Hallo,

Hartelijk dank voor uw deelname aan het onderzoek "verhuisgeschiedenis" en uw bereidheid deze enquête in te vullen. Alvorens over te gaan tot de vragen, willen wij graag ons onderzoek toelichten.

De wijze waarop wij ons binnen steden verplaatsen heeft een enorme invloed op de duurzaamheid van onze planeet. Er is een discussie gaande onder stedenbouwkundigen over de vraag of vorm en dichtheid, van invloed zijn op de wijze waarop wij ons verplaatsen en daarmee op de duurzaamheid van de aarde.

Met deze studie proberen we inzicht te krijgen in hoe mensen zich binnen de stad verplaatsen. Door de wisselwerking tussen de stad en het reisgedrag van mensen beter te begrijpen, zijn wij in staat steden te ontwerpen die duurzamer en aangenaam zijn om in te wonen.

Wij verzoeken u vriendelijk deel te nemen aan dit onderzoek door deze enquête in te vullen. De enquête bevat vragen over het verloop van uw leven, de verschillende locaties waar u gewoond hebt en de wijze waarop u zich verplaatst naar uw belangrijkste bestemmingen vanaf elk huis waar u gewoond heeft.

We hopen dat u de enquête zult invullen en voltooien en danken u hartelijk voor uw tijd en aandacht. Uw antwoorden zijn zeer belangrijk voor ons onderzoek en zullen uiteraard vertrouwelijk worden behandeld.

Indien u vragen hebt, neem dan a.u.b. contact op met:

Aïda Pontes: a.p.pontes@bwk.tue.nl

040 247 4014

De enquête

Deze enquête bestaat uit vier delen: Persoonlijke Gegevens, Levensloopkalender, Gebeurtenissen en Toekomstverwachtingen.

Bij de persoons gegevens vragen wij enkele algemene gegevens over u en uw partner. Het tweede deel van de enquête bevat een kalender over enkele gebeurtenissen in uw leven, zoals verhuizingen of veranderingen in uw werksituatie. Vervolgens vragen wij u, in het gedeelte gebeurtenissen, naar een omschrijving van uw belangrijkste woningen en uw reispatroon bij elke woning. Het laatste gedeelte gaat over uw eventuele toekomst plannen, zoals veranderingen in baan of woning.

Neemt u de tijd om de vragenlijst te beantwoorden. Indien nodig, kunt u terug grijpen naar documenten die u helpen om gebeurtenissen uit het verleden te herinneren.

Toelichting bij het formulier Persoons Gegevens

In dit gedeelte verzoeken wij uw persoons gegevens in te vullen zoals geslacht, geboortedatum, nationaliteit en opleiding.

1) Bent u...
- [ ] Man
- [ ] Vrouw

2) In welke jaar bent u geboren?

3) Wat is uw nationaliteit?

4) Wat is uw hoogst genoten opleiding?
- [ ] Geen/onbekend
- [ ] BO/LO
- [ ] LBO/VGLO/LAVO/MAVO/MULO
- [ ] HAVO/MMS/HBS
- [ ] Atheneum/gymnasium
- [ ] MBO
- [ ] HBO
- [ ] Universiteit
- [ ] Overig:

5) Wat is uw werk status?
- [ ] Werkend
- [ ] Werkzoekend
- [ ] Huisvrouw/huisman
- [ ] Gepensionnerd/VUT
- [ ] Studerend/Scholier

6) Wat is uw het netto inkomen (na belasting) per jaar?
- [ ] 7500€ of minder
- [ ] 7500€ - 15000€
- [ ] 15000€ - 22500€
- [ ] 22500€ - 30000€
- [ ] 30000€ of meer
- [ ] Geen inkomen

1) Is uw partner...
- [ ] Man
- [ ] Vrouw

2) In welke jaar is uw partner geboren?

3) Wat is de nationaliteit van uw partner?

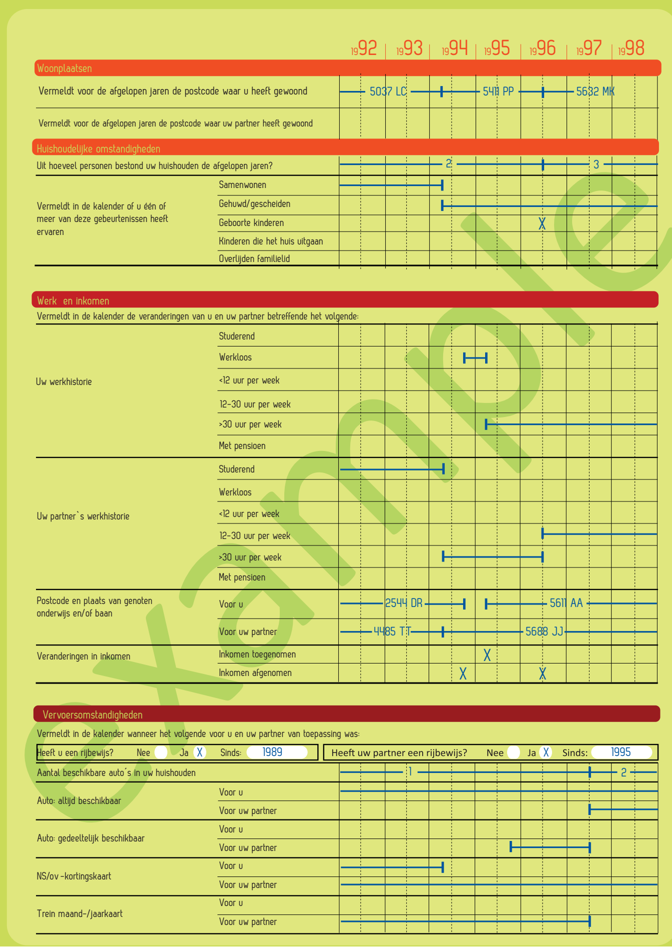
4) Wat is de hoogst genoten opleiding van uw partner?
- [ ] Geen/onbekend
- [ ] BO/LO
- [ ] LBO/VGLO/LAVO/MAVO/MULO
- [ ] HAVO/MMS/HBS
- [ ] Atheneum/gymnasium
- [ ] MBO
- [ ] HBO
- [ ] Universiteit
- [ ] Overig:

5) Wat is de werk status van uw partner?
- [ ] Werkend
- [ ] Werkzoekend
- [ ] Huisvrouw/huisman
- [ ] Gepensionnerd/VUT
- [ ] Studerend/Scholier

6) Wat is het netto bedrag van inkomen (na belasting) van uw partner per jaar?
- [ ] 7500€ of minder
- [ ] 7500€ - 15000€
- [ ] 15000€ - 22500€
- [ ] 22500€ - 30000€
- [ ] 30000€ of meer
- [ ] Geen inkomen

Toelichting bij de Levensloopkalender

Wij verzoeken u in de levensloopkalender gebeurtenissen te vermelden tussen 1992 en 2011. Op deze pagina, treft u een voorbeeld aan van een ingevulde levensloopkalender. Om u zich bepaalde gebeurtenissen te kunnen herinneren helpt het wellicht, als u begint met het vermelden van de belangrijke gebeurtenissen binnen uw gezin(zoals geboorte van kinderen, huwelijk, scheiding, e.d.). Vervolgens kunt u deze als referentie gebruiken voor andere gebeurtenissen. Het kan ook helpen als u begint met de recente gebeurtenissen en vervolgens teruggaat in de tijd.



		1992	1993	1994	1995	1996	1997	1998
Woonplaatsen								
Vermeldt voor de afgelopen jaren de postcode waar u heeft gewoond								
Vermeldt voor de afgelopen jaren de postcode waar uw partner heeft gewoond								
Huishoudelijke omstandigheden								
Uit hoeveel personen bestond uw huishouden de afgelopen jaren?								
Vermeldt in de kalender of u één of meer van deze gebeurtenissen heeft ervaren	Samenwonen							
	Gehuwd/gescheiden							
	Geboorte kinderen							
	Kinderen die het huis uitgaan							
	Overleden familielid							

Werk en inkomen

Vermeldt in de kalender de veranderingen van u en uw partner betreffende het volgende:

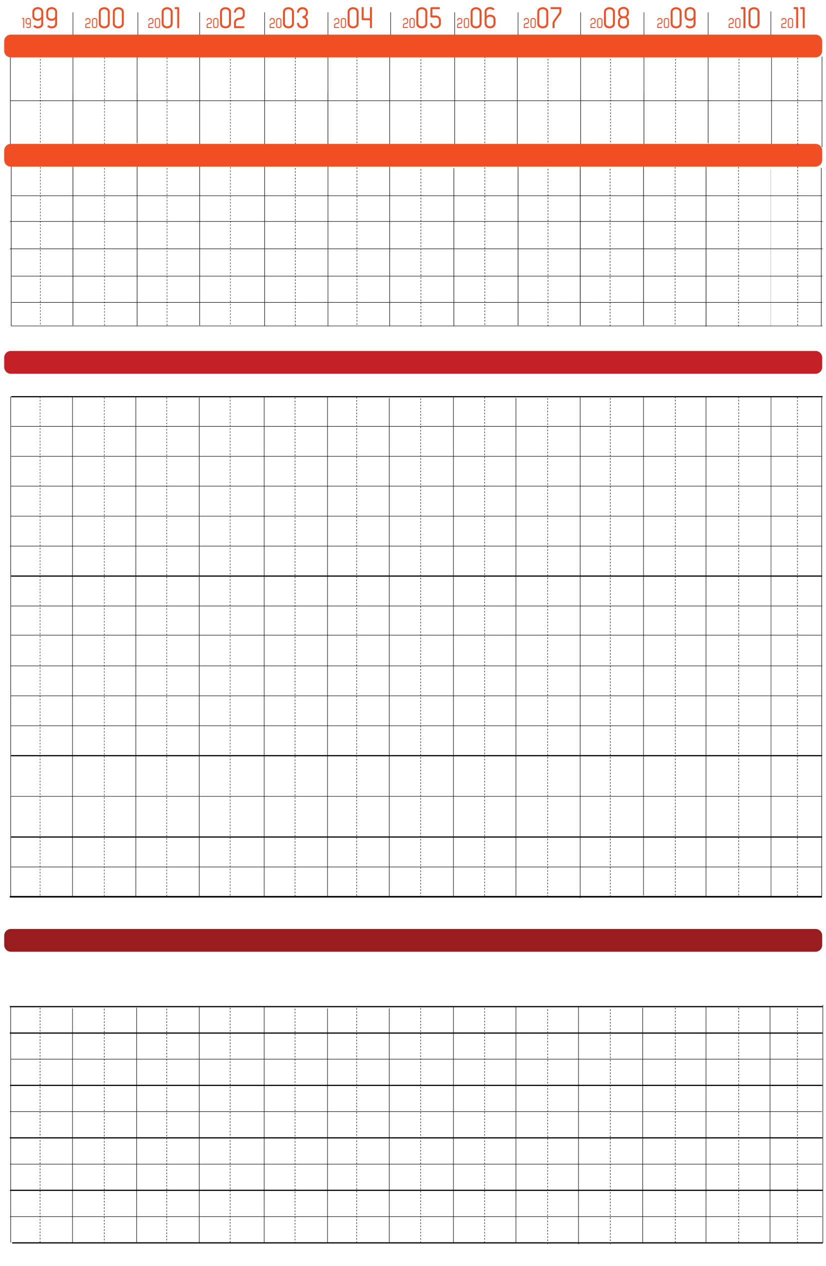
		1992	1993	1994	1995	1996	1997	1998
Uw werkhistorie	Studerend							
	Werkloos							
	<12 uur per week							
	12-30 uur per week							
	>30 uur per week							
	Met pensioen							
Uw partner`s werkhistorie	Studerend							
	Werkloos							
	<12 uur per week							
	12-30 uur per week							
	>30 uur per week							
	Met pensioen							
Postcode en plaats van genoten onderwijs en/of baan	Voor u							
	Voor uw partner							
Veranderingen in inkomen	Inkomen toegenomen							
	Inkomen afgenomen							

Vervoersomstandigheden

Vermeldt in de kalender wanneer het volgende voor u en uw partner van toepassing was:

Heeft u een rijbewijs? Nee ○ Ja ○ Sinds: ______ | Heeft uw partner een rijbewijs? Nee ○ Ja ○ Sinds: ______

		1992	1993	1994	1995	1996	1997	1998
Aantal beschikbare auto´s in uw huishouden								
Auto: altijd beschikbaar	Voor u							
	Voor uw partner							
Auto: gedeeltelijk beschikbaar	Voor u							
	Voor uw partner							
NS/ov -kortingskaart	Voor u							
	Voor uw partner							
Trein maand-/jaarkaart	Voor u							
	Voor uw partner							


1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

Toelichting bij de Gebeurtenissen m.b.t. Huishouden

De gegevens van u en uw partner zijn gescheiden in dit gedeelte. Het eerste gedeelte bevat drie pagina's en gaat over uw huishouden. Vermeldt a.u.b. uw woonplaatsen, beginnend bij de eerste woning na het beëindigen uw opleiding. Als u op meer dan vijf verschillende plaatsen hebt gewoond, vul dan a.u.b. uw huidige woomplaats in en vier andere plaatsen waarin u de meeste tijd heeft doorgebracht.

	huidige woning	vorige woning
Vul de postcode van uw woning in* * het is echt belangrijk voor het onderzoek om te weten van de postcoden waar u woonde		
Wat voor soort woning heeft/had u?	☐ Studentenhuis ☐ Vrijstaand ☐ Semi-vrijstaand ☐ Hoekwoning ☐ Rijtjeshuis ☐ Appartement ☐ Anders:	☐ Studentenhuis ☐ Vrijstaand ☐ Semi-vrijstaand ☐ Hoekwoning ☐ Rijtjeshuis ☐ Appartement ☐ Anders:
Woonlasten: vul de kale huur- of hypotheek lasten per maand in	☐ Het huis is gratis ☐ 400€ of minder ☐ 401€ - 800€ ☐ 801€ - 1200€ ☐ 1201€ of meer	☐ Het huis is gratis ☐ 400€ of minder ☐ 401€ - 800€ ☐ 801€ - 1200€ ☐ 1201€ of meer
Hoeveel slaapkamers heeft/had uw woning?		
Geschatte bouwjaar van de woning.		
Heeft/had u een tuin?	☐ ja ☐ nee	☐ ja ☐ nee

woning

Enkele aspecten over uw buurt

		huidige woning	vorige woning
Groenvoorzieningen en/of parken	Aanwezig:	☐ Niet aanwezig	☐ Niet aanwezig
	Afstand vanaf woning:		
Parkeervoorzieningen	Aanwezig:	☐ Niet aanwezig	☐ Niet aanwezig
	Afstand vanaf woning:		
Bushalte	Afstand vanaf woning:		
Treinstation	Afstand vanaf woning:		
	Soort treinstation:	☐ centraal ☐ anders	☐ centraal ☐ anders

Hoe zijn/waren de omstandigheden t.a.v. de volgende kenmerken per buurt waar u gewoond hebt? Slechts één keuze mogelijk.

	Erg slecht	Slecht	Redelijk	Goed	Erg goed	Erg slecht	Slecht	Redelijk	Goed	Erg goed
Groenvoorzieningen en/of parken										
Parkeervoorzieningen										
Hoeveelheid verkeer										
Verkeersveiligheid										
Persoonlijke veiligheid										
Geluidsoverlast										
Kwaliteit van de leefomgeving*										
Nabijheid bussen										
Nabijheid treinen										

buurt

*leefomgeving wordt bepaald door: stank, drukte, voorzieningen, (slecht) onderhoud e.d.

voorlaatste woning

- Studentenhuis
- Vrijstaand
- Semi-vrijstaand
- Hoekwoning
- Rijtjeshuis
- Appartement
- Anders:

- Het huis is gratis
- 400€ of minder
- 401€ - 800€
- 801€€ 1200
- 1201€ of meer

ja nee

Niet aanwezig

Niet aanwezig

centraal anders

Erg slecht | Slecht | Redelijk | Goed | Erg goed

2e voorlaatste woning

- Studentenhuis
- Vrijstaand
- Semi-vrijstaand
- Hoekwoning
- Rijtjeshuis
- Appartement
- Anders:

- Het huis is gratis
- 400€of minder
- 401€ - 800€
- 801€ - 1200€
- 1201€ of meer

ja nee

Niet aanwezig

Niet aanwezig

centraal anders

Erg slecht | Slecht | Redelijk | Goed | Erg goed

3e voorlaatste woning

- Studentenhuis
- Vrijstaand
- Semi-vrijstaand
- Hoekwoning
- Rijtjeshuis
- Appartement
- Anders:

- Het huis is gratis
- 400€ of minder
- 401€ - 800€
- 801€ - 1200€
- 1201€ of meer

ja nee

Niet aanwezig

Niet aanwezig

centraal anders

Erg slecht | Slecht | Redelijk | Goed | Erg goed

Geef per woning uw (heen) reistijd en vervoerswijze aan naar uw belangrijkste bestemm
vervoersmogelijkheden aan (bijv. 3 dagen per week met de auto en 2 dagen per week met d

bereikbaarheid

		huidige woning		vorige woning	
		Reistijd	Vervoermiddel	Reistijd	Vervoermiddel
Werk/studie	1e				
	2e				
Boodschappen	1e				
	2e				
Winkelen	1e				
	2e				
Restaurants en café's	1e				
	2e				
Groenvoorzieningen en parken	1e				
	2e				
Culturele centra (museum, bioscoop e.d.)	1e				
	2e				
Sport- en ontspanningscentra	1e				
	2e				

Wat vindt/vond u van de bereikbaarheid naar uw belangrijkste bestemmingen vanaf elk huis waar u gewoond hebt? Slechts één keuze mogelijk (van erg slecht tot erg goed).

	huidige woning					vorige woning				
	Erg slecht	Slecht	Redelijk	Goed	Erg goed	Erg slecht	Slecht	Redelijk	Goed	Erg goed
Werk										
Boodschappen										
Winkelen										
Restaurants en café's										
Groenvoorzieningen en parken										
Culturele centra (museum, bioscoop e.d.)										
Sport- en ontspanningscentra										

mingen. Als er sprake was van meerdere vervoersmogelijkheden naar een bepaalde bestemming, geef dan de twee meest gebruikte
le fiets naar het werk). Alleen bij sporadisch gebruik van een ander vervoermiddel (bijv. 1x per maand), geef dan het meest gebruikte aan.

voorlaatste woning		2e voorlaatste woning		3e voorlaatste woning	
Reistijd	Vervoermiddel	Reistijd	Vervoermiddel	Reistijd	Vervoermiddel

Erg slecht	Slecht	Redelijk	Goed	Erg goed	Erg slecht	Slecht	Redelijk	Goed	Erg goed	Erg slecht	Slecht	Redelijk	Goed	Erg goed

Verhuisredenen

	huidige woning	vorige woning
Is/was het huis gehuurd of gekocht?	☐ Gehuurd ☐ Gekocht	☐ Gehuurd ☐ Gekocht
Wanneer woonde u in dit huis?	Van: maand/jaar Tot: maand/jaar	Van: maand/jaar Tot maand/jaar
Waarom bent u hier naartoe verhuisd? (meerdere antwoorden mogelijk)	☐ Beter/leuker wonen ☐ Familie-omstandigheden ☐ Dicht bij het werk ☐ Dicht bij het centrum ☐ Goede openbaar vervoer voorzieningen ☐ Dicht bij culturele voorzieningen ☐ Dicht bij groenvoorzieningen of parken ☐ Goede school ☐ Woning-gerelateerde omstandigheden ☐ Kwaliteit van de leefomgeving ☐ Werk-gerelateerde omstandigheden ☐ Dicht bij familie en vrienden ☐ Anders:	☐ Beter/leuker wonen ☐ Familie-omstandigheden ☐ Dicht bij het werk ☐ Dicht bij het centrum ☐ Goede openbaar vervoer voorzieningen ☐ Dicht bij culturele voorzieningen ☐ Dicht bij groenvoorzieningen of parken ☐ Goede school ☐ Woning-gerelateerde omstandigheden ☐ Kwaliteit van de leefomgeving ☐ Werk-gerelateerde omstandigheden ☐ Dicht bij familie en vrienden ☐ Anders:
Ging uw voorkeur uit naar dit huis?	☐ ja ☐ nee	☐ ja ☐ nee
Zo niet, waarom kiest u niet het huis van uw voorkeur?	☐ Financiële redenen (te duur) ☐ Beschikbaarheid ☐ Urgentie ☐ Reisflexibiliteit ☐ Mijn ouders huis ☐ Anders:	☐ Financiële redenen (te duur) ☐ Beschikbaarheid ☐ Urgentie ☐ Reisflexibiliteit ☐ Mijn ouders huis ☐ Anders:

voorlaatste woning	2e voorlaatste woning	3e voorlaatste woning
Gehuurd	Gehuurd	Gehuurd
Gekocht	Gekocht	Gekocht
Van: maand/jaar Tot: maand/jaar	Van: maand/jaar Tot: maand/jaar	Van: maand/jaar Tot: maand/jaar
Beter/leuker wonen	Beter/leuker wonen	Beter/leuker wonen
Familie-omstandigheden	Familie-omstandigheden	Familie-omstandigheden
Dicht bij het werk	Dicht bij het werk	Dicht bij het werk
Dicht bij het centrum	Dicht bij het centrum	Dicht bij het centrum
Goede openbaar vervoer voorzieningen	Goede openbaar vervoer voorzieningen	Goede openbaar vervoer voorzieningen
Dicht bij culturele voorzieningen	Dicht bij culturele voorzieningen	Dicht bij culturele voorzieningen
Dicht bij groenvoorzieningen of parken	Dicht bij groenvoorzieningen of parken	Dicht bij groenvoorzieningen of parken
Goede school	Goede school	Goede school
Woning-gerelateerde omstandigheden	Woning-gerelateerde omstandigheden	Woning-gerelateerde omstandigheden
Kwaliteit van de leefomgeving	Kwaliteit van de leefomgeving	Kwaliteit van de leefomgeving
Werk-gerelateerde omstandigheden	Werk-gerelateerde omstandigheden	Werk-gerelateerde omstandigheden
Dicht bij familie en vrienden	Dicht bij familie en vrienden	Dicht bij familie en vrienden
Anders:	Anders:	Anders:
ja nee	ja nee	ja nee
Financiële redenen (te duur)	Financiële redenen (te duur)	Financiële redenen (te duur)
Beschikbaarheid	Beschikbaarheid	Beschikbaarheid
Urgentie	Urgentie	Urgentie
Reisflexibiliteit	Reisflexibiliteit	Reisflexibiliteit
Mijn ouders huis	Mijn ouders huis	Mijn ouders huis
Anders:	Anders:	Anders:

Toelichting bij "toekomstige gebeurtenissen"

Vult u a.u.b. de volgende vragen in over uw plannen voor de toekomst. Wij zijn geïnteresseerd in wat u zou willen veranderen in uw leven met betrekking tot woning, werk en vervoer, om naar uw idee een ideale situatie te bereiken.

Huisvestings omstandigheden

1) Bent u van plan om naar een andere plaats te verhuizen in de toekomst?

- Nee
- Ik weet het niet/misschien
- Ja

2) Als u gaat verhuizen, in welk deel van de stad zou u willen wonen?

- In het centrum
- Dichtbij, maar niet in, het centrum
- Buiten het centrum
- In een rustige buurt
- Dorp buiten de stad
- Op het platteland
- Op elke locatie, ik wil een tuin hebben

3) Hoe belangrijk zijn de volgende zaken voor u bij de keuze van een woning/wijk (0 = onbelangrijk; 10 = zeer belangrijk):

	punten
Groen in de wijk	
Goede beschikbaarheid van openbaar vervoer in de wijk	
Dicht bij familie	
Dicht bij vrienden	
Goede voorzieningen in de wijk	
Goede culturele voorzieningen in de wijk	
Goed amusement voorzieningen in de wijk	

Vervoersomstandigheden

1) Hebt u een of meer auto`s?

- Ja
- Nee

2) Bent u van plan een auto te kopen?
Als u reeds in het bezit bent van een auto, geef dan aan of u van plan bent een tweede auto te kopen

- Ja
- Nee
- Ik weet het niet/misschien

3) Als u een auto hebt gekocht zou u in dit geval naar een andere locatie verhuizen?

- Ja
- Nee
- Ik weet het niet/misschien

4) Geef aan of u uw dagelijkse vervoerssituatie wenst te veranderen.
Meerdere antwoorden mogelijk

- Mijn belangrijkste vervoerswijze veranderen — Welke? van: naar:
- Mijn partner's belangrijkste vervoerswijze veranderen — Welke? van: naar:
- Minder reistijd voor mij
- Minder reistijd voor mijn partner

Hartelijk dank voor uw deelname!

Wilt u deelnemen aan de tweede fase van dit onderzoek? Dit bestaat uit een face-to-face interview van 30-60 minuten.
Als u wilt deelnemen, geef ons uw contactgegevens (telefoonnummer of e-mail).

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Designing and shaping cities to trigger people to travel in a more sustainable way is an objective pursued for long in the fields of urban planning, urban design and transportation. Several studies have been published on the relationship between urban form and (facets of) activity-travel patterns, achieving however no consensus about if and how the built environment affects people's choice for their travel behaviour. However, studies on how life trajectory affects activity-travel behaviour demonstrate that people are less prone to change their travel behaviour after a certain stage of life. Based on these two perspectives, this thesis argues that there is a potential of examining the relationship between urban form and activity-travel behaviour in the larger context of a life trajectory approach: life events happening in people's life might influence their choices of both residential location and activity-travel behaviour. According to this approach, the built environment mediates the effects of life trajectory events on activity-travel behaviour. To investigate this hypothesis, longitudinal data were collected about the life course and changes in the travel behaviour for a sample of 350 Dutch residents. The direct and indirect effects were analysed using Structural Equation Modeling. Overall, results support the hypothesis that the dynamics of the relationship between life trajectory, built environment and activity-travel behaviour can be understood as life trajectory affecting activity-travel behaviour with the built environment mediating this relationship.

/ Department of the Built Environment

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